The 10 most common reliability mistakes made in Railway Industry

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The Reliability pitfalls are technical misunderstanding or lack of perception about the necessity and importance of the application of the proper reliability engineering concepts and method to analyse products and system along their life cycle. Because of such pitfalls, many organizations throughout the Globe are facing big issues with their product and system and in many cases the leaders even know about that. In order to clarify the most top ten pitfalls in reliability engineering, the concepts with examples will be explained to clarify such issues.

Pitfall 1: Generalize the constant failure rate for all types of equipment.

In order to predict the RAM perform indexes based on the RAM analysis as well as validate such performance, it’s during the warranty period, it´s necessary to carry out the lifetime data analysis. Therefore, it´s required to have reliable historical data, which demands time and, in some cases, a huge effort to be accomplished. Unfortunately, many organizations avoid the best and robust approach and put in place the easier solution, which consist to use data from generic databases, which in most of cases are described in the constant failure rate, MTTF and MTTR.

The first problem with generic database such as MIL standards, Telecordia and others is that such data base represents equipment failures under certain operational condition, which may be totally different from the assessed equipment operation conditions. In fact, the problem is not in the database, it´s a user misunderstanding.

Additionally, the assumption of exponential PDF for all types of equipment is a wrong assumption. Based on lifetime data analysis, it´s possible to prove that dynamic mechanical equipment/ component such as valve, pumps, compressors, bearing, rotor`s component, diesel motor´s component and static mechanical equipment such as vessels, wheel axles, wheels, brake pads, pipes, pantograph arms have an increasing and not constant failure rate. Such

increasing failure rate is minimized with preventive maintenance.
Unfortunately, many assessments carried out by excel sheets are not able to consider the proper effect of PM in reliability. For dynamic and static mechanical equipment, the preventive maintenance such as schedule and predictive are being able to restore such reliability before the failure occurs, which is not considered in many poor RAM analysis, which in carried out in excel templates.
For electric and Electronic equipment cases, the perfect replacement will restore the reliability to the state as good as new as will be demonstrated in chapter 6.
Whether the proper PDF and PM are input in the RBD model in RAM analysis, whenever the preventive maintenance and replacement takes place before the most probable time of failure, the failure will be avoided. The figure 1.6 shows the classical increasing failure rate time case when some preventive maintenance must take place.
It´s must to be clear that exponential PDF is a possibility to represent some equipment failure, but it´s necessary proving that such PDF is the best fit for the failure historical data based on lifetime data analysis. However, it´s necessary to be careful because in some cases, some small number of historical failure data are available, and based on the lifetime data analysis, prediction, the exponential PDF as the best fit. Basically, that´s happening because the life cycle of such asset is short, and the increasing failure rate time doesn't achieve so far.

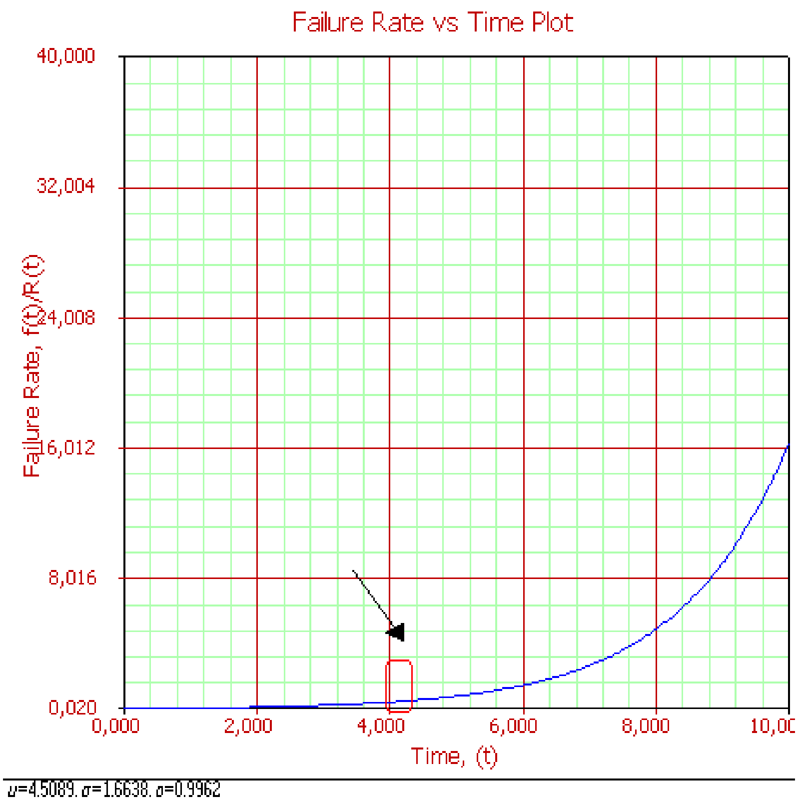

Figure 1-1 Increasing failure rate

The chapter 4 will describe clearly the steps of lifetime data analysis which will enable the reader the understanding about such method as well as the importance to have a historical failure and repair database.

Pitfall 2: To use MTBF as performance index.

In many cases, MTBF are defined as a performance index basically because of the simplicity of such index calculation and understanding.
The main wrong assumption is that the MTTF is the inverse of the constant failure rate, assuming an exponential PDF for all types of equipment. Despite the simple understanding, such index does not describe the performance of equipment and component effectively and precisely like the index reliability or expected number of failures.
In fact, depending on the PDF, the MTBF is dislocated to the right or to the left of the most probable time to failure, leading the manager to a wrong decision about interventions such as inspection, preventive maintenance and assets replacement time.
In Lognormal PDF cases, the MTBF is dislocated to the right of the most probable time to failure occurs as shown figure 1.27 (Weibul PDF: (β=0.8530 and η=2818.16 h). The consequence of take decision based on MTBF, in this case, is that the time to perform the preventive action will be later than the failure time and most probably the failure will occur before the preventive maintenance or inspection. In this specific case demonstrated in figure 1.27, the reliability in 24470 h (MTTF=24470 h) is 34.21%. In other words, a very high chance to have a failure until 24470 h. Such error is only possible to be detected when the PDF and MTTF are plotted as show figure 1.27

