DEVELOPMENT OF TRAINING METHODS TO ACCELERATE THE COMPETENCIES ON WEIBULL ANALYSIS: CASE STUDY IN THE AUTOMOTIVE INDUSTRY

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In the automotive industry, statistical methods are well used in areas such as design, production or analysis of customer returns. However, real problems are often poorly formalized which creates special difficulties of implementation: choosing the appropriate method, selection of data for the model, physical and technical interpretation of results… Weibull analysis is a statistical method used to characterize the lifetime of a product during testing or in-service. It gives indication on failure mechanisms and the causes of product failures. It also predicts the expected number of failures based on real observed failure data. This paper focuses on the characterization of professional knowledge for Weibull analysis. It is based on analysis of technical notes written by engineers from RENAULT SA. The aim is to improve internal training. We present the context of the study, describe the implementation of the method and then explain how to use our results to improve training.

INTRODUCTION

The deployment of optimization methods, robust engineering, reliability and statistics has a strategic interest in the world of business and the manufacturer RENAULT SA is particularly attentive those methods.

As part of the automobile engineering, these methods proved their effectiveness.

- The robust engineering: it aims to make a system less sensitive to disturbance factors like the risks of manufacturing and environment, in such a way that the product functions well in any circumstance. Among the associated methods we can quote the experiments designs.
- The experimental and predicted reliability: it aims to predict future reliability from test results, simulation and calculation; to ensure the system function in conditions of maintenance and warranty. Among the associated methods we can mention the Weibull analysis.
- Operational reliability: it aims to estimate and characterize the reliability of automotive systems in service from return customers in the networks maintenance and repair. The Weibull analysis has become an essential method.

The implementation of these methods requires multidisciplinary expertise that is long and expensive to acquire. Tutoring, a priori essential in this process of growing competence, consumes resources of expert not very available and has a variable efficacy. Consequently, the deployment of methods is currently hampered by the scarcity of specialists able to apply them and provide technical support to accompany the "operational" (users of these methods).

The work presented here is in this industrial context. The objective is to study the development of methods of training and support to accelerate and improve the quality of the growing expertise of specialists in the three areas mentioned above, optimization, robust engineering, reliability and statistics.

This research must provide methods and supports (process training and support, tutorials, tools for simulations of real problems) allowing in the short run to accelerate the growing competence of specialists and ensure consistent quality of training.

The methods that we will have to develop are based on existing training and have long-term goal either to improve them, or to supplement them, or to replace them.

In K. Makar, B. de Sousa, & R. Gould (Eds.), *Sustainability in statistics education. Proceedings of the Ninth International Conference on Teaching Statistics (ICOTS9, July, 2014), Flagstaff, Arizona, USA.* Voorburg, The Netherlands: International Statistical Institute. iase-web.org

One of the originality of this research is that the whole of the methods studied make all with statistical bases. Our goal is to provide a detailed scientific expertise.

PROBLEMS

In our paper we report on a study conducted in the context of my thesis concerning precisely Weibull analysis, method used in operational reliability. This study aims to improve the training of engineers at Renault SA to this method.

What is a Weibull Analysis?

Weibull distribution, named by Waloddi Weibull engineer and mathematician recognized for his work on tiredness of materials and statistics is a probability distribution describing the lifetime. It models the distribution of failures and can be adjusted on most modes of noted failures. It expresses the probability of failure (or the proportion of defaulters) based on mileage, of a time of use, a number of cycles noted "t" below. It is able to describe each phase of the life cycle of an electronic or mechanical device by an instantaneous rate of failure of the form:

$$\lambda\ (t) = \text{Error! Bookmark not defined.} \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}$$

The Weibull distribution is a continuous function with three parameters: β, γ, η.

The parameter of form β. This is the most important parameter of the Weibull distribution. It is directly involved in the expression of the instantaneous rate of failure. Depending on the value of the parameter β, we determined which phase of the life cycle of the material we are:

- *β <1: the instantaneous rate failures decreases with time*. This is the period of youth, running or debugging equipment. The cause of the failure can be a problem with a new manufacturing process, but also with a characteristic product too dispersed, compared to the functional need.
- *β = 1: the instantaneous rate of failures is constant*. This is the period of maturity: the failures are random (human errors, natural disasters but also mixture of populations). Failure follows an exponential law. This case is characteristic of equipment with electronic component.
- *β > 1: the instantaneous rate of failures increases with time*. The risk of failure increases with use. This is the period of aging of the organ: they are failures wear (belt ...), breakdowns of tiredness (oligocyclic, with a large number of cycles, corrosion, fatigue...).

The position parameter: γ. This is the time / mileage at which the first failures begin to appear.

The scale parameter η (also called characteristic lifetime). If γ = 0, this is the time/mileage at which 63.2% of organs are failing.

