EVALUATION OF PROGRAMS AND POLICIES FOR LIFE SUPPORT SYSTEMS

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Summary

Life support programs and policies are quite complex and varied. Does the program or policy work? Is it worth the cost? Can and should it be implemented elsewhere? It is the reputed purpose of evaluation to provide answers to these and related questions. Unfortunately, program/policy evaluation has not lived up to expectations. The field of evaluation is littered with efforts that do not adequately address the important issues or objectives, that do not employ valid controls for comparison purposes, that rely on inadequate measures or include expensive collections of data on measures that are in fact never used in the evaluation, that rely on inappropriate measurement methods, or that employ inadequate analytic techniques.

Most, if not all, of the above-cited problems could be mitigated by developing—at the beginning of an evaluation effort—a valid and comprehensive evaluation design. Although there is no stock evaluation design that can be taken off the shelf and implemented without revision, there should be an approach or process by which such designs can be developed. Indeed, the author has identified a systems approach—that is at once purposeful, systematic, and consistent—for developing valid and comprehensive evaluation designs—it has since been successfully employed in a number of evaluation efforts. The approach is discussed in this paper, together with its impact on evaluating life support programs/policies. Additionally, it is shown that the approach is also

applicable to any analysis that seeks to be purposeful, systematic, and consistent. In this regard, the words "analysis" and "evaluation" are quite interchangeable.

1. Introduction

The 1992 Earth Summit in Rio de Janeiro and the 1997 Kyoto Protocol underscore the importance of sustainable development. In order to achieve the sustainable development of life support systems, appropriate programs and policies must be identified to ensure the security of the world's water, energy, environment, and food resources, which together sustain life on planet Earth. Programs and policies are determined to be "appropriate" if their efficacy is ascertained through a purposeful, systematic, and consistent evaluation analysis.

Life support programs and policies are quite complex and varied; they can be behavioral, social, cultural, organizational, economic, political, legal, or technological in nature. As illustrated in Figure 1, it is convenient to group such programs and policies into two categories: those that seek to decrease or mitigate the demand for water, energy, environment, and food; and those that seek to increase or renew the supply of these same resources. Further, within each resource group, the decrease in demand could be effected by consumption, conservation, system management, and public information and education, while the increase in supply could be effected by new sources (or rejuvenation), pollution control, and new technologies.

PROGRAMS/ POLICIES THAT:	LIFE SUPPORT SYSTEMS			
	WATER	ENERGY	ENVIRONMENT	FOOD
• DECREASE DEMAND	• **Consumption** (People, Animals, Industries, Urbanization, Rural Development, Agriculture, Aquaculture, Sanitation, Recreation, Ecosystem)	• **Consumption** (People, Industries, Transportation, Urbanization, Rural Development, Agriculture, Aquaculture, Sanitation, Recreation)	• **Consumption** (People, Industries, Transportation, Urbanization, Rural Development, Agriculture, Aquaculture, Sanitation, Recreation, Ecosystem)	• **Consumption** (People, Animals, Agriculture, Aquaculture)
	• **Conservation** (Residential, Commercial, Industrial, Utility, Transportation, Agriculture, Aquaculture, Urban, Suburban)	• **Conservation** (Residential, Commercial, Industrial, Utility, Transportation, Agriculture, Aquaculture, Urban, Suburban)	• **Conservation** (Atmosphere, Hydrosphere, Cryosphere, Lithosphere, Pedosphere)	• **Conservation** (Diet, Plant Habitats, Plant Crops, Fruits/Nuts, Forests, Animals, Fisheries)
	• **Systems Management** (System Modeling/Simulation/Evaluation, Codes, Standards, Restructuring, Regulation, Pricing)	• **Systems Management** (System Modeling/Simulation/Evaluation, Codes, Standards, Restructuring, Regulation, Pricing)	• **System Management** (System Modeling/Simulation/Evaluation, Codes, Standards, Regulation, Pricing, Pollution Taxes, Green Design)	• **System Management** (System Modeling/Simulation/Evaluation, Codes, Standards, Regulation, Pricing, Land, Water, Energy, Biodiversity, Pesticides)
	• **Public Information and Education**	• **Public Information and Education**	• **Public Information and Education**	• **Public Information and Education**
• INCREASE SUPPLY	• **New Sources** (Atmospheric, Surface, Ground)	• **New Sources** (Fossil, Solar, Wind, Hydropower, Geothermal, Nuclear, Waste Product, Biomass)	• **Rejuvenation** (Ecosystem Remediation/Management)	• **New Sources** (Agriculture, Aquaculture)
	• **Pollution Control** (Storm Water, Receiving Water, Waste Water, Industrial Effluents, Chemical Pollutants, Agricultural Pollutants)	• **Pollution Control** (Hazardous Emission Tax, Renewable Sources, Energy Efficiency)	• **Pollution Control** (Air, Water, Land, Land Use, Biological, Solar, Acid Rain, Desertification, Greenhouse Gases, Deforestation, Toxic Chemical, Radiation)	• **Pollution Control** (Pest, Disease, Deforestation, Desertification, Radiation)
	• **New Technologies** (Water Storage, Bioremediation, Transportation, Hydraulics, Water Treatment, Desalination)	• **New Technologies** (Solar Cells, Fuel Cells, HVAC, Transportation, Drilling, Refining, Mining, Telecommuting, Production, Delivery, Cogeneration)	• **New Technologies** (Hazardous Waste Transportation/Storage, Earthquakes, Volcanoes, Cyclones, Hurricanes, Tornadoes, Droughts, Fires, Floods, Radiation, Diseases)	• **New Technologies** (Genetic Modification, Irrigation, Processing, Inspection, Preservation, Storage, Distribution)