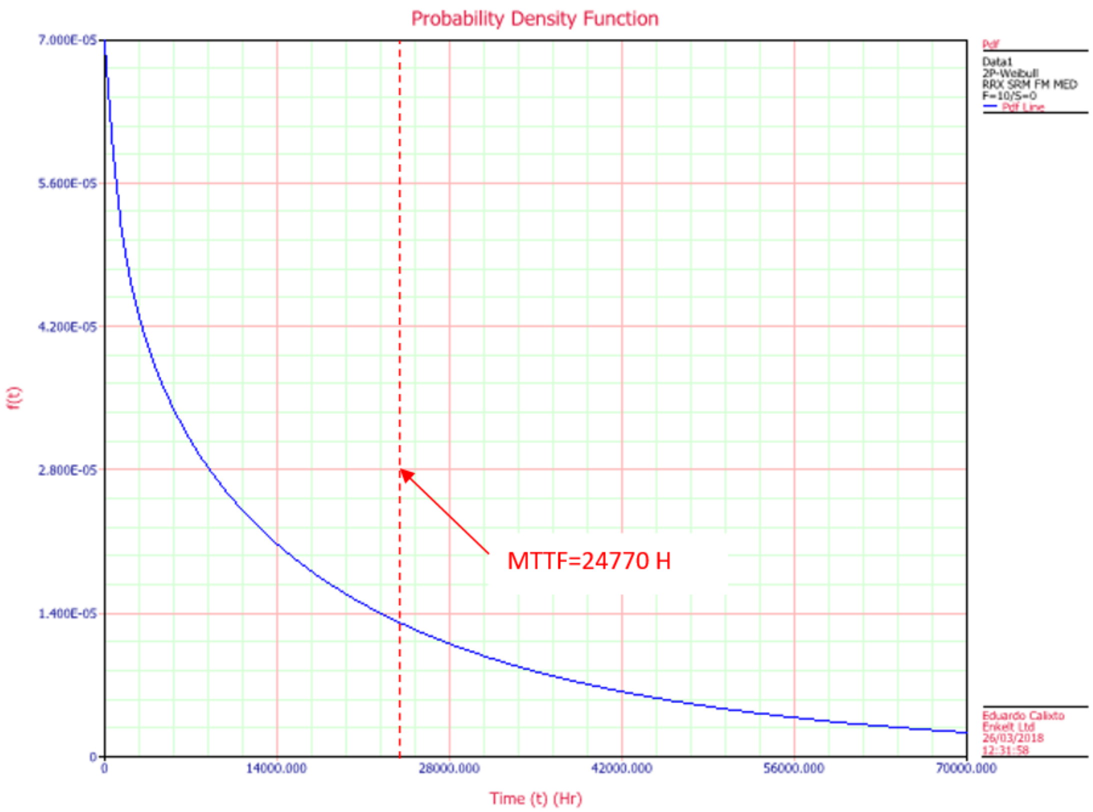

Figure 1-2 Lognormal PDF x MTBF

By the other hands, in Gumbel PDF cases, the MTBF is dislocated to the left of the most probable time to failure occurs as shown figure 1.28 (Gumbel PDF: (μ=139732 years and ∂=36969 years). The consequence of take decision based on MTBF, in this case, is that the time decided to perform preventive maintenance or inspection is set up too early. Therefore, many preventive actions will be taking place and the cost of preventive maintenance will be higher than necessary. The other possibility is when performs some inspection too early, and consequently the failure is not detected because the inspection time is out of the P-F interval.

