Société de Calcul Mathématique SA
(Mathematical Modelling Company, Corp.)
Tools for decision help
since 1995

Checking the quality of an industrial process

For any industrial process, basically, two situations can be found: either the Industry accepts a small proportion of defects (usually covered by a guaranty), or all products are subject to precise requirements (usually situations of safety). But the distinction between both is not as precise as one might think.

I. Guaranty situations

The simplest case is as follows: The Industry wants to launch a new product (for instance, a new model of electric heater), and, before they put it on the market, they want to test a small number of items, in situations which are as realistic as possible. The question is: how large should the sample be, and what decision is to be taken from the sample results?

For instance, the Industry will test 500 heaters, and would like, from the observed number of defective products, predict the rate of rejection upon a production of 100 000 units per year. They hope for instance that the rejection rate will be lower than 1/100.

The mathematical theory which is used in order to handle such situations is described in our books [IEPE], [MPPR] and [NMP]: if n objects are defective, out of N trials (the test population), the probability to have n' defective objects in a population of size N' (the real users) is given by an explicit formula, which can be easily deduced from the density of the risk rate.

But such an approach is very academic: it assumes that all devices work independently, and that there were no common defects (for instance factory defects, all affecting the same line of production). It assumes also that the conditions of exploitation, in real life, were correctly anticipated by the test period. Both assumptions are disputable.

Another situation of the same type deals with the "guaranty extensions", which exist for instance for home appliances and cars. In such a case, the numbers n, N refer to situations which were met during the first years (under warranty), and n', N' refer to the following years.

But again, such a formula does not take aging into account, though it plays an essential role. So, it is not completely correct.

A preoccupation of car makers is to have an "early warning system", saying for instance: "on this type of car, there is an important number of failures for the gearboxes after 80 000 km"; so, they have to prepare for the corresponding interventions.

It is rather easy to detect such variations, by probabilistic tools, and to take them into account in order to compute the number of necessary parts or hours of work. However, it is quite difficult to obtain a precise quantitative law, about the number of failures which might occur, say within two years. Indeed, the defects may concern only a very small sub-series (not all vehicles of the same model), or, conversely, reveal some general weakness, meaning a mistake in the conception.

II. Safety situations

In some situations, no failure at all is expected: this is the case for all safety components. Still, the fabrication is not regular and cannot be absolutely perfect. In some cases, the only way to make sure that the component is correct is destructive testing (for example cut a metal piece and verify the composition at each point). But, of course, this is very costly.

So, what the Industry does is usually to take some samples at random and check these elements; they expect that the results obtained from this checking can be extended to the whole production.

But here a mistake is often made, which is to repeat the process of the first paragraph (the Guaranty case). Indeed, here, we would like to make sure that everything works correctly, so our investigation should concentrate upon the precise places where the defects are more likely to be found.

In order to explain this, let us take the example of some metallic parts; the Industry wants to check the percentages of an alloy, which should remain constant from one piece to the next and inside each piece.

Say we can test 100 pieces. We will first choose 10 at random (uniform law) and see what this testing gives. Perhaps, for instance, it will reveal that some percentage is slightly higher in the left top corner of the piece. But then, we take this information into account for the next 10 tests, which will be more concentrated in the top left corner, because this is where we suspect that something might happen. And so on: each series of testing brings more information, which we use for the next series. We call this approach "dynamical testing".

More precisely, at the n^{th} stage of the testing, we build a probability law, for instance of the discrepancy of the alloy (or any defect we want to investigate). Then, the $n+1^{st}$ stage of the testing is made according to this probability law, which is then modified according to the results.

III. Comparing several productions

The basic situation is as follows: several industries produce the same type of parts, and some buyer, or some authority, wants to rank these producers according to their quality, which should never fall below a certain level.

In practice, say that each industry produces 100 parts, supposed to be of same weight. The industry communicates the weight of all parts. The authority will take 10 at random, weigh these 10, and compare the weight it has measured with the weight communicated by the producer. If, for most items, both coincide within a certain threshold, the whole production is accepted; otherwise, more tests are made, until we buyer decides to reject or not the production.

The questions are here:

– To decide if the number of tested objects is sufficient.

– If the producer may be considered as reliable.

Such questions are quite different from the ones which are met about polls. We do not care about an average of the differences, but about the number of situations where the difference is above a threshold, fixed by the authorities, to be the maximum acceptable.

So we work here on the difference $I_k - A_k$, where I_k is the value announced by the Industry and A_k is the value measured by the Authority. This difference may be positive or negative. The mathematical principle we use here is to "propagate" the information from the parts where it has been obtained to the parts where it is unknown. This is done using our probabilistic method called EPH, which is presented in our book [PIT].

Using the EPH, we obtain a probability law for the difference $I - A$, for all parts, including those for which no measurement by the Authorities exists. We deduce a global probability law; if this law is concentrated enough near 0, then the producer may be considered as satisfactory. More precisely, the variance of this probability law leads to a ranking of the producers.

If some part does not have a probability law which is concentrated enough, it is a good candidate to be chosen for the next sample, if more measurements are made. So, the EPH gives also a truly clear method in order to decide if the sampling is sufficient or not, and, if not, where are the parts which should be chosen for further investigation.

