A Glance at Operations Research, Cybernetics and Society

S Madan
Human Resource Development Group (DSTP), CSIR Complex, New Delhi 110012, India

Revised received 23 July 2001; accepted 28 August 2001

The paper details the two eras of knowledge processing, one characterized by the application of operations research (OR)—whose domain is relatively static knowledge—and, the other, is characterized by cybernetics—that considers change in structure and has been defined as the science of control and communication. Currently the society is moving towards a knowledge based society in which quality environment plays an important role. The paper presents the two scenarios with considered examples, including that of environment, vis-à-vis society.

Introduction

The forties saw the birth of two new fields: cybernetics and operations research (OR)—one after the second world war and the other, before, and during the war through Blackett’s circus of OR. Though Blackett’s team stressed heavily on the systems approach in solving problems of military strategy with the applications of OR concentrating subconsciously on treatment of problems within the part of systems and sub-optimization. Only a few stalwarts like Ackoff and Stafford Beer have been trying to emphasize a systems or cybernetic approach to operational analysis.

When Blackett started the OR Group during the World War II as a problem solving aid to the Allied forces, he applied a systems view for most of the problems undertaken by his team. With proliferation of applications of OR in industry, economy, social spheres, etc., in the post war period; many of the problems undertaken had excellent applications as well - but in many cases problems were solved for an isolated subsystem without having considered the impact of a bigger system. Too much emphasis was given to optimization, and with comparatively little on the problems of balancing of elements of the system, effects of mutual feedback within the elements, and feed forward effects, etc. A great advancement, no doubt, was made in the direction of modeling approach (particularly of small systems), study of mathematical properties of a class of stochastic systems, optimization (particularly within static systems), simulation techniques, and numerical analysis of various problems.

To elaborate, consider any organization complex, composed of various elements, and none of which is independent of others, and each exerting a feedback effect on others, and through others on itself. Any realistic study of social organization should take this aspect into consideration. To have a generalized model, consider a complex with \( n \) individuals whose performance is indicated by control variables \( x_1, x_2, ..., x_n \) with objective functions \( \phi_1(x_1), \phi_2(x_2), ..., \phi_n(x_n) \). Since, \( x_1, x_2, ..., x_n \) may be conflicting among themselves, it is only appropriate to take the objective function of the \( i^{th} \) individual as

\[
\max_{x_i} \phi_i(x_1, ..., x_i, ..., x_n) \quad i = 1, ..., n. \tag{1}
\]

In certain cases ‘max’ may be replaced by ‘min’. The overall objective function of the complex would be

\[
\max_{x_1, ..., x_n} \left\{ \sum_{i=1}^{n} \phi_i(x_1, ..., x_i, ..., x_n) \right\}. \tag{2}
\]

Seldom one comes across

\[
\max_{x_1, ..., x_n} \left\{ \sum_{i=1}^{n} \phi_i(x_1, ..., x_i, ..., x_n) \right\} = \sum_{i=1}^{n} m a x \phi_i. \tag{3}
\]

Generally one finds

\[
\max_{x_1, ..., x_n} \left\{ \sum_{i=1}^{n} \phi_i \right\} > \sum_{i=1}^{n} m a x \phi_i. \tag{4}
\]
suggesting that if the organization had framed an objective function (Eq. 2) by taking into consideration the interdependence of various elements ($x$), the payoff would be greater than the sum of the performances of individuals working on their own. Such a situation can occur for large number of problems in decision making, including an industrial production complex comprising various elements.

**Operations Research vis-à-vis Cybernetics**

The post war history of the development of OR was, therefore, one of developing tools for getting solutions to the optimization problems met within the management; and many of these tools have been mathematical (e.g., programming methods, techniques for dealing with problems in inventory management, congestion problems, replacements problems, etc). A phenomenal development in computation science helped in the expeditious performance of numerical computations involved in all types of OR work. Most of the problems in OR have so far been approached as mechanical problems, and solutions have been derived mostly by applying some of the new techniques developed on the information collected by a team of scientists.

A tremendous benefit accrued to industry, especially in the USA and UK by applying OR methods, but during the last decennium it has been increasingly felt that no live problem in management can nearly be treated as a mechanical problem completely devoid of human factors. To take stock of how best OR can be used in unison with human and other social factors in real life problems, one is referred to the paper by Ghosaf.

