The Improvement of Maintenance Program to Increase Locomotive Reliability through Component Class Grouping

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Abstract. The success of maintenance program for PT KERETA API (Persero) locomotives plays important role in the safety and reliability of the railway service. The existing maintenance program has problems in the lack of accurate maintenance record and the integrated information system involving the logistics, technical and operational. The improvement in the maintenance management system carried out by applying the concept of Reliability Cantered Maintenance (RCM), particularly its accurate framework to identify the likelihood of an asset, in this case a locomotive, experiences failure and the ways to prevent the failure consequences. The work focused on the classification of parts based on their individual quality obtained from component testing/inspection that done regularly in the maintenance workshop during overhaul. Here, the component class reflects its reliability. The consequence of locomotive failure regarded in the weighting of each part as significance of the component, sub assembly or assembly. The class of individual parts will affect the reliability of the relevant sub-assembly, assembly, and eventually the class (reliability) of the locomotive. The paper reports the implementation of RCM concept in the strategy for defining each component class using its testing/inspection data, weighting factors and eventually the class of locomotives. With the knowledge of the locomotive reliability class, the railway operation can be plan in an optimum way, a possible failure can be anticipate, maintenance program can be devise more effectively and eventually, the risk of railway accident can be minimized.

Keywords: *maintenance, risk, reliability, RCM, component class.*

1. Introduction

Locomotive as the main power source of a train, takes hold of strategic role to the success of the railway transportation system to meet with the railway trip plan (Grafik Perjalanan Kereta Api, GAPEKA). Failures in locomotives have direct impact on the railway trip plan, such as delays, cancellation and even worse, accidents. Figures 1 represents the main failure in a locomotive. Therefore, the reliability of the locomotives is a major concern in the business process of PT KERETA API (Persero) or PT KA. However, up to now, the reliability of the locomotives has not properly examined. The quality of each service locomotive is regard in its availability to serve its task. A locomotive is said to be ready to use is it has been technically checked by the technician before departure. No careful examination in its reliability has been carried out, so that one cannot predict the risk level of failures the locomotive has.

With only a limited number of locomotives available, the maintenance is important in the reliability of service of PT KA. However, there are some problems related to maintenance process, namely: lack of accurate maintenance data record, and lack of integration between logistic, engineering and operational. The current problem in maintenance record keeping is that maintenance activities on a particular locomotive is carried out not only in one place, but in different places without integrated information system. Hence, the information related to a particular locomotive is untraceable. Therefore, it requires improvement in the maintenance management system. The work involves: proposing maintenance record database, and integrating to the existing PT KA database for locomotives (SIPERLOKA).

