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A Heuristic Look at the Differences in Engineering Design

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Using an analysis published by Xerox that sought to explain the 50% cost difference in copiers manufactured by Japan and the U.S.A., engineering design in the two countries is shown to be based largely on the engineering heuristic. By identifying and using specific Japanese heuristics, Xerox has narrowed this gap.

INTRODUCTION

ALTHOUGH this article begins with a widely accepted definition of engineering design, it is not an explicit defense of this definition. Neither is the objective of this article an analysis of the relative competitiveness of various countries. Instead, its objective is to present specific examples of the differences in engineering practice in different countries and to insist that these differences are, in fact, just different engineering heuristics. Space limits this analysis to a consideration of Japan, but equally important comparisons could be made between engineering practice in the U.S.A. and other countries. Implicitly, of course, this article does support the given definition, indicate the direction for improving engineering design in the U.S.A., and present a challenge to any engineer that proposes a competitive definition.

DEFINITION OF ENGINEERING DESIGN

We accept the definition of Engineering Method as 'the use of engineering heuristics to cause the best change in a poorly understood situation within the available resources' [1, 2]. In this widely accepted definition of engineering, the word 'heuristic' is taken as anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification, and potentially fallible. A convenient near-synonym for the heuristic is the engineering 'rule of thumb'. Engineering heuristics vary in complexity from these simple rules of thumb to complex strategies to allocate resources and control risk. The interested reader is referred to the literature cited for a discussion of the implications of this definition and numerous examples of engineering heuristics. Here we mention four specific authors who have commented on the difference in engineering practice in the U.S.A. and Japan and conclude that these differences are due to using different heuristics.

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EXHIBIT ONE: BARRY BEBB

In a presentation as keynote speaker at a National Science Foundation Design Theory Workshop [3], Dr H. Barry Bebb, Vice President of Xerox, made the following points (I capture, correctly I hope, the essence of his oral presentation):

> By the middle 1970s Xerox was in trouble with respect to its competitiveness with Japan in the copying field; by the late 1970s, we were aware of it. To produce a comparable copying machine the Japanese needed one half as many people; one half the cost; and one half the time.

In his presentation, Dr Bebb outlined the steps Xerox took to regain its pre-eminence in the field. The strategy was to recognize differences in the way the Japanese and American companies designed copying equipment and to make changes at Xerox when appropriate—in the words of this presentation, they changed heuristics. For example, he insisted that there is a fundamental difference in American and Japanese engineering with respect to the investment of resources throughout the design cycle. Creation of engineering products follows an S-shaped curve from early innovation and rapid growth to a plateau of diminishing return as a technology matures. Bebb asserts that American engineering invests more resources in the early innovation states of a technology than the Japanese, who allocate relatively more of their resources at the top of the curve in mature technologies. Dr Bebb then concludes that 'Mature technology is the engine of a big corporation.' What are we to call this final quotation? It is plausible, experience based, and it certainly helped Xerox. Yet it is potentially fallible. It is clearly an heuristic.

Dr Bebb does not limit himself to the copier field, but presents the following figure (Fig. 1) taken from an article by L. P. Sullivan [4]. In this figure the number of changes processed in the development of a product is plotted against the time before and after a product is placed on the market (indicated by the point labelled Job #1). Among a number of conclusions that Dr Bebb draws from this figure is the difference in the number of prototypes of a new product used in Japan (represented by the solid line) and in the U.S.A. (represented by the dashed line). Americans typically work from three prototypes; the Japanese from only one. Americans, also, make significant numbers of changes in the product after it is placed on the market; the Japanese almost none. This figure clearly represents differences in engineering design. But what is the nature of this difference? It is heuristic.

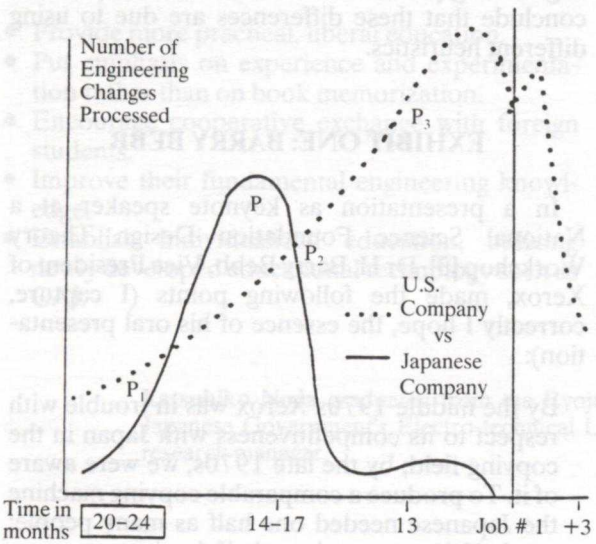

Fig. 1. Benchmark comparison of engineering changes in Japan *vs* the U.S.A.