Figure 1. Example program and policies to sustain life support systems

In reviewing the example life support programs and policies in Figure 1, several comments should be made. First, some programs and policies are focused on mitigating the ravages of nature. Interestingly, in certain cultures, it is assumed that anything natural must be safe or benign; unfortunately it should not be forgotten that humanity has spent most of its history attempting to protect itself from the destructive forces (e.g., earthquakes, hurricanes) of nature. Indeed, so-called organic food (i.e., grown in animal manure) can contain several virulent bacteria, including E. coli and salmonella. Second, it is obvious that only brief descriptions of programs and policies are contained in Figure 1. Moreover, each description may reflect a range of possibilities. As an example, "green design" could describe a system oriented, life cycle approach to producing, warehousing, selling, using, and, finally, recycling a product, or it could just be focused on the product's biodegradable material. Third, the complexity of the programs and policies are also not reflected in Figure 1. As examples, the maintenance of economic growth by substituting technology for energy and other scarce resources and the development of "sinks" for greenhouse gases are both large-scale and complex in their undertaking. Such complexities are further aggravated by the fact that the four life support components interact in substantive ways. Water is needed to develop energy (e.g., acid mine drainage, hydropower), to sustain the environment (e.g., aquifers, climate cycles), and to grow food (e.g., agriculture, aquaculture); energy creation is, for the most part, detrimental to the environment (e.g., global warming, nuclear waste repositories); the environment sustains life by providing the raw material for water (e.g., oceans, reservoirs), energy (e.g., fossil fuels, solar energy), and food (e.g., wetlands, croplands); and food is the output of a judicious combination of water, energy and the environment's bounty.

Interestingly, from a global perspective, water—or the lack thereof—is becoming a very serious issue and is threatening the world's food security. In short, water is being diverted from land irrigation to meet the needs of fast-growing urban centers and industries. (In regard to consuming water, agriculture is simply more voracious than industry; in China, for example, a thousand tons of water produces one metric ton (ca. 2000 pounds) of wheat, while the same amount of water used in industry yields an output worth many times the value of one metric ton of wheat.) China and other countries (e.g., in Africa, the Middle East) that are facing a water shortage may, of course, import food items; however, it is becoming more costly as the world's grain reserves have decreased over the last decade. Instead, new programs—including technologies—and policies are being introduced in water management (e.g., conservation, pollution control, treatment, desalination) and food production (e.g., irrigation efficiency, yield through genetic modification, processing, preservation). It is obvious that the efficacy of such programs and policies must be carefully evaluated or analyzed, especially as the water shortage and food security problems become increasingly exacerbated as the world's population grows by 50 percent in the next 50 years (i.e., from 6 billion to 9 billion) and as the population prospers and demands a larger and better diet.

Does the program or policy work? Is it worth the cost? Can and should it be implemented elsewhere? It is the reputed purpose of evaluation to provide answers to these and related questions. The need for conducting evaluations becomes more critical as programs/policies become more complex and more costly and, concomitantly, as the tax base or resources for their funding remain fixed or decrease. Unfortunately, program/policy evaluation has not lived up to expectations. The field of evaluation is littered with efforts that do not adequately address the important issues or objectives, that do not employ valid controls for comparison purposes, that rely on inadequate measures or include expensive collections of data on measures that are in fact never used in the evaluation, that rely on inappropriate measurement methods, or that employ inadequate analytic techniques. Most, if not all, of the above-cited problems could be mitigated by developing, at the beginning of an evaluation effort, a valid and comprehensive evaluation design.

Although there is no stock evaluation design that can be taken off the shelf and implemented without revision, there should be an approach or process by which such designs can be developed. Indeed, the author has identified a systems approach—that is at once purposeful, systematic, and consistent—for developing valid and comprehensive evaluation designs—it has since been successfully employed in a number of evaluation efforts. The approach is outlined in the next section, followed by a discussion of the elements that constitute an effective evaluation design. Several remarks are made at the conclusion of this paper.

2. Evaluation Approach

The proposed evaluation approach is defined below in terms of its process and its framework, followed by a discussion of threats to validity.

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Biographical Sketch

Dr James M. Tien received the BEE degree from Rensselaer Polytechnic Institute, Troy, NY, in 1966 and the S.M., E.E., and Ph.D. degrees in Systems Engineering and Operations Research from the Massachusetts Institute of Technology, Cambridge, MA, in 1967, 1970, and 1972, respectively. He has had extensive experience in both industry and academia. He has been a member of the technical staff at Bell Telephone Laboratories (1966–1969), a Project Director at the Rand Corporation (1970–1973), and a Principal and Vice President of Structured Decisions Corporation (1974–present). He joined the Department of Electrical, Computer and Systems Engineering at Rensselaer Polytechnic Institute in 1977, became its Acting Chair (1986–1987), served as the founding Chair (1988–present) of a unique, interdisciplinary Department of Decision Sciences and Engineering Systems, and twice was appointed Acting Dean of Engineering (1992–1994, 1998–1999).Dr. Tien's areas of research interest include the development and application of computer and systems analysis techniques to public information and decision systems. He is on the editorial board of several journals, including the *IEEE Transactions on Systems, Man, and Cybernetics (SMC)*. He has published extensively, with over 200 publications to his credit. He has received over two dozen teaching and professional honors, including being elected a Fellow of the IEEE and a recipient of the prestigious Joseph G. Wohl Outstanding Career Award, the IEEE Third Millennium Medal, and the IEEE Major Educational Innovation Award. Dr. Tien is also an elected member of the National Academy of Engineering.