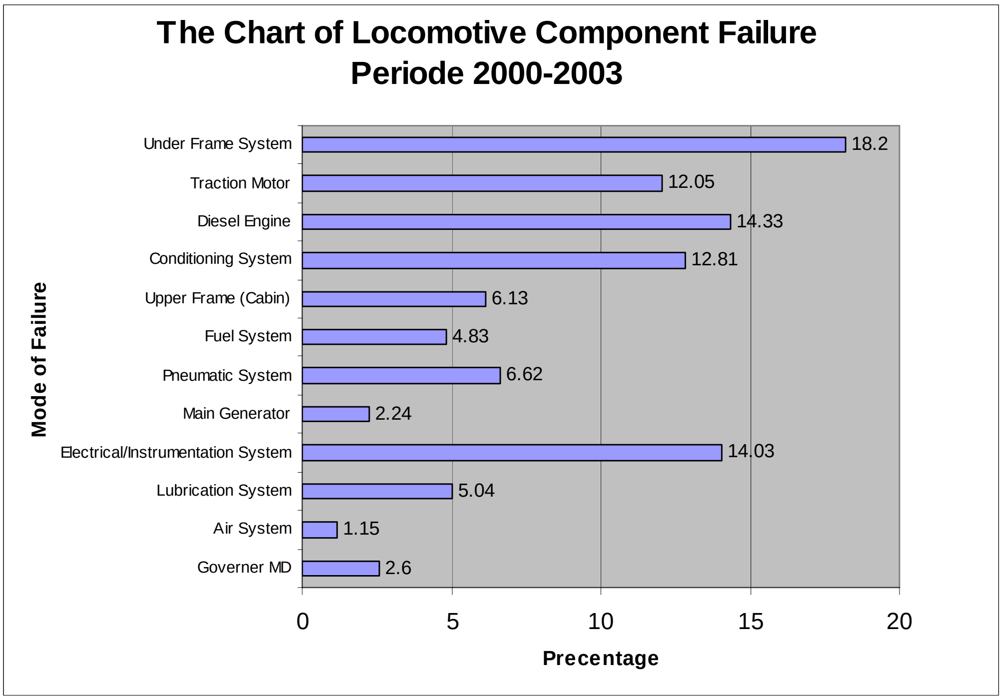
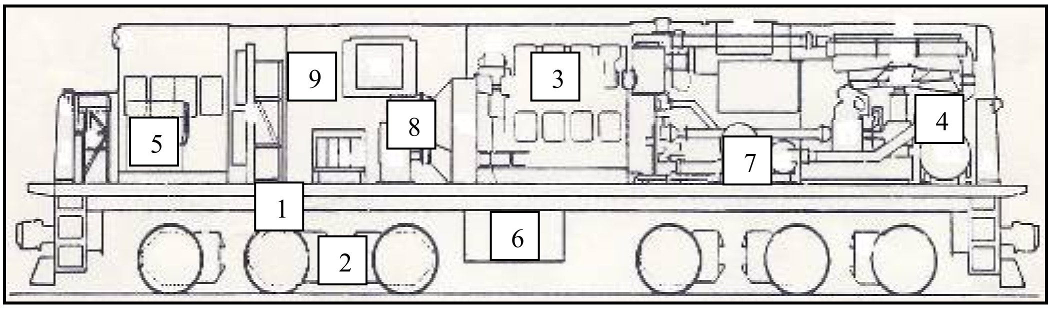


Figure 1 Pareto diagram of locomotive failure
[**Source**: Divisi Sarana PT KA]

The improvement is based on the Reliability Centered Maintenance (RCM) concept. RCM is a set of tasks generated based on a systematic evaluation that is used to develop or optimize a maintenance program. RCM incorporates decision logic to ascertain the safety and operational consequences of failures and identifies the mechanisms responsible for those failures.

While the maintenance management system is set applicable for all components in a locomotive, the work is focused on the underframe system of locomotive since it contributes the highest probability of failures in a locomotive (See. Pareto diagram Figure 1). Components of a locomotive can be grouped in 9 elements as shown in Figure 2.



1: Underframe System.
2: Traction Motor.
3: Diesel Engine.
4: Conditioning System.
5: Upper Frame (cabin).
6: Fuel System.
7: Pneumatic System.
8: Main Generator.
9: Electrical/Instrumentation System

Figure 2 Locomotive Assembly
[**Source**: Manual Instruction General Electric]

2. Methodology

The improvement of maintenance system is carried out using the methodology as explained in Figure 3. The approach strategy in this paper is a modification of RCM methods, and described as follows.

1. Identification of each equipment (assembly, subassembly and component).
2. Registration of components, subassembly and assembly
3. Weighing of components, assembly/subassembly based on its failure consequences to train operational, the performance standards, and the physical effects of each failure mode. The category of consequences follows the concept of RCM.
4. Establish the criteria of to determine the class of component.
5. Determine the class of component.
6. Establish software implementation.
7. Check the implementation of software.
8. Update maintenance-data history.
9. Determine component, subassembly, assembly and locomotive class.