IV. Correcting a lack of quality

It may happen that an Industry faces a situation where too many parts are found to be inappropriate and are rejected at the final stage, because they do not comply with the initial requirements. This is usually due to some variability in excess in the industrial process: one of the parameters (or several of them) are not controlled as tightly as they should be.

Our probabilistic method for hierarchization of parameters
(see our competence sheet http://scmsa.eu/fiches/SCM_Hierarchisation.pdf)
provides an easy way to "rank" all parameters according to their influence upon the final quality. Then, the Industry checks that the control on the first parameters is sufficient, and so on, until the reason is found. We used in for Naval Group (2013) in order to find the best tuning of parameters in a welding process.

The same method allows to build a "similarity index" between industrial objects; we used it in the framework of a contract with Air Liquide (2011). If an object is found to be defective, what objects are "almost similar" to this one, meaning that they deserve a preliminary investigation?

V. Risk analysis

A related subject is the analysis and classification of various risks (natural or not). Please see our competence sheet "Risk analysis": http://scmsa.eu/fiches/SCM_risks.pdf

References

1. Books

[IEPE] Bernard Beauzamy : Introduction à l'étude des Probabilités Expérimentales. SCM SA, ISBN 979-10-95773-02-3, ISSN 1767-1175. January 2023.

[MPPR] Bernard Beauzamy : Méthodes Probabilistes pour l'étude des phénomènes réels. SCM SA, ISBN 2-9521458-0-6, ISSN 1767-1175. March 2004. Second Edition, June 2016.

[NMP] Bernard Beauzamy: Nouvelles Méthodes Probabilistes pour l'évaluation des risques. SCM SA, ISBN 978-2-9521458-4-8. ISSN 1767-1175. April 2010.

[PIT] Olga Zeydina and Bernard Beauzamy: Probabilistic Information Transfer. SCM SA. ISBN: 978-2-9521458-6-2, ISSN: 1767-1175. May 2013.

2. Recent contracts

- SNECMA Propulsion Solide, 2009-2010: Probabilistic Methods for reliability of plane components.
- Areva, 2010: Probabilistic methods for the analysis of nuclear waste.
- Groupe Total, 2010: Probabilistic methods for the evaluation of the amount of pollutant.
- Caisse Centrale de Réassurance, 2010-2011: Probabilistic methods for the evaluation of extreme phenomena.
- PSA Peugeot Citroën, 2011: Probabilistic studies for the extension of warranties for the cars.
- Réseau Ferré de France, 2011: Probabilistic studies related to the delays of the trains in the Paris region.
- Groupe Total, 2011-2012: Investigation about possible breaches in large oil containers.

- Suez Environnement, 2011-2012: Probabilistic methods for water quality.
- ArcelorMittal, 2011-2012: Probabilistic methods for the quality of an industrial process.
- Air Liquide, 2011: Hierarchy of parameters and construction of a similarity index between pipelines.
- Réseau de Transport d'Electricité, 2012: Comparison between a connected network and an isolated network, in terms of quality of service.
- Réseau Ferré de France, 2012-2013: Defining criticity indicators for the delay of trains.
- Air Liquide, 2012: Databases for reliability.
- Areva, 2013: Probabilistic methods for the evaluation of mechanical properties of components.
- DCNS, Indret, 2013: Hierarchy of parameters in an industrial process for welding.
- DCNS, 2013: Preliminary analysis of the reasons for insufficient quality on a production site.
- Coop de France déshydratation, 2013: Hierarchy of parameters and their influence upon a deshydratation process.
- IRSN, 2013-2014 and 2015: Analysis of the quality of the TELERAY network (surveillance of the environment).
- 2015, Solétanche-Bachy: Hierarchy of parameters and their influence upon the deformation of a construction.
- 2016, 2017, COSEA: Probabilistic study related to water quality.
- 2017, Syndicat des Eaux d'Île de France (Water Authority, Paris region): Mathematical tools for the analysis of the network.
- 2018, Eramet: Probabilistic methods in order to improve an industrial process.
- SARP Industries, 2019: Hierarchy of parameters and their influence upon an industrial process.
- Orano Mining, 2019: Hierarchy of parameters and their influence upon an industrial process.
- Group Atlantic, 2019: Probabilistic Analysis of the calls to the Consumer Service.
- Air Liquide, 2021: analysis of the service life of certain components.
- SARP Industries, Limay site, 2021: Study of parameters influencing CO2 production.
- Eiffage Rail, 2021: Tools for analyzing equipment reliability.
- RATP, 2021: Modeling the behavior of trains in an emergency braking situation.
- Teréga, 2021: Probabilistic methods for checking the integrity of pipelines.
- Bouygues Energies & Services, 2022: Methodological support for the design of a "Malfunctions and Maintenance" information system.
- Befesa Valéra, 2022: Prioritization of the parameters involved in the adjustment of a furnace.
- SNCF, 2023: Methodological support for rail inspection plans
- Cristal Union, 2023: Probabilistic methods for comparing biocide trials