LA DURABILITE: MANAGEMENT & EXPLOITATION DES DONNEES EN CLIENTELE DANS LE SECTEUR AUTOMOBILE
DURABILITY and RELIABILITY: MANAGEMENT & EXPLOITATION OF THE DATA FROM CUSTOMERS' USAGE IN THE AUTOMOBILE INDUSTRY

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Résumé
Cette communication aborde la durabilité dans l'industrie tant sur le plan managérial que technique. Les enjeux sont la maîtrise des coûts d'entretien et de réparation liés au vieillissement. L'originalité de l'approche est d'aborder la question dans son ensemble pour s'adapter au cadre projet : avec une analyse DMAIC pour l'aspect managérial et statistique pour l'exploitation des données. Le bilan est l'amélioration d'un outil statistique avec un gain en réactivité pour détecter et quantifier les crises qualité, ainsi qu'en robustesse, tout en assurant la vulgarisation et l'accessibilité de l'outil pour un meilleur déploiement dans les métiers.

Summary
This communication tackles the durability for industry, both on the managerial and technical plan. The main issue is to control costs of maintenance and costs of failures due to the ageing of components. The originality of the approach is to consider a global issue in order to adapt to the planning’s constraints of Projects: while deploying an analysis DMAIC to deal with the managerial and statistical features of the analysis of data. The assessment is an improvement of the statistical software that estimates the vehicle’s durability. It means reactivity and robustness to detect and quantify the quality crises, while insuring a good accessibility for a best deployment on each domain of design.

Issue

1 Purpose
This communication clarifies how the durability can be approached in the industry both on the managerial and technical plan. Durability means here “the capacity of a system to carry out a required function – under given conditions of usage and maintenance, until a limit state is reached”. The limit state (definitive cessation of the use of the system) is due most of the time to wear or degradation of a component. The irreparable state of a system can also correspond to a cost of repairing that could be considered as unacceptable by the Customer.

The challenges of the durability are thus the control of the costs of maintenance and costs of failures due to the ageing of components (resultant functional degradation of components during and after the warranty period), and the control of their impact on the image of products in terms of reliability (Szymczak, 2016).

2 Difficulties
From a managerial point of view, the problem is that the reliability is considered as a prerequisite or an established during the conception. Furthermore the designers have to answer to more and more hard technical and economical compromises and need to be supported by decision-makers who are concerned by the mastery of the reliability in use (Farley, 2016).

Concerning the analysis of customers’ data, the main problem is time’s constraints.
On one hand the designers and the decision-makers need to have the results of predictive reliability of components early since the beginning of the Project; on the other hand, it is necessary to wait a minimal time to get the warranty data of replaced vehicle in order to constitute the reliability feedback.

Approach

1 Principle
At the beginning of a new Project, a maximum of information on the ageing of the product is necessary. These data of reliability are available only after an incompressible time required to get first reliability results in clientele. Then a solution has to be found to provide this kind of information just in time to be compatible with the planning of a Project.

The originality of this approach is to consider a global issue in order to adapt to the planning’s constraints of Projects while deploying an analysis DMAIC to deal with the managerial and statistical features of the analysis of data.
- the managerial process is improved by an analysis DMAIC (confer Management Plan)
- the delay to get the required information is reduced by more than one year thanks to the improvement of the statistical method (confer Customers data operation)

2 Management plan
The current process has been analyzed with the method DMAIC by Black Belt 6 sigma of our company. As a reminder, DMAIC means:
The members of a Reliability network are requested to implicate them according to the principle on the figure below. According to this principle, the Black Belt helps in the analysis and the measure, and then guides the person in charge and his team so that they define themselves the evolutions of Process or action plan to be led.

During steps D to A, the clients and the suppliers are interviewed in order to identify the expectations of all of us. The result of this is the Measure of the current process "the methodological support for a deployment in project". The major interest of these steps is: knowing how to define the frame of the studied process and the associated needs (deadline, type of data) which are resultant of other processes.

