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Case Study based on Inequality Indices for the Assessments of Industrial Fleets

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Abstract: This contribution illustrates the advantages of measures and indicators based on the notions of Shannon entropy which is widely implemented in thermodynamics, information theory, econometrics, and biology. The presented case study applies these indicators to a fleet of industrial assets, introducing innovatively the entropy concept to the field of availability. There is no reason to deal the effect of performance variables in assets independently without taking into account disparities in terms of reliability, operation hours, applied maintenance, operating conditions, and usage profiles, etc. Therefore, the characteristic of the method and their independence from the heterogeneity of the sample that compares is intended to be promising for applications in availability analysis. In other words, this research presents a derivation from well-known concepts such as the Gini, Hoover and Theil indices illustrating their application by the support of an example where attributes for different groups of assets are compared. To illustrate the application we are using two relevant and innovative scenarios as case study examples.

Keywords: Asset and maintenance management; Reliability, Statistical Approaches; Diagnostics, Prognostics, Reasoning, Decision Support.

1. INTRODUCTION

From the notion of Shannon entropy, this contribution presents an application of indices for inequality measures (Gini, Hoover, and Theil index) for the analysis of the availability in fleets of industrial assets. This is in order to make possible comparisons among fleets operating under different boundary conditions and usage profiles. The obtained indices refer to that portion of the total group of assets that has to be redistributed in order to obtain a 100% equal fleet, in terms of availability and performance. The given approach and application of the entropy concept to the field of availability is innovative. Particularly the characteristics of the method and their independence from the heterogeneity of the sample that compares, is intended to be promising for applications in availability analysis. The application, proposed with the help of two scenarios, is also relevant in this new area of study and tries to illustrate this development.

It is assumed that components operate individually. However their availability has certain dependency with the associated components since they belong to the same system. This aspect is clarified throughout this paper. With that aim, the paper presents how these indicators can be implemented for the analysis of the life cycle of an industrial asset. The theoretical development of such methodology (including Shannon entropy, application of in-dices, and all these keywords) is developed in reference to Gonzalez-Prida et al 2016. A summary of formulae are shown here below:

Shannon Entropy:

$$H=\sum_{i=1}^{n}\left(-\frac{(UA_i/p_i)N_i}{\sum_{i=1}^{n}((UA_i/p_i)N_i)}\ln\left[\frac{(UA_i/p_i)N_i}{\sum_{i=1}^{n}((UA_i/p_i)N_i)}\right]\right)$$

Gini Index:

$$G=1-\frac{(\sum_{i=1}^{n}G_i)/(\sum_{i=1}^{n}N_i)}{\sum_{i=1}^{n}(UA_i/p_i)}$$

Hoover Index:

$$Hv=(1/2)\sum_{i=1}^{n}\left|\frac{(UA_i/p_i)N_i}{\sum_{i=1}^{n}((UA_i/p_i)N_i)}-N_i/(\sum_{i=1}^{n}N_i)\right|$$

Theil Index:

$$T_{sym}=(1/2)\sum_{i=1}^{n}\left[\left(\frac{(UA_i/p_i)N_i}{\sum_{i=1}^{n}((UA_i/p_i)N_i)}-N_i/(\sum_{i=1}^{n}N_i)\right)\ln\left(\left(\frac{UA_i/p_i}{\sum_{i=1}^{n}(UA_i/p_i)}\right)/(N_i/(\sum_{i=1}^{n}N_i))\right)\right]$$

These concepts are implemented in a practical case study, referring to the comparison of two scenarios (A and B). Nevertheless, this situation can be used in various applications including different phases of wind farms where the severity of the environment is different from one phase to

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another; exportations of products from emerging countries to developed countries competing with the local manufacturing, etc. After the case study, the paper concludes with some interesting future research possibilities.

2. CASE STUDY

Nobel Prize winner Akerlof G. indicated that, in a second-hand market, customers do not really know exactly if the relationship between quality and price is fair when they are buying a used car (Akerlof G, 1970). Uncertainty due to this asymmetric information, causes the sellers of high quality cars to be positioned out of the market, since owners of cars with lower quality have the same opportunities to sell their vehicles at a high enough price. The proposed approach is intended to com-pare different fleets of industrial assets, where scenarios have different attributes (e.g., productivity and unavailability). Nevertheless, it could be useful to compare second-hand car markets. Comparing inequality indices enables to detect what scenario present more equality in the items' behaviour of its population. The higher is the equality, easier the foreseeing of how will be the remaining useful life of the physical assets in operation and, as a consequence, the worthwhileness of one fleet over the other one. In order to provide a practical application of the above mentioned theoretical subjects, we proceed now to synthesize an example that shows the utility of the described inequality indices, with a case study related to a fleet of complex industrial assets with different behaviour and degradation along their lifetime.

