



OPERATIONAL RISK ANALYSIS FOR THE MANAGEMENT OF RAILWAY INFRASTRUCTURE MAINTENANCE

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ABSTRACT

This paper proposes a methodology for the analysis of operational risks that are caused by railway infrastructure failure. The objective of this methodology is to assist the engineers that manage railway infrastructure maintenance to forecast the frequency of these operational risks, the cost of rehabilitating railway infrastructure after these operational risk events and the impact of railway infrastructure maintenance strategies on the frequency and cost of these operational risk events. The proposed operational risk methodology is applied in a case study concerning a railway company called African Railway Ltd for the sake of confidentiality. The train derailments that are caused by infrastructure component failure are analysed in the case study. Historical data and the results of questionnaires that were used during face-to-face interviews are discussed. The frequency of train derailments, the cost of rehabilitating railway infrastructure after train derailments and the impact of railway infrastructure maintenance on these two issues are forecasted. The case study concludes with a comparison of the forecasted and actual frequency of train derailments and cost of rehabilitating the railway infrastructure after a train derailment.

1. INTRODUCTION AND RESEARCH METHOD

The infrastructure of a railway system consists of fixed facilities that support the movement of rolling stock (i.e. locomotives and wagons) from one point to another [1]. A typical railway infrastructure system consists of the following major subsystems: track, bridges, electrical, train authorization and telecommunication.

The life cycle of railway infrastructure components consists of the following phases:

- a) planning and specification;
- b) design;
- c) construction;
- d) operation;
- e) research; and
- f) maintenance and retirement phases [1].

The planning and specification phase starts with the compilation of a mission statement. The mission statement contains the business goals, key assumptions, the target market and constraints. This phase ends with the development of specifications in which the form, function and features of the infrastructure components are described. The design phase begins with high level design and is followed by detailed design. The construction phase consists of testing, refinement and production ramp-up. Railway infrastructure components are used during the operation phase. The research phase involves the discovery of ways in which the maintenance of railway infrastructure components can be optimised. The maintenance of these components is performed during the maintenance phase. During the retirement phase, the infrastructure components are disposed or recycled.

Maintenance includes all actions necessary for retaining a system or product in, or restoring to a serviceable condition [2]. The maintenance of railway infrastructure can be effectively performed by executing the following steps of the maintenance cycle:

- a) Identification of the need for maintenance
- b) Maintenance cost justification
- c) Resource allocation planning
- d) Scheduling
- e) Assignment of tasks
- f) Execution of maintenance activities
- g) Feedback.

The need for the maintenance of infrastructure can be identified by having a clear understanding of the infrastructure components. This understanding can be achieved by using tools such as failure mode, effects and criticality analysis (FMECA). The principle of FMECA is used to consider each mode of failure of every component in a system and to further ascertain the effects on system operation of each failure mode in turn [3].

The total cost of maintenance comprises of preventative and corrective maintenance costs. Preventative maintenance costs are comprised of the costs for scheduled maintenance activities (e.g. labour, material and equipment) and downtime costs (the amount of money that the company could have earned during the downtime). Corrective maintenance costs consist of costs for unscheduled maintenance activities and downtime costs.

Resource allocation planning must be done by an individual with the necessary technical expertise regarding a particular system. The process ensures that resources are available



during the maintenance activities. These resources include equipment, material, engineering drawings, etc.

Scheduling determines the manner in which time and resources in the form of equipment and people with the necessary technical skills are used for the completion of maintenance tasks. In the railway environment occupation is an important factor to consider. Occupation is the permission to ensure that no trains may move in a particular area so that maintenance activities can be carried out. It is imperative that the planner requests, and is granted this permission, to ensure the prevention of damage and the safety of maintenance personnel and train crew, respectively.

During the assignment of tasks phase, maintenance tasks are assigned to personnel with the necessary skills. Personnel may perform their tasks individually or work in teams. Maintenance activities are executed after this phase. A maintenance history database is used to record information concerning the executed maintenance activities. This database can be used for planning, analysing, costing, resource allocation and scheduling.

The term 'risk analysis' is used to denote methods which aim to provide a comprehensive understanding and awareness of the risk associated with a particular variable of interest [8]. Operational risk analysis is an important tool for railway infrastructure maintenance planning because it allows the impact of any maintenance strategic decisions on operational risks to be forecasted.

