SOUTENANCE DE THÈSE

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Soutiendra sa thèse de **doctorat** sur le sujet **:**

Élaboration d'un modèle économique optimisant la stratégie de maintenance

Unité de recherche : ***Heudiasyc – UMR CNRS 7253***

Le vendredi 22 octobre 2021 à 15h30
à l'université de technologie de Compiègne,
Bâtiment Blaise Pascal, salle GI-042

Devant le jury composé de :

M. Walter SCHÖN, professeur des universités, président du jury
Université de technologie de Compiègne, laboratoire Heudiasyc, Compiègne
Mme Hind EL HAOUZI, professeur des universités, examinateur
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Invités :
Mme Reine TALJ, maître de conférences, laboratoire Heudiasyc, Université de technologie de Compiègne
M. Jean-François BARBET, PDG et fondateur du groupe Sector, Villebon-sur-Yvette
M. Jérome FENWICH, industriel, cofondateur Synox, Montpellier
M. Laurent BARBAGLI, économiste et directeur général, examinateur
AXA MATRIX RISK CONSULTANTS SA, Paris

Elaboration of an economic model for decision aid optimizing the maintenance strategy of transport systems

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Mai 2018 - July 2021

Summary

The implementation of predictive maintenance is an important issue for industrial companies. First, this type of maintenance is very advantageous comparing to other types of maintenance such as corrective and preventive maintenance. In fact, corrective maintenance is expensive because it is only applied once the system fails. Preventive maintenance is performed on predetermined regular intervals of time which does not allow an optimisation of system exploitation and may not effectively prevent system from failure.

Predictive maintenance comes to overcome the drawbacks of corrective and preventive maintenance by making a failure prognosis to anticipate the failure of the system on the basis of interpreting real data coming from industrial connected sensors. This allows to avoid system failure and provide an optimal use of the system in the same time. The data coming from sensors are processed by computer to assess the health state of the system. One of the measures to assess the health state of the system is the remaining useful life.

The remaining useful life is a frequently used measure to perform failure prognosis on the system. It is defined as the expected length of time the system is likely to operate before it fails. The remaining useful life is an important functional aspect of an efficient prognosis and health monitoring in predictive maintenance as its prediction is necessary to verify if the mission goal can be accomplished in time and is important to help in online decision-making activities such as fault mitigation, mission re planning, etc.

Once the remaining useful life of the system is predicted in time, it remains a challenging task for experts to determine the optimal time for predictive maintenance that minimizes the total cost of maintenance. Therefore, we propose in this thesis an original methodology for maintenance strategy optimization;

the objective being to determine the optimal inspection interval and a remaining useful life threshold for predictive maintenance that minimizes a total cost function. This total cost function contains direct maintenance costs and indirect maintenance cots. The direct maintenance costs include the cost of inspection, the cost of corrective maintenance, the cost of predictive maintenance and the cost of system downtime due to maintenance. The indirect maintenance costs, on the other hand, contain the risks incurred by system deterioration and failure.

Maintenance risks are various and can be human loss, environmental loss or financial loss. While it is easy to evaluate financial risks of maintenance in terms of monetary losses, environmental risks and especially human risks are difficult to evaluate in terms of money. Adequate methods should then be used to determine the financial values of environmental and human risks. Some measures are inspired from economics such as the value of statistical life. This measure represents the marginal rate of substitution between income (or wealth) and mortality risk. It indicates how much individuals are willing to pay to reduce the risk of death.

In reality, the evaluation of risks by the decision maker is impacted by his psychology and his attitude to risks. Prospect theory comes up to consider the psychology and the human cognitive process in the process of decision making. The prospect theory starts with the concept of loss aversion, an asymmetric form of risk aversion, from the observation that people react differently between potential losses and potential gains. Thus, people make decisions based on the potential gains or losses relative to their specific situation (the reference point) rather than in absolute terms: this is referred to as reference dependence. For example: faced with a risky choice leading to gains, individuals are risk-averse, preferring solutions that lead to a lower expected utility but with a higher certainty; while faced with a risky choice leading to losses, individuals are risk-seeking, preferring solutions that lead to a lower expected utility as long as it has the potential to avoid losses. The prospect theory takes then another turn from the classic model of the expected utility theory, which only considers choices with the maximum utility.

Usually, decision making is performed in uncertain situations, meaning that the probability distributions of possible events following a decision are not known or partially known. This is also due to the fact that the estimation of the remaining useful life of the system is only predicted and cannot be precise. Decision making criteria such as Wald, maximax, Hurwicz and minimax regret criteria, are used to deal with this problem of uncertainty.

All the different previously cited aspects on risk and uncertainty in human decision making are integrated to our proposal for maintenance strategy optimization, namely the maintenance risks, the prospect theory applied to maintenance risks and uncertainty in the decision to perform maintenance or not. This makes our proposal simple to understand and easy to apply as the proposed methodology remains generic and modular.

Finally, in order to taste the validity and illustrate the applicability of our proposal, we first compared our proposal with a similar methodology on maintenance strategy optimization inspired from literature. This comparison was made by studying the different results obtained by both methodologies under variation of an input parameter while maintaining fixed the other input parameters. Second, our proposed methodology for maintenance cost optimization was applied on different critical components integrating complex systems, once by ignoring maintenance risks, then by considering them and finally by considering them with the prospect theory. Last but not least, the consideration of decision criteria such as as Wald, maximax, Hurwicz and minimax regret criteria in human decision making were also illustrated in a practical case study.