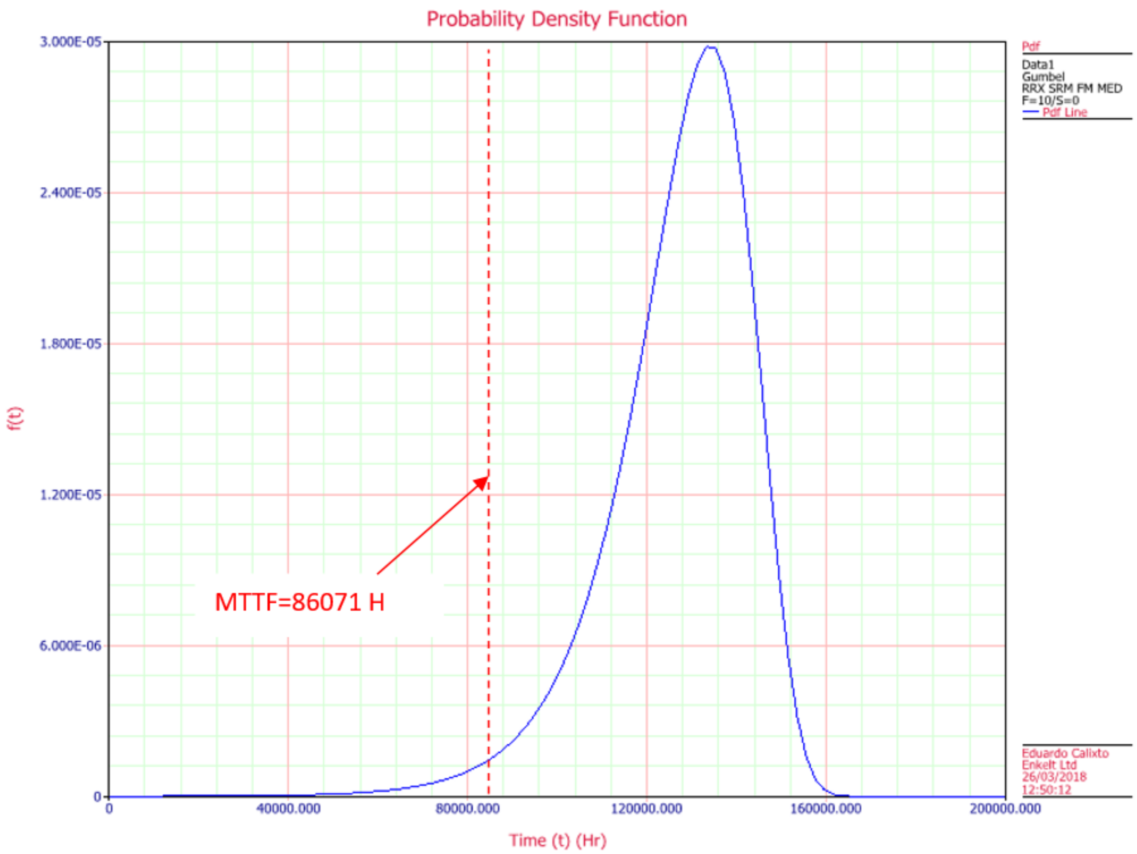

Figure 1-3 Gumbel PDF x MTBF

In case of normal PDF, the MTBF (8760 h) is equal to the most probable time to failure occurs as shows figure 1.29 (Normal PDF: (μ=8760 h and ∂=333 h). Even though, it´s necessary to know the standard deviation to mitigate the risk of taking a decision on preventive intervention too late or too early. The problem of earlier preventive action decisions is that again, in case of an inspection, the failure might not be detected. In case of later preventive action, there will be a higher risk that failure happens before the preventive action.

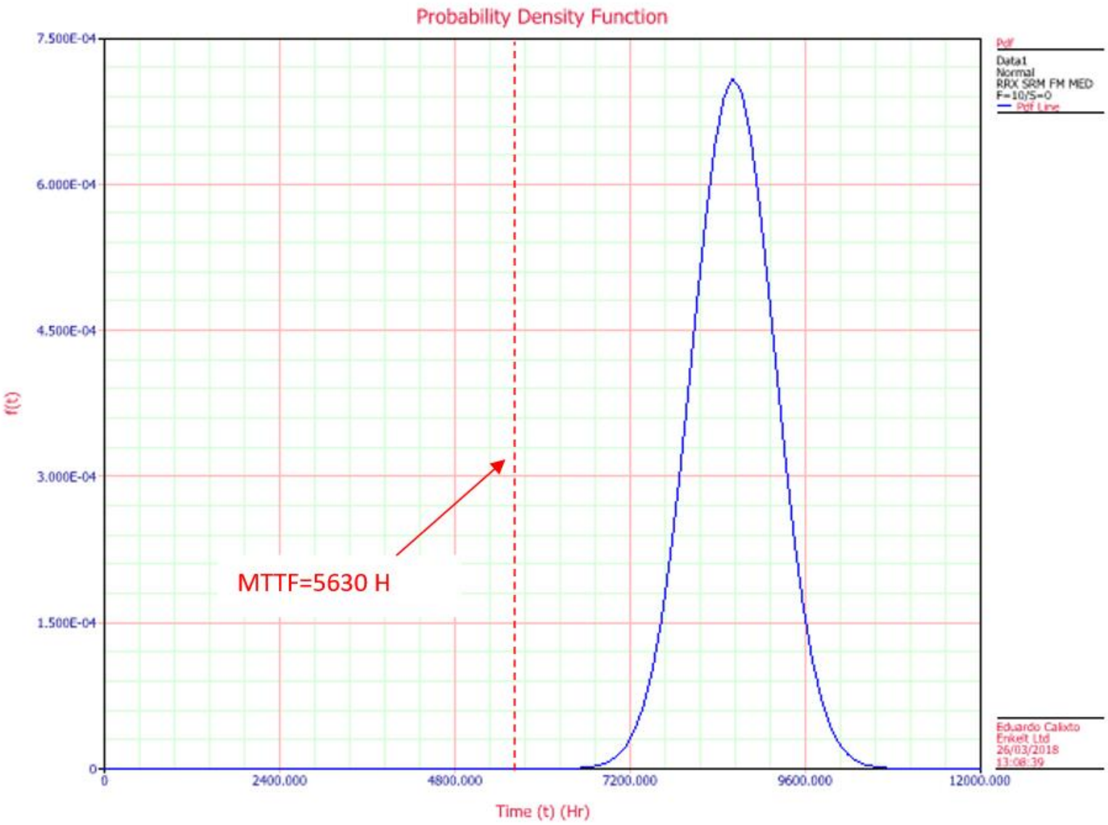

Figure 1-4 Normal PDF x MTBF

In case of exponential PDF, the MTBF is also not a better reference because failure can happen at any time. In this case, the better option is to monitor in the equipment condition or perform an inspection or test to check if the component is available. Concerning performance index, the reliability is the best option which enables to face a lower risk of failure occur.

In fact, for all cases, the most probable time to failure occurs must be verified based on PDF shape. In addition, the reliability for a specific period of time is a better index because such performance is associated with a warranty term condition where is expected a specific time without failure.

Basically, the reliability index shows the chance of equipment perform it function successfully along the period of time. That´s enable a better decision on time rather than other index such as constant failure rate and MTBF. The chapter 4 will show the real reliability engineering concept in detail, including the different types of PDF applied to railway industry assets. The chapter 5 will demonstrate a proper application of MTBF based on the Crow AMSSA model which enable to show the trend of MTBF, in other words, if MTBF increase, decreases or remain constant along time.