A case study was made of the operational risk analysis of the train derailments that are caused by railway infrastructure component failure that occur in ARL in a particular region. This case study involved the application of the proposed operational risk analysis methodology using historical data and the results of face-to-face interviews. The frequency of train derailments, the cost of rehabilitating railway infrastructure after train derailments and the impact of railway infrastructure maintenance on these two issues are forecasted using Bayesian network causal models. Lastly, a comparison is made of the forecasted and actual frequency of train derailments and cost of rehabilitating the railway infrastructure after a train derailment.

2. OPERATIONAL RISK ANALYSIS OVERVIEW

Operational risk is identified using one or more structures, techniques and information sources. The proposed operational risk identification methodology is structured as a discussion using the organisational chart technique with historical data as the main source of information.

Operational risk analysis allows managers to predict possible future operational losses in order to evaluate a risk management strategy that can minimize these losses. An organisation's operational risk analysis can be done with either a top-down or a bottom-up approach. The proposed operational risk assessment methodology for the management of railway infrastructure corrective maintenance adopts a bottom-up approach. This approach was selected as it assists managers to gain sufficient knowledge to effectively manage the operational risk of their departments.

There are three main types of operational risk analysis, namely qualitative, quantitative and a combination of both. Qualitative operational risk analysis often involves estimating operational risk that is difficult or impossible to calculate numerically. Qualitative operational risk analysis results are often expressed using risk maps. Examples of qualitative operational risk analysis methods are risk self-assessment, risk process flow

analysis and scenario formulation and analysis. Quantitative operational risk analysis involves the numerical estimation of operational risk. Examples of quantitative risk analysis methods are the actuarial approach and stress testing. Combinations of qualitative and quantitative risk analysis allow the advantages of both methods to be used. Examples of combinations of qualitative and quantitative operational risk analysis are causal models using neural networks or Bayesian networks. The credibility of Bayesian network causal models that use historical data is higher than that of qualitative operational risk assessment because this form of assessment is purely subjective. Assuming that past events are good predictors of the future, Bayesian network causal models that use historical data provide more accurate predictions than parametric loss distribution actuarial models. The use of Bayesian network causal models that use historical data is more effective than actuarial models for the management of operational risk as the causes of losses are specified in causal modelling. Thus the proposed operational risk analysis methodology for the management of railway infrastructure corrective maintenance uses Bayesian network causal models.

3. THE PROPOSED OPERATIONAL RISK ANALYSIS METHODOLOGY FOR INFRASTRUCTURE MAINTENANCE

Risk cannot be analysed until it is identified. Therefore, the proposed operational risk analysis methodology follows the identification of operational risk.

3.1 Operational risk identification

The proposed operational risk identification methodology for the management of infrastructure corrective maintenance occurs during a discussion using historical data. Operational risks are identified primarily using historical data, (e.g. the train accident database). Ideally, this historical data should contain the dates, times, descriptions and root causes of events that required corrective maintenance. The author suggests that operational risk identification is performed in a discussion so that any additional operational risks that have not yet occurred but have the potential to occur and their causes are identified. The people who participate in this discussion should ideally be the following:

- a senior engineer who maintains the railway infrastructure of a particular region;
- the engineers who maintain the different components of the railway infrastructure system i.e. track, permanent-way, electrical, train authorisation and telecommunication; and
- a member of the risk management department.

The organisational chart technique is performed in order to categorise the causes of the identified operational risks according to the organisation's structures that must manage these risks.

3.2 Operational risk analysis

The proposed operational risk analysis methodology for the management of infrastructure maintenance is done by developing Bayesian network causal models. Two causal models are developed for each identified operational risk for forecasting the operational risk frequency and severity. The development of a Bayesian causal model is composed of the following stages:

- causal model building;
- causal model data collection; and
- causal model data processing.

3.2.1 Causal model building

Causal model building involves the identification of operational risk causes and causal model formation. The first step of causal model building entails compiling a list of the causes of the identified operational risks and their contributing factors.