2.1 Study Scenario

Let us consider two different scenarios (A and B). These scenarios can relate to, for example, specific geographic areas or different fleets from the same company. Each scenario will include a fleet of vehicles with specific settings and configuration, which are assumed to be equal for all of them. However, the age of the vehicles will be ranging from 1 to 10 years old. Vehicles from a specific age (1 to 10) and scenario (A or B), will present: different population (Ni); different productivity (pi); different unavailability (UAi). As commented, both pi and UAi, are variables that represent characteristics of a population Ni of vehicles of the same age (i).

Table 1. Amount, unavailability and productivity per year and scenario

i (age)	Ni (A)	Ni (B)	UAi (A)	UAi (B)	pi (A)	pi (B)
1	800	3.500	0000000480	0000000400	24.0	20.0
2	850	4.250	0000006010	0000005893	17.0	16.8
3	975	4.750	0000015988	0000014677	14.6	11.5
4	1.000	5.195	0000025971	0000023356	13.4	10.0
5	1.033	6.000	0000034030	0000031018	12.6	9.0
6	1.050	6.100	0000041912	0000037601	12.0	8.0
7	1.075	7.000	0000047880	0000043243	11.6	7.5
8	1.100	8.000	0000053999	0000048107	11.3	7.0
9	1.125	8.500	0000058487	0000052335	11.2	6.6
10	1.125	9.000	0000062424	0000056044	11.1	6.3

2.2 Conditions and objective

Table 1 gathers data from the two scenarios (A and B). Scenario A, in comparison to Scenario B, assumes vehicles with productivity that remains higher as they age, although they become less available. It is assumed that the degradation trend for each vehicle, for same age and scenario, is similar year after year. The question here is how to choose the group of assets with the best availability-productivity relationship. In particular, we can observe that Scenario A has a lower truck population than Scenario B (Fig. 1).

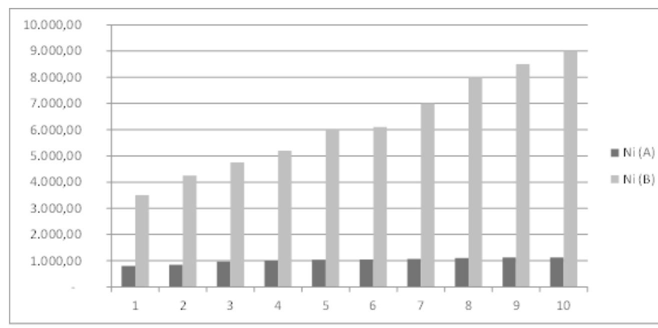

Fig 1. Amount of assets in operation per year for both scenarios

Nevertheless, due to the properties of Shannon entropy, the model is also applicable even when the scale changes. In other words, it is applicable even with different sizes of fleets. Therefore, the indices we are going to obtain are comparable. In figure 1, the abscissa refers to the year and the ordinate refers to the amount of trucks in use. In addition to this, we observe that the asset operation is different from one scenario to another; since the unavailability follows different trends (Fig. 2).

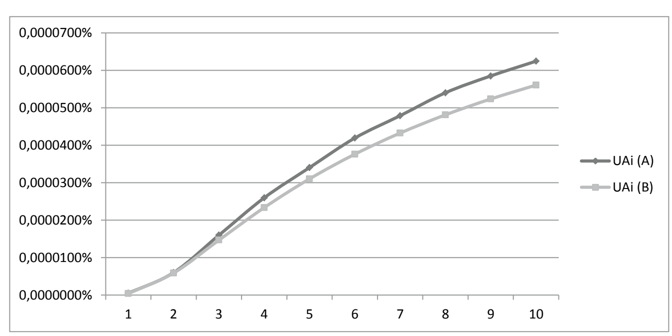

Fig. 2. Unavailability per age and scenario (%)

These differences provide us the notion of diverse usage profile or maintenance policies in both scenarios. In other words, over time, if the usage profile is similar in both contexts, then Scenario A applies a worse maintenance policy