There are three Weibull models:

- *Model 1M2P (one mode, two parameters).* It is the representation of a Weibull distribution with two parameters β and η (γ is assumed to be zero) and describing only one failure mode. γ = 0 corresponds to a possible appearance of the first failures from the actual commissioning of the system.
- *Model 1M3P (one mode, three parameters).* It is the representation of a Weibull distribution with three parameters β, η and γ ≠ 0, describing a single failure mode. When γ is positive, it is comparable to a break-in period. When it is negative, it reflects a pre-damage with kilometer 0.
- *The 2M4P model (two modes, four parameters).* It is the representation of the adjustment of two Weibull distributions with four parameters β1, β2 and η1, η2, describing two modes of failure. The same piece can fail in 2 different ways. The two failure modes coexist together, at some point (called point of the second mode), the second failure mode becomes dominating on the first.

The Weibull distribution makes it possible to describe each of the three phases of the lifetime of an organ. The modeling of the failures distribution of an organ by the Weibull distribution is to estimate the parameters β, γ, η which coincides best with incidents observed and rolling vehicles. It allows deducing the most likely failure modes and thus the ways from investigation to privilege specifically technical causes of these failures.

Observation and Research Question

Within Renault SA the services consist of Basic Work Units (BWU) that are made up of specialists and referents. BWU Numerical Methods is a transversal BWU that gives internal trainings and answers the questions from engineering (statistics, robust engineering, reliability and optimization).

In the company there are 2 Weibull analysis trainings open to any public and given by the staff in the form of course with approximately 20 people per session:

- Building a Weibull analysis in one half-day (4 hours)
- Interpret a Weibull analysis in one day (7 hours)

A guide to conduct a Weibull analysis of 58 pages is distributed during the training. Following a preliminary survey of twenty engineers who have completed training above we found that the guide is very little used and trainees are not autonomous. While being based on the requests sent to the BWU Numerical Methods, we note difficulties such as technological interpretation of β, but also that the Weibull tool remains unknown to much of the Renault public.

With a view to work out a device of rise in competence that focuses on the effective difficulties of the users of the method, the study presented here aims to answer the following question: *What are the difficulties of the engineers for the implementation of a Weibull analysis?*

This objective is similar to some research identified in the literature review (Zieffler et al., 2008), who are interested in faulty reasoning.

METHODS

Engineers in their fields do problem solving after they write technical notes stored in a database. These technical notes describe the problem to solve, the reasoning and the duration that separates the request and the answer given.

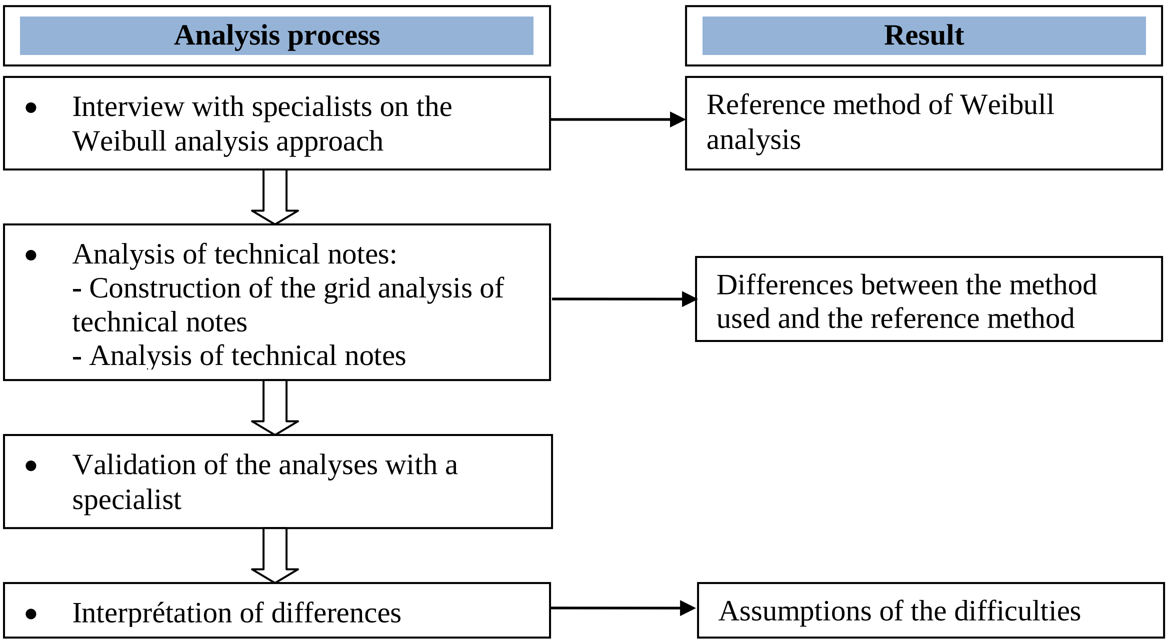

Figure 1: Summary of the approach: Analysis and Results

We analyzed 29 technical notes related to Weibull analysis. The result of this analysis was validated by BWU Numerical Methods and Statistics & Reporting service (which is requested in the event of complex problems). This approach aims to make a fine diagnosis of the difficulties and capacities of the users of the method in real cases treated. We expect a reinvestment of this knowledge in the design of new more appropriate training. Another challenge is to formalize a practical expert knowledge hitherto implied, which serve us a reference for analysis but also for training and coaching practices. The diagram above (Figure 1) summarizes the approach that we adopt.