During causal model formation, the elements of the list of the identified operational risks, causes and contributing factors are selected to become the nodes of the causal model. A node is a representation of a random variable which is either continuous or discrete, with a finite number of states. Each node that represents a random variable that is continuous contains a density function. Each node that represents a random variable that is discrete contains a distribution function. This type of node has a probability table that is associated with it which contains the values of the distribution function. Only the nodes that represent discrete random variables are used in the proposed operational risk analysis methodology. The structure of the causal model is formed by linking the nodes with arrows that display the dependencies and causal relationships between the nodes.

Railway infrastructure components are inspected to check for defects on a regular basis, the frequency of the inspections depend on the type of railway infrastructure component. The author has assumed that each operational risk cause has the following three (3) contributing factors:

- a) a defect of an infrastructure system component that was not detected during the inspection of that component;
- b) a defect of an infrastructure system component that was detected during inspection but caused an operational risk event before it was repaired; and
- c) a defect of an infrastructure system component that was detected during inspection, was repaired but caused an operational risk event due to inefficient repair.

3.2.2 Causal model data collection

Causal model data collection can be constructed using a combination of objective and subjective data. Objective data is used for frequency model data collection to obtain the probability distribution function of the contributing factors of the operational risk causes. This data can be obtained from an organisation's risk register which contains historical operational loss data indicating the number of loss events. Additionally, data from the maintenance activities database can be used to determine the dates in which maintenance activities were scheduled. Objective data is used for severity model data collection to obtain the probability distribution of the contributing factors of operational risk costs. This data can be obtained from an organisation's risk register to obtain historical loss data. Additionally, data from the financial claims database can be used to obtain the records concerning the amount of money that was claimed for rehabilitating railway infrastructure after operational loss events.

Subjective data is used for frequency model data collection to obtain the conditional probability distribution functions of operational risks and their causes. This data is estimated by railway infrastructure maintenance experts. In the proposed operational risk assessment methodology, subjective data is collected through face-to-face interviews with experts. The advantages of face-to-face interviews above other methods (e.g. complete questionnaires) and telephonic interviews are the following:

- any issues that the expert is unsure of can be dealt with immediately, thus they are able to make predictions more accurately as a result of having a better understanding of the questions that are posed; and
- the interviewers are able to gain better insight from the experts.

The interview questionnaire consists of an introduction and main questions section. The introduction consisting of the following:

- a) Interview circumstantial information i.e. the date and venue;
- b) The expert background information i.e. job position, duration in which the expert has been at their current position, nature of work, previous work experience;
- c) A description of the target sample e.g. track maintenance experts;
- d) An explanation of the purpose of the research;
- e) An estimation of the time required to complete the interview;
- f) The assurance that the participant's participation is voluntary;
- g) The assurance that it is acceptable for the participant's to not respond to every question;
- h) The instructions that must be followed in answering the questions.

The main questions of the questionnaire were developed based on the technique for the subjective quantitative estimation of probabilities that was developed by Kwabena (2005). The experts are asked to estimate the conditional probabilities of the operational risks and their causes. The order of the questions is set in such a way that probabilities from the same conditional distribution are grouped together in order to allow the experts to estimate these probabilities simultaneously and probabilities of the same and adjacent nodes are grouped together.

The interview begins with the exchange of the introductory information; this is followed by a review of the following concepts: probability theory basics, the recommended probability estimation technique and the format of the interview questions. Thereafter, the interviewer requests the conditional probability distribution values from the experts and captures the answers in a tabular format.

Subjective data is not used for the development of severity models.

3.2.2 Causal model data processing

During causal model data processing, the collected objective and subjective data are entered into a computer program that develops Bayesian network causal models. This data must be entered in a form that can be encoded into the frequency and severity causal models. The probability distribution of the operational risk frequency, severity and causes are obtained during this stage.

4. AFRICAN RAILWAYS LTD'S INFRASTRUCTURE MAINTENANCE AND OPERATIONAL RISK ANALYSIS BACKGROUND

ARL is a South African company that provides railway transportation. The management of ARL's infrastructure maintenance activities occur in seventeen (17) depots that are situated throughout South Africa. A typical depot consists of departments such as human capital, finance, per-way, track, electrical and signals. Each depot is managed by a senior engineer referred to as a depot engineer. The per-way, track, electrical and signals departments are each managed by one maintenance manager and one production manager. Maintenance and production managers are engineers, technologists or senior technicians. The sub-ordinates of maintenance and production managers are technicians, foremen, technical assistants and labourers.