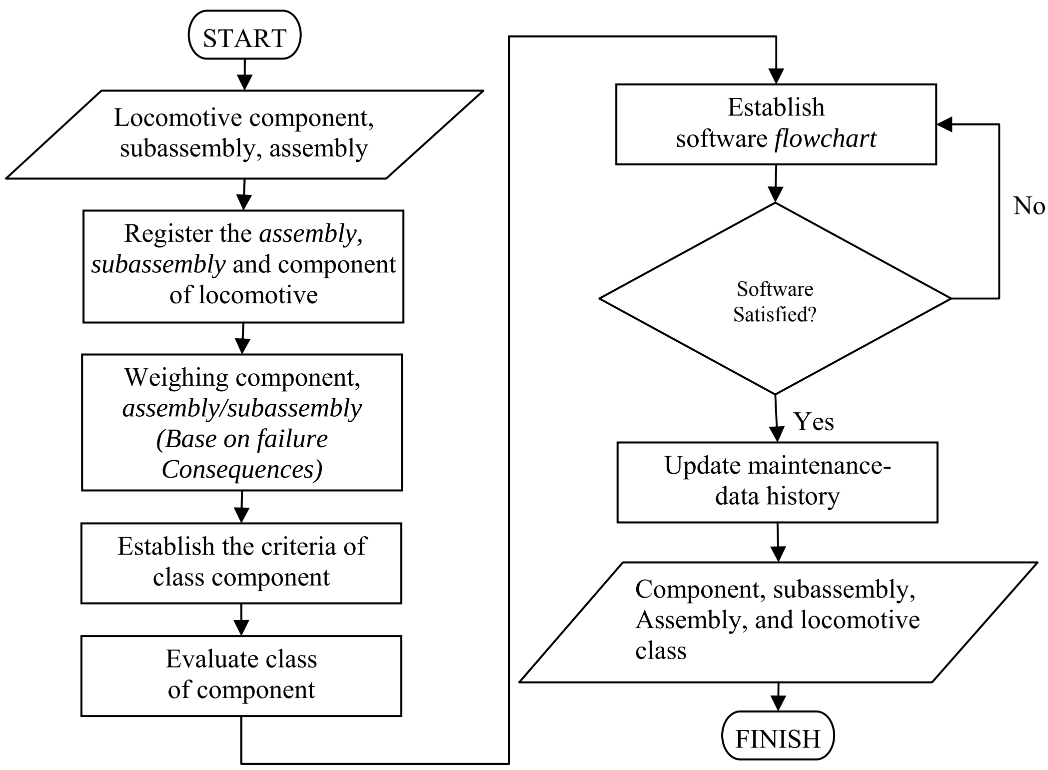


Figure 3 Approach strategy to increasing maintenance quality and reliability locomotive

3. Case Study

3.1. Identifying Equipment

Locomotive elements is divided into several main assemblies, i.e. under frame system, traction motor, diesel engine, conditioning system, upper frame (cabin), fuel system, pneumatic system, main generator and electrical/instrumentation system (Figure 2). Component identification is carried out as in Figure 4

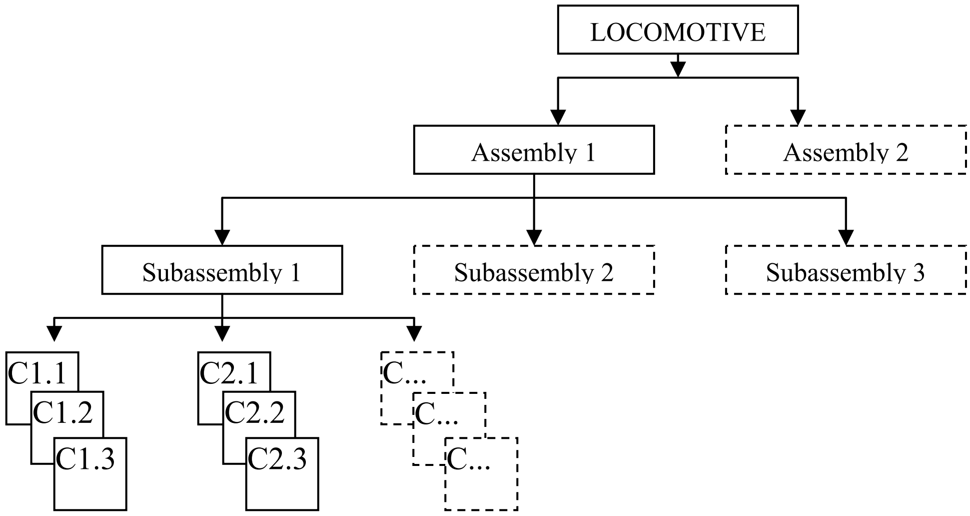


Figure 4 Equipment identification

3.2. Component Register

With a simple but informative component register, the maintenance record will be easier in inputting the data of maintenance and inventory spare parts. It is proposed a structure of equipment register that is integrated to the existing data base system as in Figure 5.