Cybernetics has been defined in a number of ways by various scientists. Wiener was the first noble laureate and a scientist who defined it "as the science of control and communications in the animal and man", and thereby, restricted its scope to the physical world. Stafford Beer put it more broadly: "The new science of cybernetics is the science of control and communications—whenever these occur in whatever kinds of systems". The core of cybernetic research is the discovery that there is unity of natural law in the way control must operate, whether the system controlled is animate or inanimate, physical or biological, social or economic.

Klir and Valach defined a cybernetic system $S$ by the relation

$$S = \{X; R\},$$

where $X$ is the set of input elements of the system, i.e., $X = \{x_1, x_2, \ldots, x_i\}$, and $R$ is the set of controls that defines the rules and regulations of the system, which operates on the input set $X$, and thereby, a set of output $Y = \{y_1, y_2, \ldots, y_j\}$ is obtained as a result of function $f$ of the system as follows:

$$f(X; R) \rightarrow Y,$$

whereas, a system can be classified under any of the following three categories of a cybernetic system:

(i) A closed system, implying that there is no effect of the environment on the system.

(ii) An open system, implying that there is always an effect of the environment on the system.

(iii) A partially closed system, in which case the environment has an effect only on a subset or a few subsets within the system.

The set $R$ that defines the rules and regulations of the system can be mathematically considered as a set of control elements, i.e., $set R = \{ R_1, R_2, \ldots, R_j \}$. The nature of these elements is, therefore, responsible for the nature of the composite function $f$. It is possible to consider each element $(R_1, R_2, \ldots, R_j)$ or combination of two or more elements as a subset or the set $R$.

For example, if one considers a city or state with population congestion (e.g., Delhi, the capital city of India), then, based on social factors, the population at the state level can be classified as:

(a) average level of persons getting food facility

(b) average level of persons having housing facility

(c) average level of persons getting medical facility

(d) average level of persons getting educational facility

(e) average level of persons getting employment facility

Therefore the working system of Delhi can be expressed in the form of (Eq. 6.)

$$f(X'; R') \rightarrow Y',$$

where $X' = (x_1', x_2', \ldots, x_i')$ and $R' = (R_1', R_2', R_3', \ldots, R_j')$. It is quite possible to define a subset $R'$ of $R$, i.e.,
\( R^* = (R^*_1, R^*_2) \subset R \) such that \( R^* \) to be a set of industrial control. That is, the set \( R^* \) controls the population based on industry within the state. Also, a bigger subset \( R'' = (R^*_1, R^*_2, R^*_3) \subset R \) can be treated to be a set of industrial control.

Let us consider the set \( R^* = (R^*_1, R^*_2) \) to be the control set due to industry within the city/state that can cater for the input set \( X \) and consider the total population of the state to be \( X \). Then,

\[
\begin{align*}
  f \left( X^*; R - R^* \right) &\rightarrow Y^*, \\
  f \left( Y^*; R - R^* \right) &\rightarrow Y''^*,
\end{align*}
\]

whereas the sets \( R \) and \( R' \), \( R'' \) are additive. On analyzing the input–output response of the systems, Eqs 7, 8 and 9, if one concludes that the workings of the system, Eq. 8 or 9 is far better to cater for the smaller population \( X^* \) or \( X''^* \) than \( X \) from the point of view that the industrial control does not exist in the city/state. Such a practice, therefore, calls for the industry to be installed outside the city not within the city as in the case of Delhi. In other words, the population congestion is controlled by the behavioral control set \( R - R^* \) or \( R - R''^* \) which interacts with the state population at the level \( X^* \) or \( X''^* \) instead of \( X \). This may improve the social and behavioral factors affecting Delhi in the following ways:

(i) Less housing needed to cater for the population at the level \( X^* \) or \( X''^* \).

(ii) Low housing rent due to lesser population \( X^* \) or \( X''^* \).

(iii) Cost of land and sale of houses go down.

(iv) Road maintenance cost is projected less than before.

(v) Water scarcity is controlled due to availability of drinking water to the population level \( X^* \) or \( X''^* \) thus declaring \( X \) to be uncontrollable level of state.

(vi) Finally, social problems can be met adequately so far the availability and use of resources are concerned, and thereby a quality environment is generated in the state, and so on.