The ARL risk management department is situated in Johannesburg, South Africa and is responsible for ensuring that the following activities are performed:

- operational risk management processes are implemented throughout ARL;



- business continuity management is implemented that will allow ARL to continue to be sustainable during abnormal conditions that may interrupt the business;
- ARL complies with all the applicable safety, health and environmental legislation and regulations; and
- operational loss prevention and control is performed.

The rehabilitation of the railway infrastructure after operational risk events such as theft, sabotage, natural disasters, train accidents etc is done by the staff of the depot that maintains the area in which the event occurred. Thereafter, the depot engineer gets reimbursed for the funds expropriated for the rehabilitation of the infrastructure from ARL's risk management department.

Annually, members of the risk department, analyse ARL's operational risk in order to forecast the funds that will be needed during the following financial year for the management of operational risk. The ISO 31000 is the methodology that is used to analyse ARL's operational risk analysis. This methodology involves the qualitative rating of the consequences and likelihood of operational risk events. Thereafter, the ratings are plotted onto a risk matrix. ARL's risk appetite is determined by the ARL board. The risk appetite and the quadrant, in which the estimated operational risk falls on the risk matrix and determines the decision of whether the risk will be accepted, controlled, transferred or avoided. Additionally, to ensure that ARL will be sustainable during abnormal conditions, Scenario formulation and analysis, is performed using historical data.

The limitation of the current ARL operational risk methodology is that it does not assist the depot engineer to forecast the effect of railway infrastructure maintenance strategies on operational risks.

5. THE PROPOSED OPERATIONAL RISK ANALYSIS METHODOLOGY APPLICATION FOR AFRICAN RAILWAYS LTD'S INFRASTRUCTURE MAINTENANCE

The consequences of operational risk events that are caused by railway infrastructure system failures are train delays, cancellations and accidents. The largest operational losses that are caused by railway infrastructure system failure are the latter. In this case study, the proposed operational risk analysis methodology is applied for the analysis of the train derailments that occur in the ARL Johannesburg central region. Operational risk analysis was performed using Bayesian causal modelling. This involved causal model building, data collection and data processing.

5.1 Causal model building

ARL uses a risk register to capture the information about all the train derailments that have occurred. This information is divided into 61 categories e.g. the train derailment area, date, causes, etc. Data from the risk register of the 2005/2006, 2006/2007 and 2007/2008 financial years were used to identify the causes of the train derailments that occurred in the Johannesburg central region.

A total of fifteen (15) train derailment causes that were related to railway infrastructure component failure were found. The Pareto principle of the 'significant few and the insignificant many' was used to select the main train derailment causes that would be used for further analysis. Thus the following five (5) causes of derailments which caused the most derailments were used to analyse train derailments:

- defective points machine;
- incorrect rail gauge;

- defective retarder/advancer;
- rail broken; and
- rail slack.

Defective points machines cause the most train derailments that are related to failures of railway infrastructure. Points machines are track equipment that enable trains to move from one track to another. Derailments are also likely to occur when the distance between the rails is not within the prescribed length. A retarder/advancer is a cylindrical apparatus that is used for decelerating or accelerating the wagons and locomotives during shunting. When this apparatus is not well maintained, it can cause a shunting derailment. Broken rail commonly cause derailments to occur. Slack occurs when one of the rails is higher than the other; the resulting movement of a train that passes a rail with slack may result in a derailment.

For frequency causal model formation, the author has assumed that train derailment causes have the following general contributing factors:

- a) a train derailment is caused by a defect of an infrastructure system component that was not detected during the inspection of that component;
- b) a train derailment is caused by a defect of an infrastructure system component that was detected during inspection but caused a derailment before it was repaired; and
- c) a train derailment is caused by a defect of an infrastructure system component that was detected during inspection, was repaired but caused a derailment due to inefficient repair.

The identified operational risk, causes of the operational risk and the factors that contribute to these causes are represented by a node in a frequency causal model. A demo version of Hugin Lite version 7.1 software was used to construct the frequency causal model.