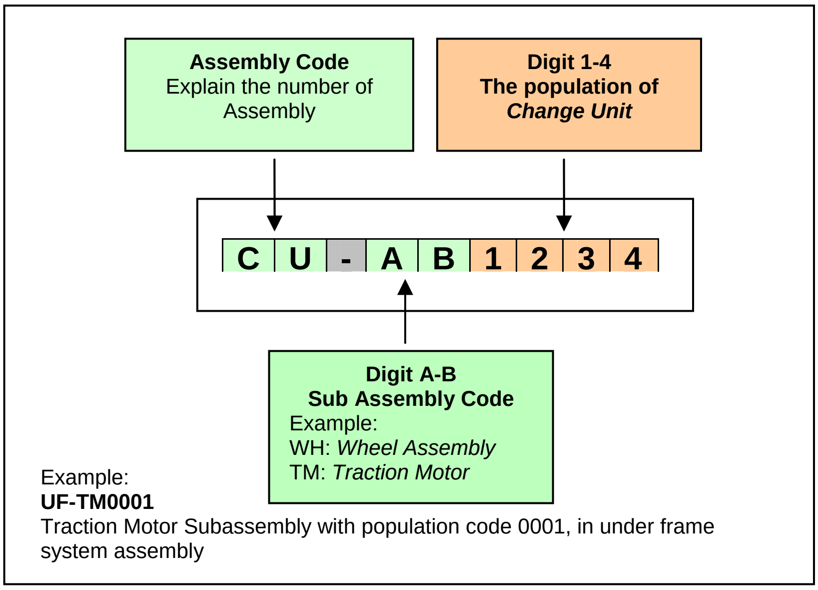


Figure 5 The structure of component register

3.3. Component Weighting Factor

The RCM process groups failure consequences into four categories, in two stages. The first stage is to separate hidden function from evident function. Hidden function is one whose failure will NOT become evident to the operating crew under normal circumstances. These functions are separated from the evident ones because they need special handling. They are usually associated with protective devices, which are not fail safe.

The next stages are to classify evident failures into three further categories in descending order of importance, as follows:

1. *Safety and environmental consequences*. A failure has safety consequences if it could hurt or kill someone. It has environmental consequences if could lead to a breach of any corporate, national, regional, or international environmental standard.

2. *Operational consequences*. A failure has operational consequences if it affects production or operations (output, product quality, customer service or operating costs in addition to the direct cost of repair.
3. *Non-operational consequences*. Evident failure that fall into this category affects neither safety nor production, so they involved only the direct cost of repair.

3.4. Criteria for Component Classification

The purpose of classification of class components is to give information on the condition and quality of each component. Component classification is based on the functionality, observed physical condition as well as from standardized tests. Table 1 represents an example of classification including weighting factor criteria and parameter for the case of traction motor as one of the sub-assemblies studied in this work.

Table 1 Component classification, weighting factor and criteria for the case of traction motor

No	Component name	Weighted Factor	Criteria	Parameter
1	Rotor	12	High port	3000-3500 Volt AC
			Meager	≥ 5 Mega Ohm
			Surge Test	700-800 Volt
			Tan Delta	Max 12,5 % from 200 Volt
2	Armature Shaft	15	Diameter shaft	PT Max 130.00-130.05 mm
				E Max: 90.00 – 90.03 mm
			Collar support	Max 1112 mm
3	Roller Bearing	15	Clearance	0.0000 – 0.0889 mm
4	Ball Bearing	13	Clearance	0.0000 – 0.0889 mm
5	Motor Pinion	15	Surface area	80% – 98%
			Gear worn out	0.00-0.35 mm
6	Stator	5	High port	3000-3500 Volt AC
			Meager	≥ 5 Mega Ohm
			Surge Test	700-800 Volt
			Tan Delta	Max 12,5 % from 200 Volt
7	Mounting	4	Axle distance	39.9-40.1 mm
8	Axle Cap	3	Axle boor	8.125 - 8.129 mm
9	Cap Bearing	5	Physical condition	New or used
10	Collar/seal collar	5	Collar support	Max 11.2 mm
11	Cabling	3	Physical condition	New or used
12	Carbon brush	5	Stiffness of Spring	7 – 9 kg/mm
TOTAL		100		

3.5. Sub-assembly/assembly Classification

The subassembly and assembly class depend on the class of each component within the subassembly or assembly, and can be calclated using the following relationship:

$$\text{The value of class percentage} = \sum K_i \cdot B_i \quad (1)$$

with:

K_i = class percentage
B_i = weighting factor

When classifying a sub-assembly, the data for the relevant components within the sub-assembly is used with equation (1), while for assembly, the data of relevant sub-assemblies will be used.