Pitfall 3: Do not consider the PM effect on asset performance

The preventive maintenance is applied to most of the mechanical equipment. That´s means schedule maintenance, inspection and predictive maintenance. The predictive maintenance has

an important hole of the railway industry by identifying the potential failure and define an intervening time to preventive action take place before the functional failure happen.
Unfortunately, in many RAM analysis does not take into account the preventive maintenance effect on reliability and operational availability. Despite of the RAM analysis software enable the possibility of input preventive maintenance; such assessment is not carried out in many cases. That´s happened because of lack of information about the preventive maintenance tasks and also because of the limitation of some software to provide the effect of such preventive maintenance on reliability and operational availability.
The error that must be avoided, when account preventive maintenance during RAM analysis, is that the preventive maintenance and corrective maintenance downtime be accounted together with the operational availability. Such errors can happen when the calculation is carried out in excel sheets which not allowed the correct calculation.
In fact, there´s a limitation of representing the online monitoring and other predictive maintenance on RAM software because in the software all parameters are based on a time schedule. In this case, the online monitoring and predictive maintenance are associated with a percentage of the equipment life cycle that the failure is expected to be detected.
The preventive maintenance tasks can be defined as a list of tasks for maintenance group or as a result of RCM and RBI analysis. In addition to including the preventive maintenance task on RAM analysis, it´s also necessary to optimize such task in order to minimize the life cycle cost and maximize the operational availability as will be described in chapter 3. The figure 1.30, shows the positive effect of preventive maintenance on reliability. The figure 1.30 does not consider equipment degradation, because in this case the interval of PM will reduce time in order to re-establish the reliability.
Basically, as will be discussed in chapter 3, the preventive maintenance is a better option if the PM downtime compared with corrective maintenance (CM) downtime. In this case, the higher downtime (CM) is replaced for a lower downtime (PM), which has a positive effect on operational availability.
The other issue that´s must have considered is the cost of CM and PM. Therefore, the preventive maintenance is a better option if the PM cost is lower when compared with corrective maintenance (CM) cost.
In addition, the safety aspect, it´s also important and is more relevant than downtime and cost. That´s means, the PM must be taking place to mitigate a risk even if the downtime and cost is higher than CM. The chapter 6 will demonstrate in detail such approach and the influence of preventive maintenance in the reliability.

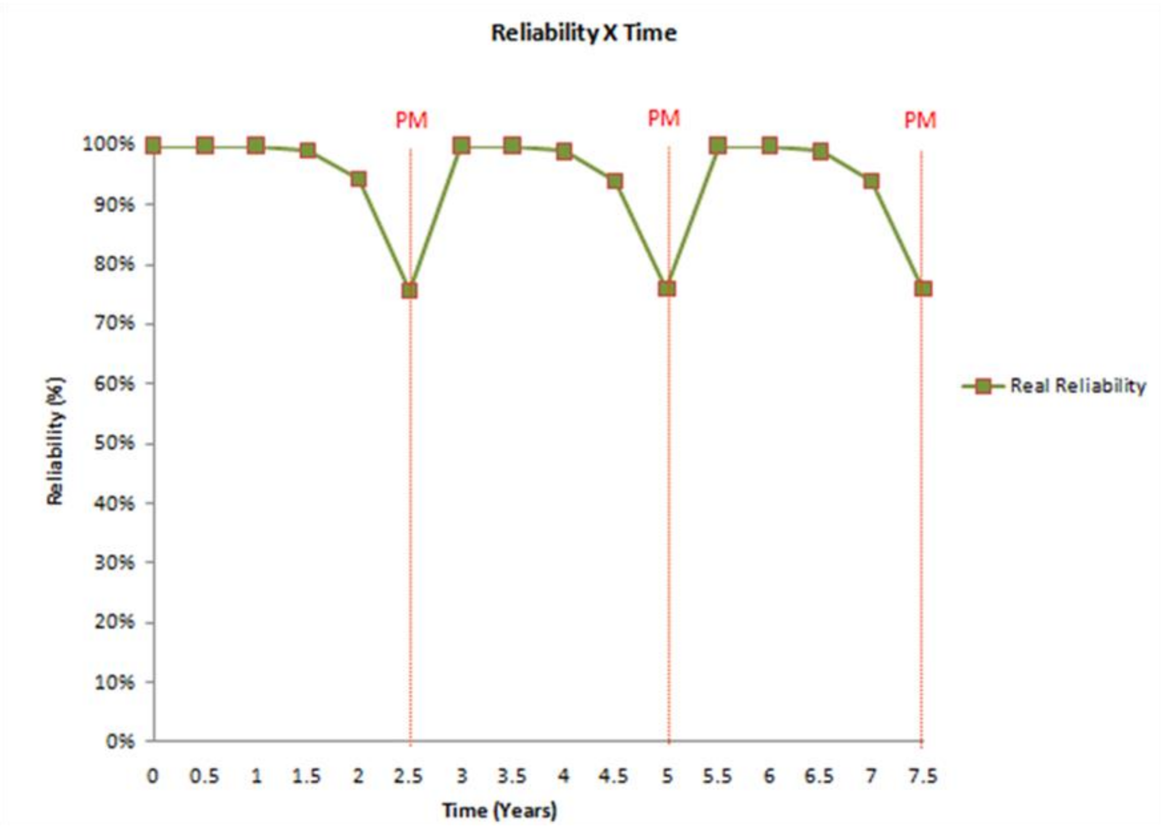

Figure 1-5 Preventive Maintenance effect on reliability

Pitfall 4: Do not consider the human factor effect on asset performance.

The assumption on no human error is, unfortunately, a very common approach when qualitative or quantitative reliability and safety analysis is being carried out. Despite of the recognized influence on equipment failure and accident, the human error hasn't been taken into account as deserved in most of RAMS programs. The deeper equipment failure and accident root cause has, in many cases, some aspect related human error hidden as shows the figure 1-31.

Inside organizations, in many cases, to deal with human error is a big challenge because discuss about human error can lead an employee punishment. By the other hands, some organization, due the internal competitiveness between employees to achieve always high performance and get a promotion, it´s not feasible to discuss about human error.

In fact, such organizations aspects are the huge barriers to implement human reliability analysis together with other safety and reliability analysis in the RAMS program. In terms of methodology, as will be explained in chapter 6, many methods can be applied to perform human error predictions and understand the effect of human performance factors.

