". . .a brief characterization of the two technologies is made to establish their relevance to the problems of transportation."

Computers and Operations Research in Transportation*

by

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INTRODUCTION

Scope and Objectives

Computer and operations research (OR) have been applied in many areas and subject matter. Transportation is only one of them; and perhaps, one of the most important. And their applications need not be in the context of 'rationalization' either. The latter term has been avoided in this paper principally because:

- rationalization has gained some notoriety as a result of its misuse to describe certain actions or measures which, on closer analysis, have not satisfied the criteria of objectivity, optimality, and general welfare;
- the word is too emotive, connoting as it does the existence of an irrational transportation system, to which I do not agree;
- it has the implication that the objective in transportation planning and management is rationality; it is not.

OR and computers are two technologies suited to problems of resource utilization and complex systems. We have learned a great deal about using them to untangle complicated relationships, to project the implications of a variety of designs and services on different groups, and to uncover attractive solutions. Transportation in the Philippines is not exactly a stranger to these technologies, but not many successful examples can be cited.

This paper omits a review of the transportation field and the decision processes that govern it; these should already be familiar to most readers. Instead, a brief characterization of the two technologies is made at the outset to establish their 'credentials' and relevance to the problems of transportation. Some known applications are cited, as prelude to a discussion of the problems or constraints which hamper widespread use. The paper concludes with suggestions for adaptation of these essentially-Western technologies into the Philippine environment.

What are we talking about?

Operations research involves the "application of scientific methods, techniques, and tools to problems involving the operation of a system so as to provide those in control of the system with

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optimum solutions to the problems. Almost always, a mathematical model is used which, because of complexity invariably requires the computational power of computers to solve. The emergence of the computers then has facilitated the application of OR in many fields of endeavor.

OR can be viewed as a series of systematic steps, as shown in Figure 1, or a collection of mathematical models such as queuing theory, linear and nonlinear programming, game theory, network models, and optimization algorithms. There are three basic essentials of an OR project, namely:

1. *Its system orientation.* OR is concerned with whole problems, not just its parts. This concern represents a realization that an activity by any part of an organization has some effect on every other part. Hence we see that the optimum for some other part of a system may not be optimum for some other part. If some part of the system suffers a smaller level of attainment of its objectives when another part is optimized, the system is said to be sub-optimized.
2. *Interdisciplinary character.* Analysis is usually conducted by mixed teams of scientists from diverse disciplines such as economics, psychology, mathematics, and sociology.
3. *Mathematical formulation.* Its methods and approaches to problem solving follows a certain structure. The problems involved are complex decision problems where it must be determined which alternative a decision-maker should choose based on some objective function. A model is usually developed that expresses the measure of effectiveness as a function of the alternatives and the uncontrollable variables in the problem, with the form as follows:

$$E = f\ (C, U)$$

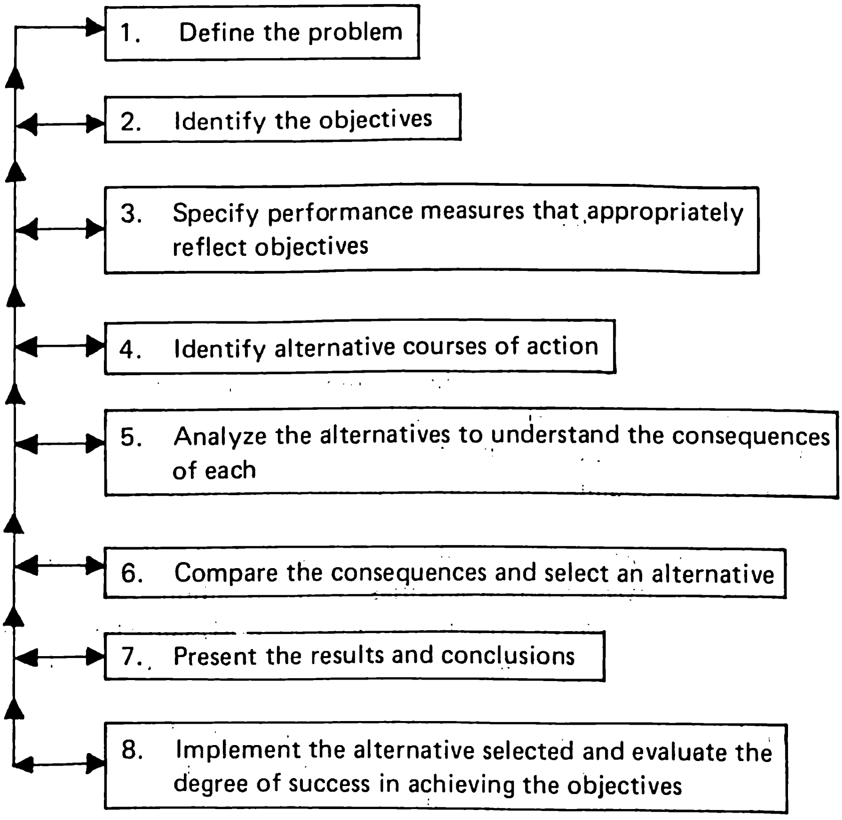


Figure 1. Eight Steps in an Operations Research Study

No brief is offered here about computers; there are enough articles floating around to have caught the attention of anyone worth his salt. It may, however, be helpful to keep in mind its strategic import as pictured in Figure 2, with the 1st quadrant "Research Technology" as the more appropriate for this paper, although transport organizations' uses of computers may fall on the other quadrants — such as airline reservation system which is under the "Programmable Technology" environment.

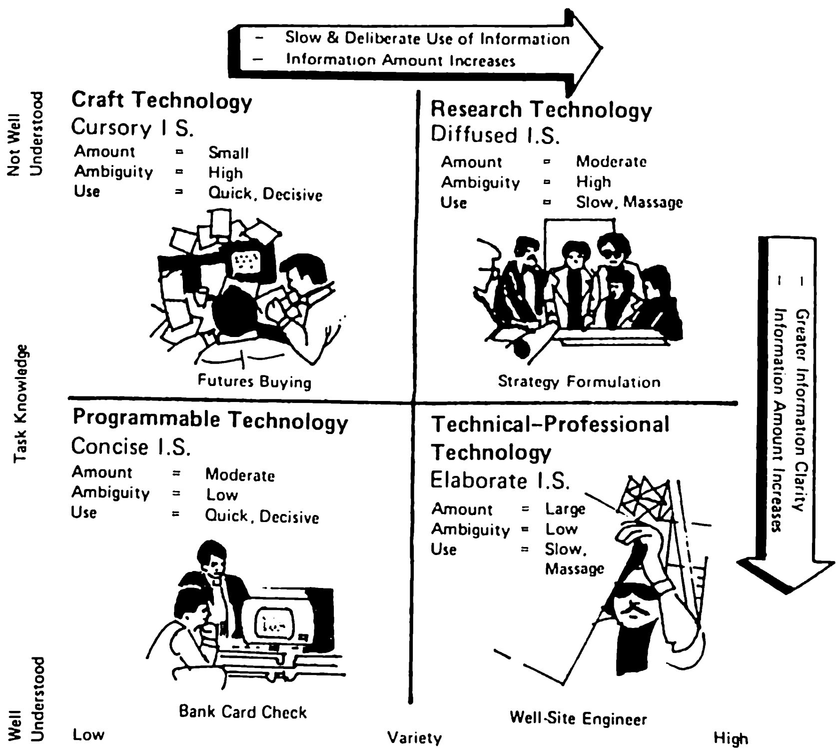


Figure 2. Technology and Information Systems Model

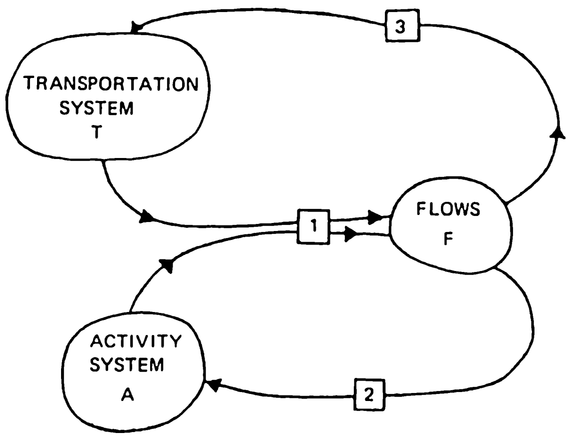
In relation to transportation

OR and Computers, how do they impact the planning and management of our transportation systems? Manheim's framework (see Figure 3) on transportation system analysis is useful in this regard which posits only three basic options: travel market equilibration, activity system equilibration, and transport-service equilibration. Computer modelling is at the heart of the prediction problem (see Figure 4).