Percentage system is used to represent the component quality and divided into three classes as follows:

1. Class 1, $R \geq 90\%$
2. Class 2, $80\% \leq R < 90\%$
3. Class 3, $70\% \leq R < 80\%$

3.6. Software Implementation

The software developed in this work integrates with SIPERLOKA software (existing PT KA software for locomotives), and the maintenance-data history can be updated from various places of maintenance with updating authority, i.e. DIPO and Balai Yasa. The software contains the following information:

1. Locomotive data base
   It gives the information about number and identity locomotive, Position and DIPO, the last PA/SPA (PA: Annual Overhaul, SPA: Semi-annual Overhaul, 6 month), and Class locomotive.
2. Drawing and components descriptions
3. Maintenance history and the latest recorded quality of components.

An example of sub menu form for updating the maintenance history of a sub-assembly is presented in Figure 6. A “sub-assembly” is named “change unit” in PT KA. The calculated reliability class is shown as 3, based on the components within the sub-assembly.

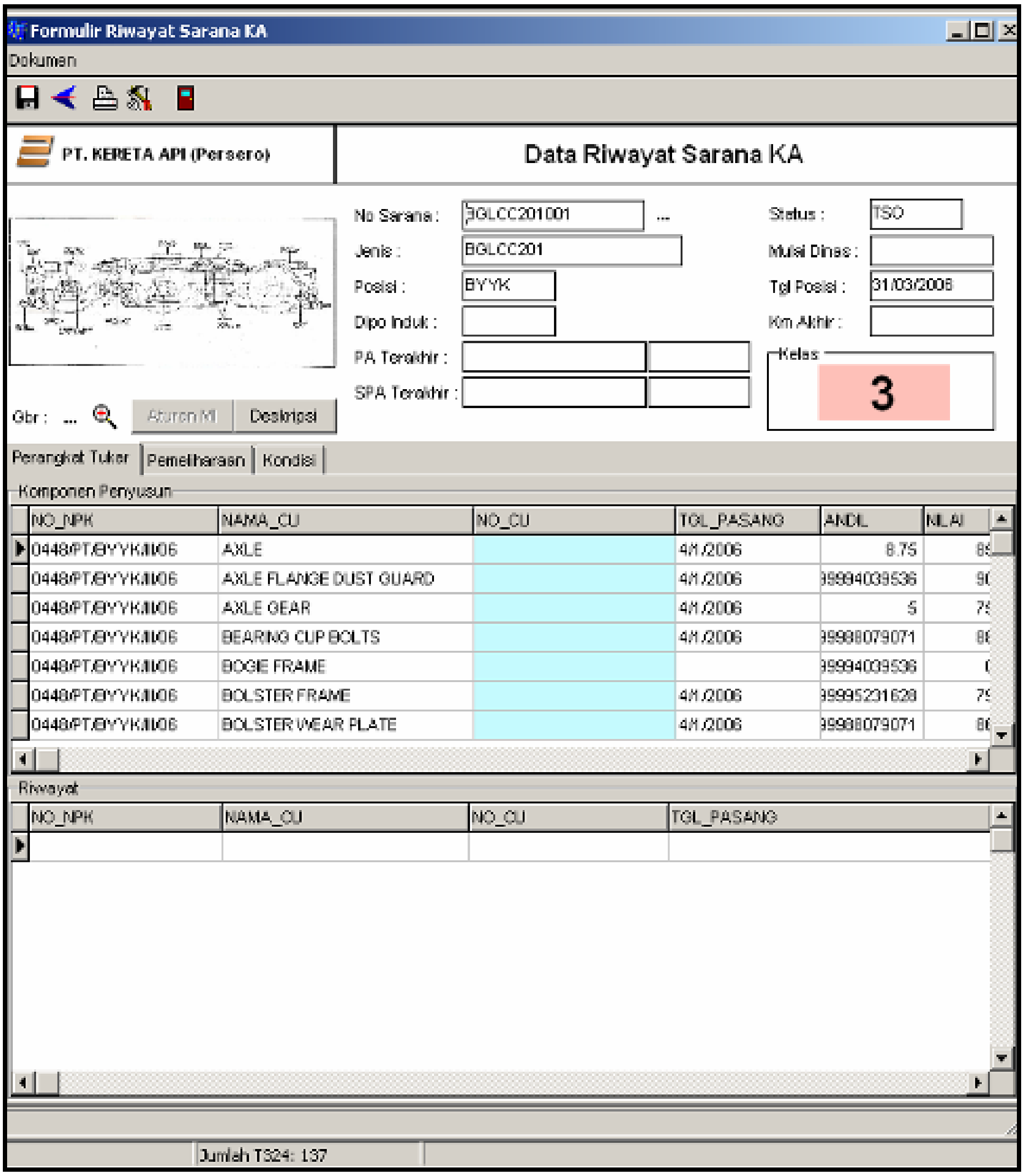


Figure 6 Example of Maintenance History Sub menu form

4. Concluding Remarks

The proposed improvement of the maintenance program through component class grouping to increase locomotive reliability is currently implemented at PT KA. From the work reported in this paper, the following remarks can be presented:

1. Quality of locomotive maintenance can be improved through both management and technical aspects. The management system is being the focus of the work, while using technical data that is currently not much considered systematically.
2. The proposed approach enables the improvement of maintenance management through systematic and integrated maintenance information system
3. RCM concept has been implemented to improve locomotive maintenance performance, with the result of the information of the reliability class of each locomotive in service.
4. By using a well classified locomotive, the locomotive's operation can be optimized to increase reliability of operation and to reduced the risk of failure or/and accident

5. Recommendation

Since the proposed improvement of maintenance management system is being implemented, it is recommended to evaluate and update the factors and considered in the software based on the data and condition of the on-going maintenance program.

6. Acknowledgement

Authors would like to thank Pusrenbang PT KA Indonesia and Balai Yasa Yogyakarta, for the support of this work.

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PREFACE