Interview with Specialists on the Weibull Analysis Approach

At this stage, we interviewed experts on the "right" way to conduct a Weibull analysis. We have identified three steps that constitute what we have called "reference method":

Checking of the basic conditions. It is imperative to check the homogeneity of the perimeter by realizing a GMR curve (Guaranteed Month Reliability). MWR curve shows the number of incidents based on months of runs.

It also should be checked that there are at least 6 points to draw a Weibull, each point corresponding to an incident.

Construction of the Weibull curve. It is necessary to choose a model among those three that exist (1M2P; 1M3P; or 2M4P). We test the first one and according to the result we kept or choose another model. The model is kept if the curve fitting obtained is visually good compared to the points. In cases where the fit is bad the 2M4P model is chosen if the curve has a net slope change.

Interpretation of the parameters of the curve. One of the important points for this part is to check the consistency between the failure mode and β. For example β > 1 must guide us on a fault that is probably due to an aging piece (example: cracked material...).

Analysis of Technical Notes

The analyzed technical notes are traces of the studies conducted by engineers. They do not allow building the chronology of steps taken. On the other side they contain clues to characterize the coherence of the written study. Indicators that we worked out can be divided into two categories named "parameters of information" and "identified errors". In the first (which describes the treated case and the choice of the engineer) we note all the information on the curve (e.g. the model chosen for the construction or the number of points used to plot the curve, the value of β...). The second category of indicators allows us to check if the choices and criteria interpreted by the engineer are relevant taking into account parameter of information: for example, the choice of model, the correlation between β and the failure mode indicated.

Indicators of errors correspond to each stage of the reference method (Figure 2).

	Information Parameters							Errors identified				
	Numbers of incidents	Type of model	parameters values	last incident on the curver	Failure	— — — - -		Consistency between β and failure mode	Consistency of the model	Identification of two failure mode	— — — - -	
Case 1												
|												
|												
|												
Case 29												

Figure 2: Grid of analysis

RESULTS

Once the 29 analyzed technical notes, we made validate the resulting table by a specialist. This table allowed us to highlight the frequency of difficulties (Figure 3).

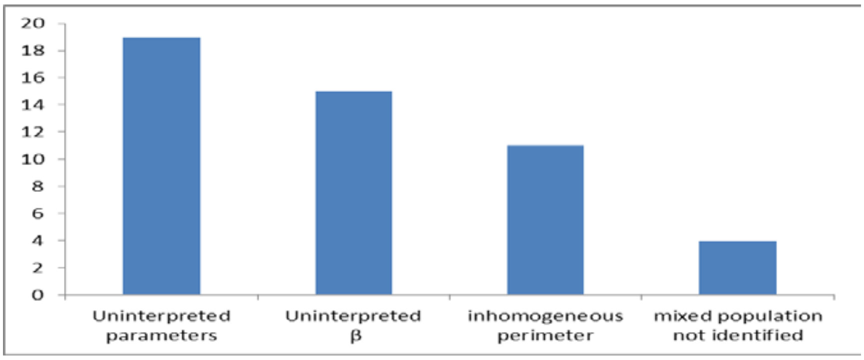

Figure 3: Frequency of the identified difficulties

This graph confirms the report on the difficulty of interpreting β physically (to establish the link with the noted failure) but also reveals other difficulties:

- The lack of interpretation of η and γ parameters (first column): However γ can reveal a failure with the delivery.
- The choice of the perimeter: By repeating the request (found on the Weibull curve) of the engineer, the specialist was able to validate the quality of perimeter choice.
- The identification of a mixture of population from the shape of the curve.

We noted incomplete interpretations in some technical notes. We interpreted them like errors, significant of difficulties or lack of competence. However it is possible that the absence of drafting is due to the fact that the engineers considered these situations too obvious.

This approach allowed us to characterize the potential difficulties that represent obstacles to access predefined skills. We set up a grid of quality of "a good" Weibull analysis focused on these difficulties listed to guide the engineers in their analyzes of Weibull. This grid validated in meeting of specialists and experts, describes for each step criteria to validate. It is also distributed to the trainees.

CONCLUSION

The type of questioning adopted from specialists to formalize the reference method was anthropological: the posture of "beginner" facilitated obtaining information on the expert method that is usually not formalized.

This study does not have as an ambition to provide generalizable quantitative results to the frequency of difficulties, but is a study of 29 cases that draws up a panorama of the types of difficulties.

The adopted method made it possible to identify training needs and more specifically which parts to emphasize in training. Moreover, the analysis grid implementation can be remobilized as a training tool or guide to lead a Weibull analysis. It is easy to use and less bulky (2 pages) unlike the old guide provided to the trainees.

In the future we plan to set up an internal club of type "Community of Practice" (Wenger, 1998) which meets monthly where the specialists go up the difficulties on the various treated cases of Weibull. This would detect problems earlier and to tailor content to the public to be formed.

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