For severity causal model formation, the following types of train derailments that determine the cost of rehabilitating railway infrastructure after their occurrence were identified:

- derailment running line-these are derailments of locomotives and wagons that occur along the running line of the track;
- derailment shunt-these are derailments of locomotives and wagons that occur at the shunting yards;
- derailment wagon-these are derailments of wagons that occur in shunting yards and along the running line of a track; and
- derailment-these are derailments of locomotives and wagons that occur at places along the track that are not along the running line and in shunting yards.

The severity of the identified operational risk and the factors that contribute to the severity of the operational risk are represented by a node in a severity causal model. A demo version of Hugin Lite version 7.1 software was used to construct the severity causal model.

5.2 Causal model data collection

At the ARL Johannesburg central region depot, an inspection of the railway infrastructure track components is performed weekly by trackmasters. A list of any defects that are found during the inspection is made. Thereafter, a reference number is assigned to each maintenance work that must be done in order to repair the detected defect. A list of the 2005/2006, 2006/2007 and the 2007/2008 financial years reference numbers, detected

defects, planned dates and areas were obtained from the Johannesburg central depot finance department database. Data from the risk register and the Johannesburg central depot finance department was analysed to find the amount of times in which the following occurred:

1. a defect was not detected during inspection i.e. a particular defect was not discovered in a particular area during inspection yet that defect resulted in a train derailment during the week of its inspection;
2. a defect was detected during inspection, was assigned a reference number but resulted in a train derailment before it was scheduled to be repaired; and
3. a defect was detected during inspection, was assigned a reference number and was repaired however this defect still caused a train derailment on the same week that the defect was detected.

Risk register data was used to obtain the probability distributions of the nodes that represent the factors that contribute to the causes of operational risk. The probability of a factor that contributes to operational risk is estimated to be equal to the number of cases in which derailments occurred due to a particular factor that contribute to operational

risk B divided by the number of defects A, thus $P = \frac{B}{A}$.

Individual face-to-face interviews with one engineering technician, one engineer and one senior engineer were conducted by the author to obtain the conditional probabilities of the following:

- train derailments that are caused by the failure of infrastructure system components and
- the main causes of these train derailments i.e. defective points, wrong track gauge, defective retarder/advancer, broken rail and slack.

The author recorded the estimated conditional probabilities in a matrix format. Thereafter, each state's conditional probabilities were added and divided by three (3) to obtain the average conditional probability distribution for all of the causal model nodes. The average conditional probability distribution consists of two states which represent the occurrence and nonoccurrence of a train derailment when one or more of the following conditions exist in isolation or simultaneously with others in one area along the track:

- defective points machine;
- incorrect rail gauge;
- defective retarder/advancer;
- broken rail; and
- slack.

Data from the 2005-2008 financial year risk registers was used for the forecasting of the cost of rehabilitating railway infrastructure after train derailments caused by infrastructure component failure. The probabilities of the train derailment types (Td) were calculated by dividing the amount of each derailment type with the amount of all the derailments that had occurred (i.e. 179 train derailments). The states of the train derailment cost contributing factors per trip were calculated by multiplying the probability of each train derailment type with the probability of a train derailment per train trip (i.e. 4.02%) which was obtained from the results of the frequency causal model processing.

The ARL depot engineers make claims to the risk management department for the rehabilitation of railway infrastructure after derailments have occurred and keep records of the claims. The records of these claims that were made during the 2005-2008 financial

years were used to determine the conditional probability of the train derailment cost node.

The costs of rehabilitating railway infrastructure were calculated for different scenarios concerning the occurrence of particular types of derailments per year. The rehabilitation costs were allocated to six (6) cost ranges, the amount of costs that fell under each range were divided by the number of financial years i.e. three (3). The resulting probability distribution was used to represent the states of the train derailment cost node.

5.3 Causal model data processing

A demo version of Hugin Lite version 7.1 software was used to obtain probability distributions for defective points machines, incorrect rail gauges, defective retarder/advancer, broken rail, slack and train derailment frequency.

The defective points machines probability distributions indicate that there is a 23.19% probability that a points machine is defective and results in a derailment under the following circumstances:

- an 84% probability that the defect was not detected during visual inspection;
- a 5% probability that the defect was detected and was scheduled to be repaired but caused a derailment before the day in which it would be repaired; and
- an 11% probability that the defect was detected and inefficiently repaired resulting in a derailment.

