Testing for 'New Better than Used'— Oxygen Monitoring Systems at the Spallation Neutron Source

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We statistically analyzed empirical reliability data from two systems managed by the Protection Systems Team at the Spallation Neutron Source at the Oak Ridge National Laboratory. That is, finding when a new item has the same life expectancy as a used item of any given age. We sought to find whether or not each systems life distribution is New Better than Used[1]. A life distribution F is New Better than Used if $\hat{F}(x+y) \leq \hat{F}(x)\,\hat{F}(y)$, where $\hat{F} = 1 - F$, holds for all x, $y \geq 0$. To determine if a systems life distribution satisfies this inequality, we first showed that if a function is convex, then it is superadditive. Being superadditive implies an increasing failure rate, and hence is New Better than Used.

To make a New Better than Used determination, the functions we considered were the kernel density estimates of the life distributions. We looked at the finite differences between contiguous pairs of data points to find the time intervals where the system is New Better than Used. Where the value of the finite difference was strictly greater than zero corresponded with the distribution being New Better than Used, and similarly, if the values was strictly less than zero corresponded with an interval where the system was New Worse than Used. Applying the above ideas to the empirical data, we found time intervals where the failure rate was strictly decreasing, and the corresponding times where the distribution is New Better than Used.

This test can also be applied to individual components in a system. As a direct application of the New Better than Used property, we apply our algorithm to various Oxygen Deficiency Hazard (ODH) monitors in varying conditions to demonstrate its efficacy in determining whether or not to replace an ODH sensor.

References

[1] M. Hollander and F. Proschan. Testing Whether New is Better than Used, *Annals of Mathematical Statistics* 43(3) (1972) 1136-1146.

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