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Comment

Nozer D. Singpurwalla

This paper provides valuable service to those interested in reliability theory and its applications. The material in this paper, together with a cursory reading of some of its references leads me to conclude that:

1. Any serious student of reliability (and also biometry) cannot afford to overlook the *Soviet Journal of Computer and System Sciences* or its predecessor *Engineering Cybernetics*.

2. Soviet researchers appear to be more knowledgable about the developments in reliability in the West than their Western counterparts, particularly those in the United States, and that this is true even when it pertains to the work of such distinguished scholars as Gnedenko, Belyayev, Solovyev, Ushakov, Kordonskiy and Kartashov. The above is particularly disturbing—I too am guilty of it—because English language translations of *Engineering Cybernetics* and the *Soviet Journal of Computer and System Sciences* have been available for quite some time.

3. The unclassified Soviet research in reliability attempts to address technically difficult problems with a tendency to emphasize mathematical detail, many times at the cost of relevance and sometimes at the cost of elegance.

4. Unlike what is currently happening in Great Britain, Western Europe and the United States, the conspicuous and noteworthy absence of a Bayesian perspective on reliability has left the Soviet researchers working in a frame of reference that is reminiscent of an era prevalent in the midseventies and before. Thus for example, it should be the theory of extreme values for *exchangeable* random variables that should be used for system reliability modeling rather than Gnedenko's development for independent and identically distributed (iid) random variables. With Belyayev's venture into an investigation of the behavior of posterior densities of parameters in reliability models, a welcome thaw in the above state of affairs appears to be looming on the horizon. However, given Belyayev's orientation, this work emphasizes the mathematics of weak convergence of stochastic processes and in so doing loses some of its pragmatic appeal.

5. That there seems to be a dearth of Soviet literature addressing the important topics of *component dependencies* in multicomponent systems, the reliability of *multistate systems* and *measures of importance* of coherent systems. The latter appear to be widely used in the nuclear reactor industry (cf. Barlow, Fussell and Singpurwalla, 1975), and the former two are a challenge to all researchers in reliability. Given the Soviet engineer's affinity for Zadeh's (1965, 1973) *possibility theory* and *fuzzy logic*, it is surprising that the above concepts have not been explored by them for application in multistate reliability theory.

Rukhin and Hsieh's claim that the Soviet literature on reliability emphasizes probability modeling over inference has truth to it; however, this is also the case in the West, wherein the number of papers in the former overwhelms those in the latter. To appreciate this point, one has simply to scan journals such as the *IEEE Transactions in Reliability*, the *Journal of Applied Probability*, *Operations Research*, *Stochastic Processes and Their Applications* and the *Naval Research Logistics Quarterly*. The fortunate situation in the West is that journals that are predominantly statistical in orientation, such as the *Journal of the American Statistical Association*, *The Annals of Statistics*, the *Journal of the Royal Statistical Society*, *Biometrika* and *The American Statistician*, recognizing the importance of the role of statistical inference in reliability problems, have been receptive and supportive of papers in reliability. It is my hope that *Statistical Science* will also continue to uphold this fine tradition. A possible reason for the above sense

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of accommodation may be the recognition in the West of the relationship and the interplay between reliability and biometry, the latter being of great interest to many statisticians. It is apparent from Rukhin and Hsieh's paper, that with an occasional excursion into the prestigious *Theory of Probability and Its Applications*, much of the Soviet literature in reliability is published in journals that are predominantly engineering wherein concern for any reasonable solution to a different problem takes precedence over the niceties of statistical inference.

A substantive issue that Rukhin and Hsieh bring to focus in their paper pertains to *accelerated testing*. It appears that here, Soviet researchers have done more work than we have been used to believing. A noteworthy omission is a paper by Bagdanavicius (1978), wherein the author addresses the important topic of inference about the time transformation function of an accelerated life test. Rukhin and Hsieh bring to focus three physical principles suggested by Soviet scholars as the basis of accelerated tests. The three principles are the Sedyakin principle, the heredity principle and the least action principle of which the first and second appear more like reasonable probabilistic postulates (or models) and the third is based on a postulate in physics. It is fair to say that the literature in the West on accelerated testing has not entertained any notion analogous to that of the "least action principle," but then it is also hard to assess the Soviet success in using this principle. Notwithstanding the above, one must still applaud the Soviet's attempt at using postulates that have physics as their basis, as a foundation for addressing problems of accelerated life testing. The Sedyakin principle and versions of the heredity principle have been used in the Western literature, although not under the above nomenclature and presumably without awareness of the Soviet work.

The Sedyakin principle, as enunciated by Rukhin and Hsieh, lacks completeness and leaves the reader with a question, regarding purpose. A fuller appreciation of this principle can be obtained via the following discussion.