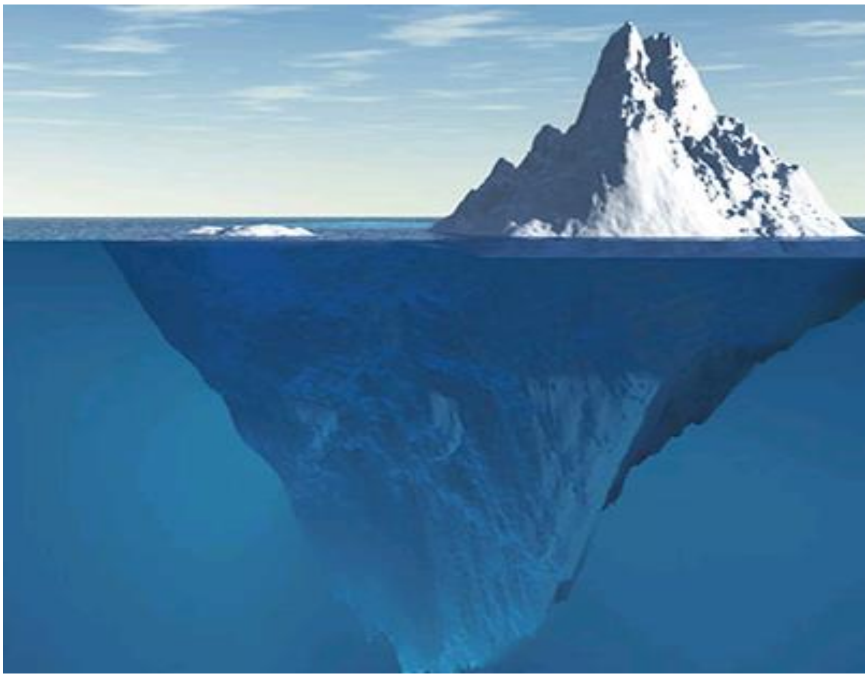

Figure 1-6 Iceberg vision of Human error

Pitfall 5: Do not consider different operation condition effects

Whenever reliability prediction takes place, one of the most important issues to be taken into account is the operational conditions. The common error in this case is to apply reliability data from standard or even historical data from similar assets but under different operational conditions.
In case of using historical data from similar equipment, which operates in harder condition, the reliability prediction will be more pessimistic, which lead to spending more effort than necessary in design improvement action.
By the other hand, whenever the reliability prediction is based on equipment, which operates in softer conditions, that will lead to a very optimistic reliability prediction, which enable a lack of effort to implement the necessary reliability improvement during design.
Once the historical data from similar equipment is available it´s necessary to check the operation conditions and for each individual equipment and components it´s important to take into account the stress factors.
The QALT methods can solve this problem and predict the reliability under specific condition based on historical failure data of equipment under other operation stressor condition. Such approach will be explained in detail in chapter 5. Such methods can also be used to predict the reliability for different operating conditions as shows figure 1.32.
In fact, despite a good approach, we need to be aware that some confidence levels are always inside of prediction. In case of the unsafe failures or even when the consequence of failures leads to the high loss of production and money, the strengths of the equipment and product need to be tested. In such cases, the HALT methods must be carried out whenever it´s feasible as described in chapter 5.

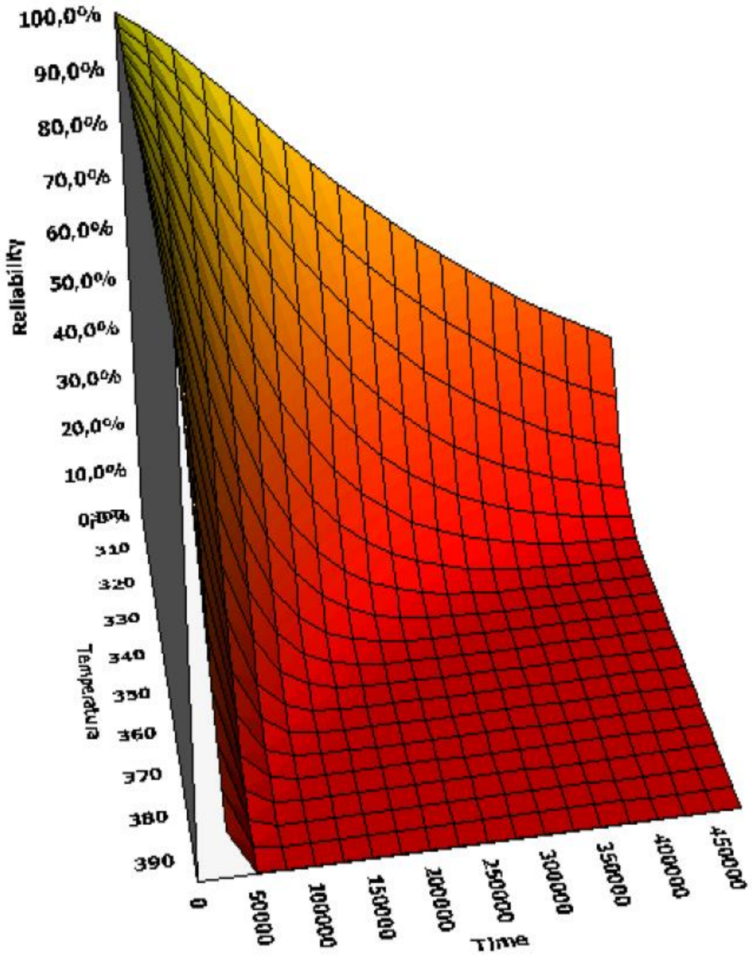

Figure 1-7 Reliability based on different operational environmental condition

Pitfall 6: Do not implement DFR methods when it's necessary

The development of new equipment and component requires applying reliability verification and validation. For electronics and electrical components, the methods such as ALT, HALT and RGA enable to predict the component reliability, test the product robustness and also monitoring the reliability increasing during improvement actions throughout the design phase. Such methods are limited to the dimension of equipment and also to the conditions that its intent to test. But even for huge equipment, in some cases, it´s possible to test the critical parts and components separately, which enable a good picture of the equipment performance.