The benefits therefore derived from the city due to structural changes can be used to establish the industry outside city/state for the social development and installation of industry. The environment of Delhi would be much safer from those industries causing pollution and congestion problems within the city.

**Environment vis-à-vis Society**

Consider here that class of systems in which the environment is always a part of the whole thus having its effects on the system. The inputs to the system at any time \( t \) are processed by functions of the system and fed back into the system that affects the inputs to the system at time \( t + 1 \). A feedback system can be described by the Figure 1 wherein environment is affecting the inputs \( X \) and the inputs are being regulated by the function \( f \) and thereby the outputs \( Y \) are being fed back into the system.
The feedback function is termed as $h$, and mathematically, we have $Y_t = f(X_t)$, whereas $h(Y)$ affects the inputs to the system $X_{t+1}$ at time $t+1$.

The nature of the environment in Figure 1a depends on and varies with system. Looking at the diagram, it needs to understand the system wherein the environment is 'quality oriented' that gives rise to positive feedback into the system whereas the environmental quality can be low, medium, or high.

Quality must lead to quality orientation process that is responsible to a great extent for the public awareness of the acceptance and non-acceptance of the goods/products that do not require cost. The public consciousness that can be awoken and thereby maintained within a quality environment. The quality environment thus generates the ability for the acceptance/non-acceptance of the goods/products available in the market. One can conclude that acceptance would be only for the quality products whereas the non-acceptance of products can lead to competition in the market that would look for the quality demand of the customers and hence the process of commercialization of products would race for the quality in all respect, from all directions.

The above concept is a logical acceptance of the feedback system. In practice, it is found that the quality of life is always sustained by quality in environment that gives satisfaction to the people and provides a healthy life and thereby the role of money becomes minor in operation of life. One can attain quality in life in all respect, from all directions in a quality environment.

It has however, become the tendency of each and every society/system to spend more and more to achieve satisfaction and consume the quality for better health while this can be very well maintained by creating a quality environment. The quality in environment is, therefore, a cybernetic control about which the article is concerned.

One can be, therefore, sure of low values of crime and thereby less involvement in corruption practices, once the quality in the environment prevails. Is it valuable? If such a situation of environment can prevail then it is certain to have higher level of development that can be understood by the term 'quality development' or 'quality in development' which implies enhancement in the development process. Here, the environment does not imply the quality of air or water, but it is a mathematical entity: $\mathcal{Y}$.

If $\mathcal{Y}$ is the entire (conceivable) space, and $\mathcal{S} = \{X; R\}$ the relevant system, in which $X$ is the set of variables, $R$ the relationship set, then $\mathcal{Y}/\mathcal{S}$ is the outer environment. For example, in a metropolis like Delhi registering a population increase about 30 per cent per 10 y, increase in pollution, congestion, accidents and unemployment among youth are natural corollaries. Accordingly corrective measures have to be adopted. For example, Singapore tries to keep the number of cars in streets within limits by imposing punitive tax on intending buyer of cars; Delhi or Mumbai does not have such plans. Problems in protection of environment need a systems approach in which quality in environment plays an important role.

The development referred here is not dependent on economy that leads to economic development but it is considered as the overall development or the integrated development. The development process itself would, therefore, receive a higher and higher value in the cycle of time till a saturation level or limiting stage in mathematical term is attained. It is implied from the Figure 1a that the development at time $t$ as such would be fed back into the system that would have an effect on the development at the next epoch of time. A feedback of the development process at time $t+1$ thus reacting within the environment leading to the varying effects on the inputs to system at time $t+1$. The environment is, therefore, a self-regulatory and controlled process in the cybernetics sense, and amid the positive feedback can definitely lead to the quality in environment.

An undesirable and destructive feedback situation may exist in the near future, such as impact of an increasing scale of Technology (and previously balanced) environment. What is required is the sustainable technology for development of a nation. On the other hand, a system where one can easily get instability is a system of alternators (alternating generators). If one has switched in an alternator at a very high wrongly phased system, the system will blow up.

The quality environment is, therefore, required in most of the developing societies/countries those are lacking in practice of cybernetic principles. The cybernetic understanding of the environmental process can save the people from mental tension, pollution, and night crimes, otherwise, heart diseases and lungs
problems along with brain hammerage problems can enlarge and thus lead to a hippie society.

It is very well concluded, therefore, that the quality environment is an asset or a control in cybernetics language for the overall development of each and every society or system in general.

References