The incorrect rail gauge probability distributions indicate that there is a 5.96% probability that an incorrect rail gauge results in a derailment under the following circumstances:

- an 89% probability that the defect was not detected during visual inspection;
- a 0% probability that the defect was detected and was scheduled to be repaired but caused a derailment before the day in which it would be repaired; and
- An 11% probability that the defect was detected and inefficiently repaired resulting in a derailment.

Considering that undetected incorrect rail gauges cause the greatest amount of derailments compared to detected incorrect rail gauges, it is important that correct and well calibrated equipment is used to measure the rail gauges. Additionally, the rail gauge measuring skills of the track masters must be improved by training. Undetected points machine defects cause the greatest amount of derailments compared to detected defects, thus it is imperative that track masters are trained to improve their defect detecting skills.

The defective retarder/advancer probability distributions indicate that there is a 30% probability that a retarder/advancer defect may result in a derailment when the defect is undetected during inspection. The probability of retarder/advancer defects can therefore be substantially reduced by improving the defect detection skills of the track masters.

The broken rail probability distributions indicate that there is a 5.8% probability that an incorrect rail gauge results in a derailment under the following circumstances:

- an 87.5% probability that the defect was not detected during visual inspection; and
- a 12.5% probability that the defect was detected and was scheduled to be repaired but caused a derailment before the day in which it would be repaired.

Considering that undetected broken rail cause the greatest amount of derailments compared to detected incorrect broken rail, it is imperative the broken rail detection

skills of track masters are improved. Additionally, the equipment that detects hidden rail defects such as ultra sonic measuring systems should be used at a greater frequency.

The slack probability distributions indicate that there is a 3% probability that a slack may result in a derailment when the defect is undetected during inspection. The probability of retarder/advancer defects can therefore be substantially reduced by improving the slack defect detection skills of the track masters.

The train derailment frequency probability distributions indicate that there is a 4.02% probability that a train derailment can occur due to the following reasons:

- a 23.19% probability of a defective points machine;
- a 5.96% probability of an incorrect rail gauge;
- a 30% probability of a defective retarder/advancer;
- a 5.8% probability of a broken rail; and
- a 3% probability of slack.

It is estimated that the average amount of trains that move along the Johannesburg region per year is two thousand (2000); the number of train derailments that are likely to occur equals the product of the frequency probability and the number of trips that trains make in a year. Thus, the forecasted frequency is eighty (80) train derailments per year when there is an average of two thousand (2000) trains that pass the Johannesburg region railway infrastructure a year.

The train derailment severity causal model was simulated to forecast the cost of rehabilitating railway infrastructure, after a train derailment has occurred. The resulting probability distribution was forecasted when the probabilities for the train derailment types are the following:

- 3.68% of derailment running lines
- 0.36% of derailment shunts
- 0.05% of derailment wagons
- 0.11% of derailments.

The forecasted cost of rehabilitating railway infrastructure after the occurrence of a train derailment was calculated by adding the products of the probabilities and the class marks, i.e. half of the difference of between the upper and lower limit of each class (each train derailment cost range). The forecasted cost of rehabilitating railway infrastructure after a train derailment that was caused by railway infrastructure component failure is R20,629,554.09. Therefore a preventative maintenance strategy, that will be implemented during a particular year, for the prevention of train derailments that costs less than the forecasted annual railway rehabilitation cost R20,629,554.09 is justifiable.

The effect of decreasing the probability of any of the contributing factors of operational risks can be forecasted using causal modelling. The probabilities of the undetected points machine defects were varied using the frequency causal model to obtain the forecasts of the probabilities of train derailments. These forecasted probabilities were used in the severity causal model to forecast the effect of varying the probability of undetected points machine on the cost of rehabilitating railway infrastructure after train derailments. The forecasted train derailment probabilities were multiplied by the probabilities of train derailment types. The resulting probabilities and their compliments were used as the states of the contributing nodes in the severity causal model.

The forecasted probability of undetected points machine defects is 84% results in the cost of rehabilitating railway infrastructure after train derailments to be R20,629,554.09.