Unfortunately, such methods are not applied in many projects because the issues of lack of time, money investment and also lack of requirement from clients for verification and validation of performance during design based on ALT, HALT and HASS.

Many organizations still believe that´s better to improve the equipment with lower performance during early life than during the design. In fact, the development during design phase to eliminate the early phase failures also avoid the impact on operational availability during the operation phase.

The DFR method's implementation such as ALT, HALT and RGA may cost some thousands of euros. The cost of ALT or HALT test is between €1.000,00 to €2.000,00 per day. One month of such method's implementation will be around €10.000,00 to €30.000,00. Therefore, such investment compared to the cost of product improvement when is released in the market is very low because it´s may cost millions of euros including the loss of company reputation. The other situation that´s required verification test such as ALT and HALT and RGA is when known equipment or component will operate in new environmental conditions. In this case, it´s also necessary to implement such test rather than predict reliability based on standards or believe that the commission acceptance test will be enough to demonstrate the equipment and component robustness.

Unfortunately, many Railways assets face problems during operations because the low performance of equipment in their early life. However, it can be avoided based on the application of the ALT, HALT and RGA methods during the design phase by the vendors that the main objective to improve the bathtub curve performance by eliminating the early life failures during design. The positive effect of ALT, HALT and RGA is demonstrated in figure 1.33.

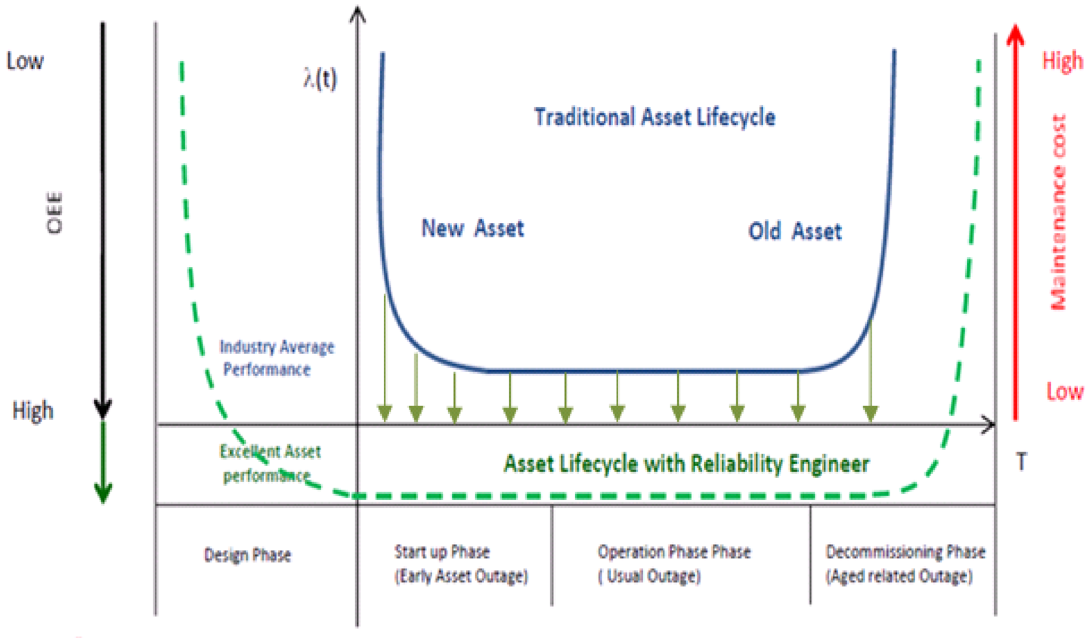

Figure 1-8 Bathtub curve improvement based on better design

Pitfall 7: To generalize redundancy to performance achievement.

The redundancy is a very good solution in many cases to reduce the asset vulnerability to external events and also to improve the asset performance.
Nevertheless, it´s not the best solution for all cases. Many projects have standard solutions to apply redundancies for specific type of components such electrics and electronics components, power supply, software and others. Even though, that will not assure the system will achieve high performance because some common cause failure may affect both redundant equipment.
The first mistake concerning the redundancy is not to define reliability targets for equipment with redundancies, which cause in some cases the high operational cost, despite the system performance target achievement. By the other hands, in some cases, the redundancies have lower reliability, which affects the system performance.
The second important issue is to understand in which conditions the redundancies operate because in some case, the redundancy is not passive but active and have the similar degradation with time when comparing with the operative equipment.

Finally, the concern of input unnecessary redundancies must be of awareness of the design engineer to avoid high operational cost.
The good example of redundancy applied to the railway industry is the TCMS (Train Control and Management System) components. The figure 1.34 shows the ETB and ECN configuration example. The Ethernet Train, Buses (ETB) are typically organized as linear buses, which

provide IP connectivity between couples consists.
An Ethernet Consist Network (ECN) is typically organized in a ring topology to provide redundant paths in the event of cable or switch failure. It provides an Internet Protocol (IP) interface to TCMS and other systems within a consist.