THIS PROCEEDING includes the information and conference papers of the international conference on Risk Technology and Management held at Institute Technology Bandung, Bandung, Indonesia, on 20th-21st March, 2007. This event is held under cooperation with many associations. Risk Technology has had an immense impact in many fields of engineering in recent years as it offers industrial solution in achieving safe operation under minimum inspection cost. This Seminar provides a forum in which researchers and practitioners can report their findings in this important and stimulating field.

The Conference papers deal with a series of development involving various fields in engineering such as risk technology, risk management and strategy, and risk modeling and analysis. There are 36 papers that are presented in this conference. The papers come from various industry and academic institutions.
The organization and hosting this seminar would have been impossible without the assistance of many people.

Firstly, we would like to thank Fakultas Teknologi Industri of ITB, Total E&P Indonesie, and Prof. Satryo Soemantri Brodjonegoro for their financial support in this seminar. We also would like to acknowledge the support from Komunitas Migas Indonesia, Indonesian Corrosion Association, Center for Internal Audit, Komite Nasional Kecelakaan Transportasi, Profesional Risk Management, and KK Perancangan Mesin ITB. We are grateful to all contributors and sponsoring institutions and companies who helped making this conference possible. Although it is not possible to name everyone involved I would particularly like to thank to all committee members, and colleagues for their support and cooperative works in organizing this seminar. Our sincere thanks and appreciation goes to our students for their enthusiastic assistance in the preparation and during the course out the seminar. Finally we would like to thank all the administrative staffs of the Institute of Technology Bandung for their assistance in the seminar administration.

Dr. Ir. Zainal Abidin
Chairman of the Conference Organizing Committee

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RISK TECHNOLOGY

Risk Assessment
Risk Based Inspection (RBI)
Reliability Centred Maintenance (RCM)
Failure Modes Effects and Criticality Analysis (FMECA)
Lifetime and Remaining Strength Assessment
Condition-Based Monitoring (CBM)
Preventive/Predictive Maintenance
Inspection, Maintenance and Repair Techniques and Technology
Safety and System Integrity
Risk Assessment Software

RISK MANAGEMENT AND STRATEGY

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Regulatory Risk Management
Legal Risk Management
Product and Market Risk Management
Operational Risk Management
Input Risk Management
Tax Risk Management
Treasury and Financial Risk Management
Maintenance Scheduling, Optimization, and Strategy
Risk Mitigation
Risk Management Software

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Model Building and Analysis
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Artificial Neural Network
Risk Analysis Software

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