Basically, transportation provides users with access to desired locations by overcoming the physical barriers of distance between separate activities. In this function, the system should attempt to minimize the time and cost of travel, while maximizing comfort, convenience and safety. Such a formulation makes transportation a natural province for OR. Hence, the number of success (and failures) stories in more industrialized societies.

Developing countries, like us, face serious problems in trying to formulate sound transportation policies to develop a balanced transportation system. Decisions must be made on the improvement and extension of existing transport systems and associated investments; the introduction of new techniques, operational methods, and technologies; and the strengthening of the institutions needed to plan, build and manage the nation's transportation system. Inherent in these decisions is the need for workable and appropriate methodologies. OR and computerization fall into this category.

However, their applications in the Philippines may not be as straigth-forward as they may seem. The perspectives are different; our systems are more complicated than the orderly transport monopolies of the West. Moreover, the transportation planning process which is being exported from the U.S. cannot be accepted as satisfactory, if judged on the basis of performance. The US has never taken a comprehensive view of the transport function as applied to its own country.



BASIC VARIABLES	BASIC RELATIONSHIPS
T	TYPE 1: F = f (T,A) TRAVEL MARKET EQUILIBRATION
A	TYPE 2: A = f (E,F) ACTIVITY SYSTEM EQUILIBRATION
F	TYPE 3: S = J (T, V) TRANSPORT SERVICE EQUILIBRATION

Figure 3. Transportation System Analysis

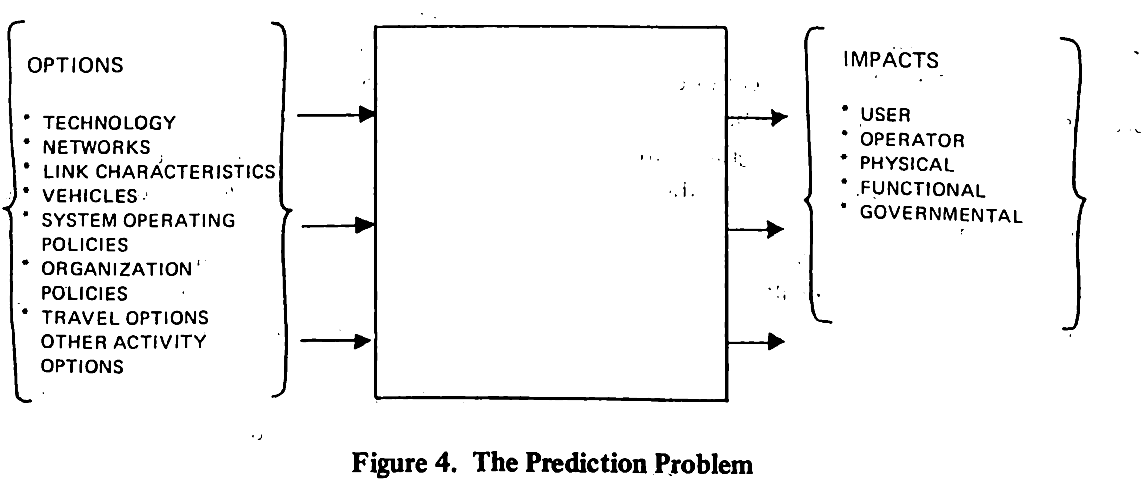


Figure 4. The Prediction Problem

IN SEARCH OF APPLICATIONS

Rise (and fall?) of OR

OR's beginnings could be considered part of the history of transport. The US Navy applied it during WW II in developing strategies for mining operations and determining the best search patterns against German U2 submarines and surface vessels. Interest in OR spread outside the military in the '60s and then caused the development of educational programs at such academic institutions as MIT, Case Institute and John Hopkins University. Today, the courses are mostly housed in engineering colleges with the Department of Industrial Engineering. Somehow along the way, OR lost its glamour among corporations who got enchanted with it initially, in the same fashion as the fascination for Japanese management techniques have occupied center stage in recent times.

Ascendancy of Computers

While computers began to gain footholds outside of the scientific labs in the 1960s, the real bloom started at the turn of the decade when microcomputers flooded the market. Transportation has a large appetite for computing power. The convergence between demand and supply has given rise to a plethora of transport application packages available on microcomputers. Canned solutions and formulas are now proliferating, promoted by the US Federal government, private think tanks and the universities. With such a formidable 'godfather', dissemination of the technologies is progressing rapidly, and spreading like wildfire among transit operators, transport planners, traffic engineers, educators and other professionals with interest in the transportation field.