Suppose that $F_1(x)$ and $F_2(x)$ are the distribution functions of the time to failure random variable X, under environmental conditions $\mathscr{E}_1$ and $\mathscr{E}_2$, respectively. Suppose that $\mathscr{E}_1$ is less severe than $\mathscr{E}_2$, so that for all positive values of x, $F_1(x) \leq F_2(x)$. Suppose that τ and t are the times at which $F_1(x)$ and $F_2(x)$ attain a common value say Q. Clearly, for all possible values of t and τ there exists a function g, such that $\tau = g(t)$ and so $F_2(t) = F_1(g(t))$. Because $F_1(x) \leq F_2(x)$, $g(t)$ must be nondecreasing; $g(t)$ is called the *acceleration* or the *time transformation function.*

Suppose that $F_1(x)$ and $F_2(x)$ are specified, and interest focuses on the distribution function $F_{1,2}(x \mid \tau)$, where the latter pertains to the distribution function of an item tested under $\mathscr{E}_1$ for a time τ at which $\mathscr{E}_1$ is changed to $\mathscr{E}_2$. Clearly

$$F_{1,2}(x \mid \tau) = \begin{cases} F_1(x), & \text{for } x \leq \tau, \\ F_\tau(x), & \text{for } x > \tau, \end{cases}$$

where $F_\tau(x)$ needs to be specified.

Sedyakin's principle states that the items having been in operation under $\mathscr{E}_1$ does not change its reliability law under $\mathscr{E}_2$; that is $F_\tau(x)$ has a relationship to $F_2(x)$. Secondly, for all $x > \tau$, $F_\tau(x) = F_2(x + \tau^* - \tau)$ where τ^* is such that $F_1(\tau) = F_2(\tau^*)$. With the above two assertions, which constitute a mathematical statement of Sedyakin's principle, we may write

$$F_{1,2}(x \mid \tau) = \begin{cases} F_1(x), & \text{for } x \leq \tau, \\ F_2(x + \tau^* - \tau), & \text{for } x > \tau. \end{cases}$$

It is interest to note that the above model for $F_{1,2}(x \mid \tau)$, is identical with that considered by DeGroot and Goel (1979), Nelson (1980) and Shaked and Singpurwalla (1982) in their study of *partially accelerated* and *step-stress accelerated* tests, respectively.

To continue along the above theme, suppose that an item is tested under $\mathscr{E}_1$ for a time period τ_1 at which time $\mathscr{E}_1$ is increased to $\mathscr{E}_2$ and the item tested for an additional time period τ_2. Let $Q_1 = F_{1,2}(\tau_1 + \tau_2 \mid \tau_1)$. Suppose now that another item is tested first under $\mathscr{E}_2$ for a time period τ_2 at which time $\mathscr{E}_2$ is decreased to $\mathscr{E}_1$ and the item tested for an additional time period τ_1. Let $Q_2 = F_{2,1}(\tau_1 + \tau_2 \mid \tau_2)$. Then Gugushvili, Zhgenti and Namicheyshvili (1975) show that $Q_1 = Q_2$ if and only if the time transformation function g is linear. This important paper and result appears to have been overlooked by Rukhin and Hsieh and is deemed worthy of mention here.

As a closing comment, Rukhin and Hsieh state at the outset that their hope is to bring to attention important results in reliability by Soviet scholars that are not familiar to researchers in this country. I think that the authors have succeeded well in fulfilling their hope. I have enjoyed reading Rukhin and Hsieh's paper and I have been made aware of much that was not known to me before; for this I am thankful to them.

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Comment

Elliot H. Weinberg

Few members of the United States scientific community follow the progress of their colleagues abroad on any regular basis. Among many contributing factors is unfamiliarity with the language. (In the United States more college students study Latin than Russian.) Other negative stimuli may fall under a category labeled in a recent issue of *US News and World Report* as "Techno-chauvinism." That article noted that while some 13,000 Japanese citizens are currently enrolled in United States colleges, the number of United States citizens studying engineering in Japan has never exceeded seven. Disinterest leads to limitations in terms of commercial interest in providing for translations of journals or texts. *US News and World Report* reports that in 1981 only 19% of Japanese scientific and technical publications were even *indexed* by western sources. In a later paragraph, the author (Daniel Greenberg) reports that "Representative Norman Mineta (D-Calif.) came back from South Korea last year with an astonishing account of 5700 translators looking at nothing but U.S. technical publications." In Japan, the collection and translation of foreign technical literature receive high priority, with more than 5000 scientists and engineers routinely processing thousands of foreign journals and technical reports. As John Caplan, executive director of General Motors research laboratories told Congress in 1984: "Sometimes we think they know more about GM's business than we do."

Turning our attention to science in the Soviet Union and East European countries, we find that the Soviets publish some 700 science and technology journals, amounting to 60,000 pages per year. Soviet patents issue at the annual rate of 10,000, with many also being taken out in the United States Patent Office, rarely to be seen again. In 1980, the Soviets published over 800 texts in the field of electronics alone. Within the Soviet Union there are perhaps 1,500 science centers, at least a few of which are acknowledged to be of "world class."

The Soviet's VINITI is known to be the world's best science and technology abstracting service, covering 35,000 periodicals in 66 languages from 130 countries. Some 25% of the world's scientists live in the Soviet Union, yet standard citation bibliometrics credit them with producing only 6% of the world's cited research. Explanations abound: some believe that the quality of their work is too low to be publishable, while others suspect that we simply do a lackadaisical job of looking for their publications. Possibly their reward system does not depend so heavily on credits earned by publishing in refereed journals.

This situation was nicely summarized at a recent Library Association meeting in Dallas as follows: "Much of the important social, political, and scientific literature produced in the Soviet Union and in Soviet-dominated countries is virtually unknown to Western libraries and scholars."

If not science, should we be concerned about their technology? Eugene Rivin, writing in *Mechanical Engineering*, April 1983 commented as follows: "One of the resources grossly underused in this country is foreign technology. This appears to be a self-imposed

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