According to the causal model simulation results, the implementation of strategies that can halve the forecasted probability to 42% can result in the overall probability of train derailments decreasing to 3% and the annual cost of rehabilitating railway infrastructure after train derailments decreasing to R13,527,430.00. Additionally, the implementation of strategies that decrease the probability of undetected points machine defects to 0% results in the overall probability of train derailments decreasing to 2% and the cost of rehabilitating railway infrastructure after a derailment to become R10,340,253.00.

6. TESTING THE PROPOSED OPERATIONAL RISK ANALYSIS METHODOLOGY

Eighty (80) train derailments which are caused by railway infrastructure component failure were forecasted to occur in the Johannesburg region during the 2008/2009 financial year. The forecasted probability of a train derailment in the Johannesburg region is 4.02%.

Historical data from the operational risk register revealed that during the 2008/2009 financial year, sixty five (65) train derailments occurred as a result of railway infrastructure component failure in the Johannesburg region. The actual probability of a train derailment occurring can be estimated to equal the ratio of the number of derailments with the number of train trips. It was estimated that there is an average of 2000 train trips in the Johannesburg region. Therefore the actual probability of a train derailment in the Johannesburg region is 3.25%.

There is a 0.77% difference between the forecasted and actual probability of a train derailment occurring during the 2008/2009 financial year.

The rehabilitation cost of railway infrastructure after train derailments caused by railway infrastructure component failure was forecasted to be R20,629,554.09. Historical data from the risk management department show that the 2008-2009 financial year's train derailment rehabilitation costs was R29,767,367.80.

There is a 0.33% difference between the most probable forecasted and actual cost range of rehabilitating railway infrastructure during the 2008/2009 financial year.

7. CONCLUSION

An engineer who manages the maintenance of railway infrastructure can greatly contribute to society by decreasing the amount of operational risk events that are caused by railway infrastructure component failure as a result of a decrease in the following:

- the amount injuries and fatalities of members of a railway company and the public;
- the amount of spillages of goods ,e.g. chemicals, which have a negative impact on the environment;
- the amount of legal restrictions that are imposed by a country's government or railway safety regulator; and
- the amount of money that the company loses due to train delays, claims and the rehabilitation of railway infrastructure.

This paper proposes an operational risk analysis methodology that transfers the approach of operational risk analysis from a macro level to a micro level. The objective of proposing this approach is to provide engineers with the tools to manage railway infrastructure maintenance more effectively and efficiently. The proposed operational risk analysis methodology assists these engineers in forecasting the impact that maintenance activities have on operational risks that are caused by railway infrastructure component failure. This allows engineers, to forecast the probability that their targets for reducing operational



risks that are caused by railway infrastructure failure will be met. Additionally, the proposed methodology enables the forecasting of the cost of rehabilitating railway infrastructure after the occurrence of an operational risk event.

The proposed operational risk analysis methodology can be used during various phases of the maintenance cycle. The forecasted cost of rehabilitating the track after the occurrence of an operational loss event can be used to justify the funds that the organisation should use on the maintenance activities that can prevent these events.

The proposed operational risk analysis methodology was made for the engineers that maintain railway infrastructure. However, other technical employees of railway companies can use it. Additionally, engineering consulting companies can use this methodology to assist companies in decreasing the amount of operational risks that are caused by railway infrastructure.

A more detailed causal model is likely to produce more accurate forecasts; the author suggests that the following contributing factors of operational risk causes may be added for increasing the accuracy of the forecasts:

- the volumes of the trains that are passed,
- the climate of the region,
- the resources that is available for preventative maintenance etc.

An increase in the train volume results in an increase in the probability of wear occurring on the rail. Defects such as broken rail can occur as a result of wear. Extreme temperatures can potentially result in defects such broken rail and slack. The lack of resources for preventative maintenance increases the likelihood of operational risk events occurring.

Possible related studies that could be made include the following:

- a comparative study of the proposed operational risk analysis methodology and other methodologies that are suited for railway infrastructure maintenance management;
- a larger survey of the implementation of the proposed operational risk analysis methodology can be made to identify the depots that have successfully implemented the proposed methodology; and
- a study of operational risk management in railway maintenance management.

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