EXHIBIT TWO: JANICE CASTRO

In a feature article in the business section of *Time Magazine* [5], Ms Castro repeats the story of Xerox given above. Instead of emphasizing the specific heuristics reported by Dr Bebb, however, she subsumes the changes at Xerox under the concept of an improvement in 'quality'. She reports that Xerox Chairman David Kearns took a lesson from his adversaries and in 1983 launched an all-out campaign for quality. To repeat a quote by Kearns:

> At Xerox we define quality as meeting customer requirements. It's an axiom as old as business itself. Yet much of American business lost sight of that. Xerox was one of these companies. But by focusing on quality, we have turned that around.

Time does not limit its analysis of the improvement in quality in American products to the quotation to Dr Kearns. We hear from Rubbermaid Chairman Stanley Gault:

> Everyone has to know that shoddy work will not be tolerated. Our customers are not there to field-test our products.

And from Robert Stempel, president of General Motors:

> We used to talk about 'commercial quality', which meant that you expected to have a certain amount of defects. We have seen what better-quality competition can do to you.

My point is not that American goods were, or are now, better or worse than foreign products. I ask for an analysis of the difference in engineering practice in various countries that presumably existed and is now changed as implied by these quotes. Where in the theory of engineering design do we codify these differences that are manifestly a part of the way different engineers do their job?

EXHIBIT THREE: WOMACK AND JONES

In discussing the third of four transformations in the design of automobiles. Womack and Jones state [6]:

> The third transformation, starting in the mid-1960s was the work of the Japanese producers. These automakers perfected Henry Ford's system of mass production by introducing two new concepts, by now well known. The first, called 'total quality,' gave workers within the plant more responsibility for the organization and performance of their work. The second, known as 'just in time,' streamlined the delivery of goods from the multitude of firms needed to produce the many parts, designs, and production tools for making automobiles. These breakthroughs at first gave Japanese producers a tremendous advantage in world competition.

Once again, we see a difference in engineering in Japan and the U.S.A. What is the name we are compelled to give this difference? The heuristic.

EXHIBIT FOUR: MICHAEL LEV

We might try to argue that all the examples above are not really just plausible, experience-based strategies that will always remain potentially fallible—i.e. heuristics. Perhaps, in some, as yet unexplained way, they are really scientific principles that transcend the cultural context in which they find themselves and represent ultimate truth. Let us consider a recent article by Michael Lev [7] who reports that Maritza and Stephen French have filed a lawsuit against Mr Takashi Morimoto, a Japanese businessman boarding in their home for six weeks, and his employer, Nissan Motor Corp. U.S.A. They accused Nissan of invasion of

privacy, fraud, trespassing, breach of contract and unfair business practices because Mr Morimoto was spying on them as part of a research project for a future Nissan automobile. Continues Mr Lev:

> The fact that a Nissan employee may have been observing the Frenches comes as no surprise in the automotive research and development field. 'It's the kind of research the Japanese have been doing for a long time,' said Dennis Keene, a Los Angeles Automotive industry consultant. 'One of the classic things they do is go to American shopping centers and watch people load and unload packages and children from cars. Then they take that information back to the design studios.'

Once again, the point is not the legal claims involved, but the possibility that differences in engineering practice are not necessarily based on immutable truths but on cultural truths as well.

CONCLUSIONS

The four cases presented above are not the only ones available. The Public Broadcasting System's MacNeil/Lehr report in October 1989, had a long section on the differing approaches to engineering design and manufacture in Japan and the U.S.A. with numerous examples of engineering design heuristics. The conclusions from all of these documents are clear:

1. Differences exist in engineering practice in various countries.
2. These differences are not exclusively differences in the state of scientific knowledge.
3. These differences are best described as plausible, helpful, experience-based strategies to solve problems.
4. Different countries use different heuristics.

Although the objective of this article was not to comment on international competitiveness or to discuss specific ways for a country to improve engineering design, the analysis clearly demonstrates that the Engineering Method is defined as the use of heuristics. If you want to improve engineering practice, if you want to improve the competitiveness of your country, improve the heuristics you use.

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