Example: during the study of process "the methodological support for a deployment in project ", one of the input data of the process "application of the durability in project" is the analysis of Pareto (list of priorities) of the replaced vehicle at the time of the commitment of the Project.

This Pareto is the list of the components that are not reliable enough, and particularly because of a problem of durability. Durability of these components needs to be improved by the designers / decision-makers.
During steps A and I, various workshops are realized to build together the action plans with the required level of quality, precision, and timing of inputs and outputs.

Example: concerning the input "Pareto", it is highlighted that a global list based on the average production is not enough precise and that the annual edition of results is insufficient. Improvement of data analysis based on statistics is also needed to reduce the processing time.

The step C is in progress, nevertheless the example proposed in the paragraph results does not leave doubt according to the expected gains.

3 Customers' data operation

The statistical analysis of failures in use of components is based on data available in the database of Warranty. This database is particularly efficient for this kind of analysis because of the exhaustiveness of failures that affect the functional state or quality in use of the vehicle of customers; firstly because it is free for customers to do repair their vehicle during the warranty period if they do it in the official network of Repair-centers; secondly because the reimbursement of Repair-centers is precisely conditioned by the transmission of the case file of each repair with data of vehicles: age, mileage, kind of failure, deficient component, verbatims of customer.

The calculation of reliability is done using Weibull statistical models based on the mileages of deficient vehicles. Recurrences are not taken into account.

The choice to do Weibull analysis according to mileages instead of ages of vehicles is arbitrary; firstly – mileages – because when we have got only mileage and age as information relative to the use of the vehicle, it is obviously the mileage of the vehicle which is probably more representative of the level of stress or damage of the deficient component; secondly – arbitrary – because it makes easier the massive treatment of data of Warranty (around 1 to 2 million of cases are computed yearly) on which it is not possible to do a pre-analysis of the kind of failure to determine the best damage parameter between mileage and age for each case (around 50 000 to 100 000 analysis are computed yearly).

However, to take into account the age of the vehicle even though, it makes sense to group vehicles according to the average monthly mileage. Doing this way, Weibull analysis could be more representative considering the fact that:
- for components on which intrinsic characteristics are affected by the time (for example the mechanical characteristic of rubber materials), at the same mileage on two vehicles, anything else being equal, there are more probabilities of being deficient on the older vehicle;
- for components on which damage is depending of the kind of runs of the vehicle (for example due to aerodynamic, thermic, vehicle speed), vehicles with the same average monthly mileage have more probabilities of having more comparable damage.

Then the statistical analysis is done on each group of vehicle using the Maximum Likelihood Method in order to determine Weibull parameters and distribution function \( F_x \) associated to mileage of vehicle, with their intervals of 80% of confidence. The distribution function \( F_a \) associated to age of vehicle is calculated (fig.1) with the \( F_x \) distribution and the \( \chi \) function which define the mileage reached by a given proportion \( u \) of vehicle at a given age \( a \).

\[
F_x(a) = \int_0^a f_x(x) \, dx = \int_0^a \frac{dF_x}{da} \, du \, da
\]

*fig.1: relation between \( F_x \) and \( F_a \) (according that \( f_x=dF/dx \))

The \( F_x \) distribution, respectively \( F_a \), on the global population of vehicles is finally obtained summing the \( F_x \), respectively \( F_a \), of each group with the ponderation of the proportion of each group in the global population.