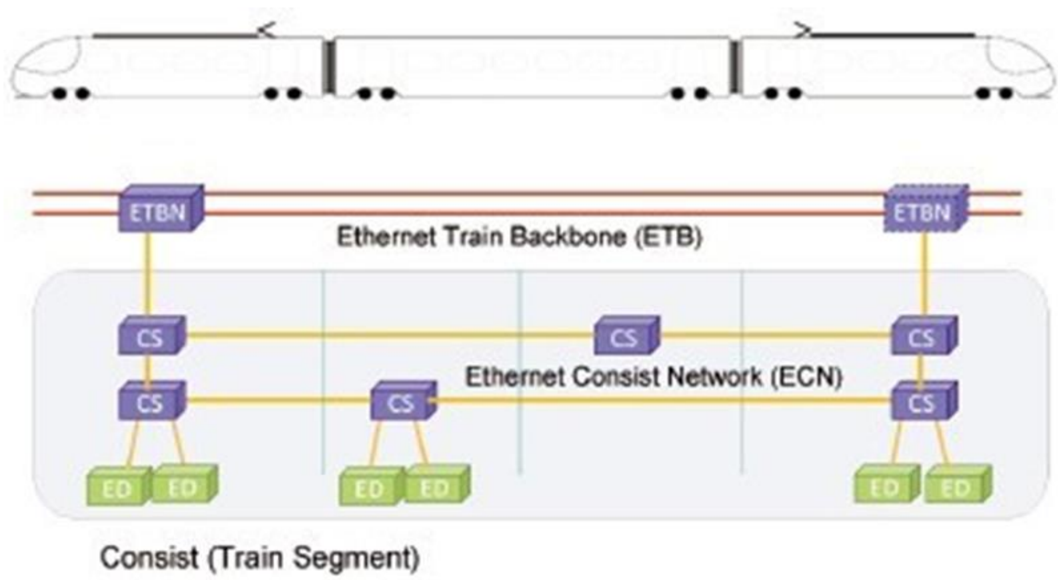

Figure 1-9 ETB & ECN redundant cables

Pitfall 8: Do not consider qualitative methods recommendation

The quantitative and qualitative reliability and safety engineering methods have different objectives, and both are important to be applied in different asset phases.
The big mistake is to believe that only quantitative methods will be enough to enable the asset high performance. It´s also a mistake to believe that qualitative methods will give all solution. In fact, the quantitative methods such as LDA, RAM, ALT, RGA, FTA and SIL are more appropriate to predict and verify asset performance, such as reliability, operational availability, risk, SIL and others index as defined in chapters 5 and 9.
The qualitative methods such as FMEA, RCM, FRACAS, RCA, PHA, FHA, HAZlog, are more appropriate to understand failures and suggest actions to prevent such failures. Such information can be applied to improve critical equipment performance defined in quantitative methods (RAM), drive design improvement (DFMEA) and drive the reliability target achievement (RGA). In addition, by safety point of view, the PHA, FHA, HAzlog enable to identify the hazards, unsafe functions, and the necessary risk mitigation actions.
The main issue is to have a clear understanding about the problem and the type of answer is needed to be solved in order to apply the appropriate method. Depends on the situation, more than one qualitative or quantitative method is required or even a combination of qualitative and quantitative methods as is shown figure 1.35.

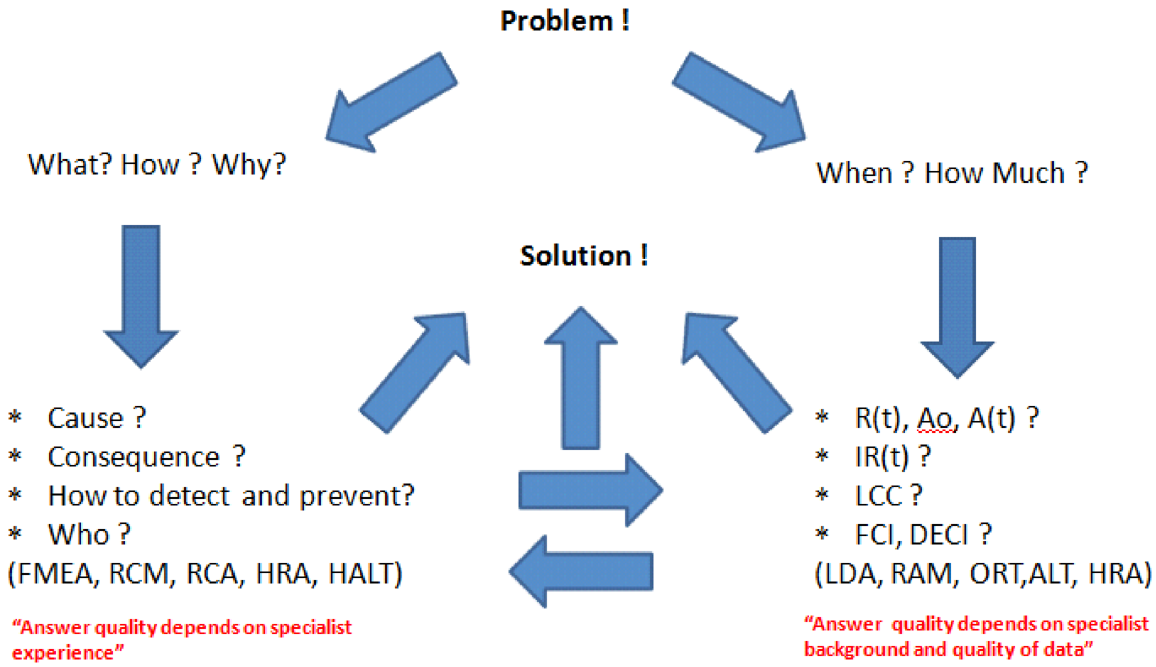

Figure 1-10 Qualitative and quantitative reliability engineering methods

Pitfall 9: Do not consider Life Cycle Cost (LCC) assessment

The additional pitfall is lack of integration between reliability and safety analysis and LCC. In many cases, the LCC analysis is carried out separately of reliability analysis. Therefore, simple assumption about the number of corrective maintenance and preventive maintenance as well as spare parts are taken into account. The best approach is taken the direct and indirect cost into RAM analysis consideration in order to provide a best LCC prediction. In addition, the state of art solution is to carry out the optimization of LCC, concerning the operational reliability target and defining the best interval of preventive maintenance and inspection as well as the minimal level of spare parts. Such approach will be described in detailed in chapter 8. In fact, depending on the asset phase and the type of methods applied the impact on LCC can be easier or harder to predict. Even though, the necessity to demonstrate the impact on LCC is to get support from the top-level organization's leaders to implement action, which may lead to a higher LCC but will enable the railway asset to achieve the performance target.

In many cases, a usual mistake that many engineers do in their proposals, presentation and discussion with higher level leaders in their organization is do not demonstrate the economic benefit or economic trade off of their technical proposed solutions.

No matter how brilliant the solution is, it's necessary to take into account the impact of LCC in order to get the necessary support for such a solution implementation.