The difficulty met by the application of the methodology consists in choosing the right number of group to be generated. Actually, the subdivision of the global population leads to a reduction of complete data (deficient vehicles) for Weibull analysis on each group, and consequently to a reduction of the level of confidence in the estimation of Weibull parameters. According to feedback on previous treatments of Warranty data done with a subdivision in 5 groups, it is highly recommended to adjust the number of group to 1, 3, or 5, depending on the resultant repartition and number of complete data in each group. Furthermore, the groups are defined so that they are representative of really differentiated average monthly mileage, and progressive. Considering the width \( w^* \) of a group, defined by the difference between the upper limit and the lower limit of average monthly mileage (\( km^*_{\text{sup}} - km^*_{\text{inf}} \)), follows a geometric sequence. Once more, the feedback shows that it is recommended to take 3 as common ratio for this geometric sequence for 3 groups, and 2 as common ratio for 5 groups

Finally, in order to give to non-expert users of the algorithm a simple way to estimate the confidence to be associated to analysis, an indicator of confidence is generated taking into account the confidence intervals of Weibull parameters and coefficient of determination between Weibull models and real data on each group (Hazard Plotting method).

This methodology is obviously not as efficient as Weibull analysis done on the real damage parameters of components and on factors that have an effect on it; however, without any available information on damage parameters, this methodology gives some key to have more representative statistical analysis only based on age and mileage of vehicles. It is the object of a patent application n°1651666 registered the 29/02/2016.
Results

The case mentioned below to illustrate the application of the methodology is about noise appearance of a component of suspension system. The problematic is to determine the reliability in use of the component, based on the occurrences of failures (noise appearance) in the first 9 months of selling of the first 6 month manufacturing of the product, and to confirm the supposition of a failure affected by the ageing of component.

The overall number of vehicles is around 160 000, and 64 deficient components have been detected during the period.

![fig.2: graph of selling of vehicles, and corresponding number of deficient vehicles](image)

On the overall population of vehicles, the distribution function of average monthly mileage observed at 24 months is modelized as a Log-N distribution. It is precisely useful to modelize the censured data (kilometers of non-deficient vehicles are not known).

![fig.3: distribution of average monthly mileage observed at 24 months](image)

Then the subdivision of the population is generated in 3 or 5 groups in order to do the repartition of the 64 deficient vehicles and to decide if 1, 3, or 5 groups have to be finally generated to go on with the Weibull analysis.

![fig.4a and 4b: subdivision in 3 groups, and resultant repartition of failures](image)

![fig.5a and 5b: subdivision in 5 groups, and resultant repartition of failures](image)

According to the resultant repartition of failures, it is recommended to generate 3 groups, because in case of a subdivision in 5 groups the number of failures in group n°1 and n°5 would be insufficient to produce statistical analysis with a good level of confidence.

The results of the Maximum Likelihood on each group give β parameter around 2.4 and η parameter around 200 000 km, which confirms the supposition of ageing failures.
The distribution function $F_x$ and $F_a$ on each group (fig.7a to 7c) are summed considering the ponderation (46%, 48%, 6%) corresponding to proportion of groups (1, 2, 3) in the global population to obtain the distribution $F_x$ and $F_a$ for the global population (fig.8a and 8b).

The prediction of unreliability is estimated to $1.9E-02$ at 24 months duration, which is 10 times the unreliability really observed at 9 months duration. This result is very useful to conclude with the consequences of the failures, and help to take adapted measure to eradicate the problem.
Conclusions

Two major results:

1) An analysis’ method to solve problem of the Durability’s management that highlights and handles the recurring difficulties in Project, with some opportunities like a continuous improvement of our culture of the client, and also difficulties like estimating the impact on the brand image

2) A statistical methodology to estimate reliability is included into the software that manages the data base of Warranty and After-sale operations. Then it gives the possibility to deal with predictive reliability of all components in every vehicle’s configuration (car family, motor, gear-box). The Pareto Durability helps designers to focus on components that need to be improved. Thanks to the last evolution of the software, prevision of reliability at 7 years / 150 000 km will be estimated from the feedback of the first 18 months period starting after the first entry into service of vehicles (current prevision is done only after 33 months).

The assessment is an improvement of the statistical software that estimates the vehicle’s durability. It means reactivity and robustness to detect and quantify the quality crises, while insuring a good accessibility for a best deployment on each domain of design.

Références

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