Indeed, different reliability methods such as LDA, RAM analysis, ALT, HALT, RGA, ORT, HRA, FMEA, RCM has different objectives and depends on the cases, such LCC prediction can be obtained or not.

In case of LDA, the LCC can be associated when compared the tradeoff between different suppliers, equipment by comparing the economic tradeoff between a higher reliability equipment with a lower reliable equipment.

During RAM analysis application, different solution in respect of redundant equipment, the system configuration impact of PM and also reduction of redundancy must take into account the impact on LCC.
During design, in order to demonstrate the reliability target achievement some reliability methods are necessary such as:

- LDA and ALT for equipment reliability prediction and assurance;
- HALT and HASS for reliability robustness achievement;
- RGA for equipment reliability improvement in the achievement of requirement target.

The main issue in all these cases is to perform the assessment of the investment during the design phase (CAPEX) which compensate the reduction of operational cost (OPEX). Such assessment depends on a supplier or customer point of view might lead to a total different conclusion concerning higher or lower OPEX and CAPEX values.
In fact, it´s necessary that Railways companies define very well the reliability target for equipment and request the assurance of such target achievement from suppliers. In many cases, such requirement does not exist or are not clear. In addition, it must be clear about the compensation cost in case of not reliability requirement not achievement that must be stated in the warranty contract term. From the supplier point of view, it´s necessary to understand that more than direct cost, the company reputation is also an indirect cost that in many cases pays off the investment of all effort during the design to achieve the reliability target defined by the client.
Moreover, it´s also important to identify the cost of recommendation defined in the qualitative reliability analysis, such as FMEA, RCM, HRA and RBI as well as safety analysis such as PHA, HazLog, and SIL.
In fact, such methods have a characteristic to identify the cause and consequence of the equipment problems as well as the recommendations to mitigate them. The recommendation of such methods focusses on project modifications, procedures and task implementation, which also has an impact on LCC. Therefore, the tradeoff analysis of such recommendation implementation as well as different possible solutions must to be taken into account in terms of LCC impact.

However, it´s necessary to be careful whenever safety issues take into account because the LCC optimization do not means the best solution for the safety point of view in many cases. In the end, whenever it´s possible, the result of solutions provided by the reliability and safety engineering qualitative or quantitative method needs to consider the impact on LCC as shows the figure 1.36.
The LCC methodology will be explained in detail in chapter 8 as part of the ILS approach.

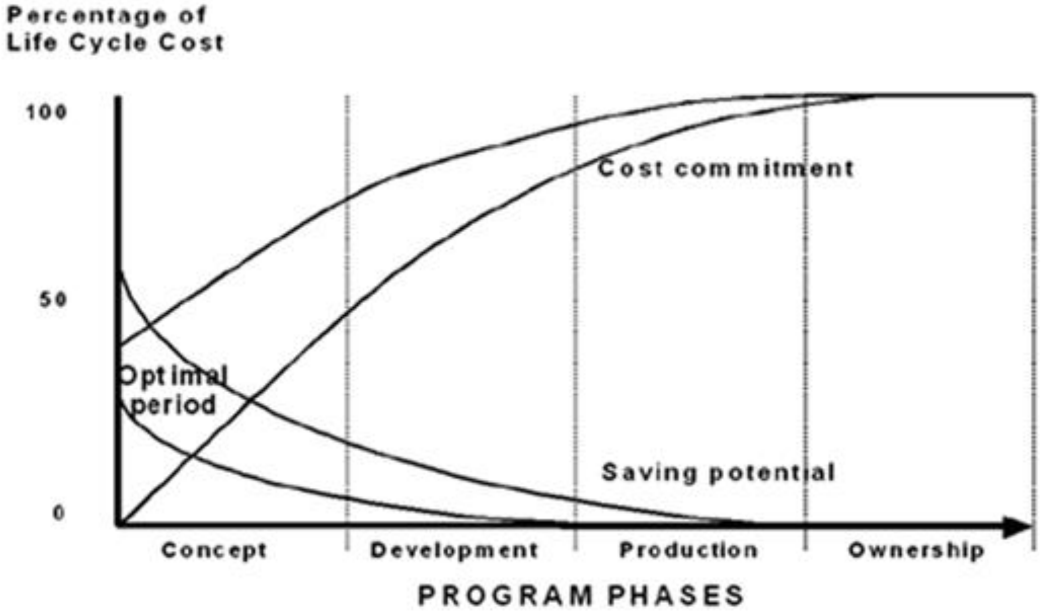

Figure 1-11 Early commitment of product life cycle cost.
Source: Michaels and Wood, 1989.

Pitfall 10: Do not consider RAMS as part of the Asset management

In general terms, the main objective of Asset management is to integrate the different organizational levels of the asset performance achievement as will be explained in detail in chapter 10.
The reliability and safety engineering have an important role in asset management because enables the achievement of asset high performance of the different application methods defined during the design phase.
In addition, during operation phase, some reliability and safety engineering methods must be integrated with an asset management program in order to support and sustain the asset management high performance achievement success.
The common mistake is to keep the RAMS program as part of the design phase and not move forward to operation phase to support asset performance achievement.
Since the problems are solved and the asset performance is achieved, the RAMS program is being realized as important by the top organization that must be maintained to the constantly achievement of the asset high performance.
Therefore, the asset management program must integrate the FRACAS, performance prediction during the operational phase in order to enable an integrated and smart solution for railways high performance achievement.

This introduction of RAMS and LCC program gets to the ends. I hope you enjoyed and understood all important issues related to the RAMS program such as:

- The RAMS and LCC process throughout the railway asset life cycle;
- The RAMS and LCC program elements;
- The reliability and safety engineering methods that must be applied in RAMS and LCC program in a different asset life cycle;
- The RAMS and LCC program barriers and pitfalls.

Now I invite you to go through the following book chapters to have a deep understanding of each reliability and safety engineering method applied to RAMS and LCC program. At the end of each chapter, there will be case studies to clarify the concept.