Because many of the application packages being distributed (many are for free) are OR-based, renewed excitement in these methodologies is being generated. The fortune of OR in transportation has thus become intertwined with that of microcomputers; the growth of the latter is setting the stage for the rebirth of the former.

Where are we?

It is difficult to make a definitive evaluation of the state of applications of OR and computers in the Philippines. The simple fact is that there is paucity of information. Practitioners, if any, are too shy to publish and discuss their experiences in the transport arena. Without a deliberate process of review and learning from the past, any intellectual field of endeavour is bound to stagnate nor can it aspire for greater heights. It is a pity. We have no shortage of materials to discuss and dissect, except that foreigners have been capitalizing on them more than we do.

Almost all the cases that could be mentioned came from the public sector. As early as 1972, UTSMMA, the first urban transport study on Metro Manila utilized a computer simulation model similar to the seminal Chicago urban transport planning model. No Filipino was sufficiently involved in the modeling exercise as to know exactly what the Japanese consultants had done, then.

When MMETROPLAN was conducted in 1976, a slight improvement in the technology transfer process transpired in the sense that a local apprentice had been immersed in the simulation work and copies of the computer program suite had been retained. Unfortunately, the documentation left much to be desired, replicating the job appears too formidable. No wonder that subsequent planning exercises skirted it.

A third simulation model entered the scene sometime in 1981 – originally developed in the Philippines by a foreign consulting firm for the Metro rail feasibility study. Called TRANSTEP, it has been subjected to successive refinements and validation tests. Manila was its laboratory and the world is now the target of its embrace. Variants of it appeared in the Metro Cebu Transport Study, in the JUMSUT project; and the final Metrorail Study (1985). With the availability of TRANSTEP for microcomputers and mainframes, we should expect it to replay for a much longer period than its predecessors – and not necessarily in the Philippines.

The Traffic Control Center has been reported to be a user of TRANSYT, a traffic signal timing optimization program in use in more than 200 cities worldwide. I do not know how much it costs MPWH to acquire it, but the program and documentation are now available through the STEAM Support Center in Cambridge for $15.00. The program provides optimal signal timing plans which minimize stops, delay and fuel consumption, and can be applied to isolated intersections or coordinated arterial or network systems.

What about the private sector? Outside of the usual management applications of computers (e.g., inventory control, accounting, payroll), I have yet to hear from the various transport operators. The toll gates on the North and South Expressways must have been designed based on Queueing Theory – a branch of OR which explores the relationships between demand on a service system and the delays suffered by the users of that system. San Miguel Corporation has an OR department that has kept mum on what it does or had done, although some years ago it admitted using Linear Programming to find the most economical way to distribute beers.

The use of microcomputers in the planning of our transport system is more widespread. The Ministry of Transportation and Communication (MOTC) alone has an array of micros. A prototype system even displays in colorful computer graphics the routes of jeepneys in Metro Manila or the different socio-economic characteristics of the metropolis. In the mainframe segment, it is pushing the computerization of drivers and vehicles records and data on public utility vehicles. The latter hopefully should improve our transport regulatory mechanism – accurate data being a sine qua non though not a sufficient condition for putting back sanity in the business of public transport franchising.

PROBLEMS AND CONSTRAINTS

Where is the market?

The primary cause of the anaemic state of OR practice in the Philippines is the lack of demand for it. How many trained OR specialists have withered away and moved into more lucrative careers because there were no clients? It can be said that OR is a set of solution techniques in search of problems, or more appropriately, in search of markets.

In the field of transportation, two facets of OR – simulation models and linear programming – have found some religious adherents. The various transport studies on Metro Manila and Metro Cebu, for example, utilized computer simulation models in various ways. A multimillion undertaking like the Light Rail Transit (LRT) project could not have been planned without the use of computer simulations. Invariably, all simulation models in urban transport studies followed the four-step structure of trip generation, trip distribution, modal split, and traffic assignment. Linear programming is generally included in many college courses; its application in product distribution could be more prevalent than what had been documented.

Outside of these few 'shining moments', which were dominated by foreign consultants by the way, I could not find many traces of OR in the real world and outside of the academe. Is it because the private, family-run and small ownership structure of many of our transport operations could not care less about scientific methods?

Do we know the technologies?

There is another fundamental reason why OR has not found a loyal following in the field of transportation. Our educational system is weak on mathematics. Many of the college graduates are not at ease with numbers. For example, there was a report that 75 percent of those who take the civil service exams fail because of poor scores in mathematics. Can you imagine how dismal the performance would be in other more difficult and technically oriented vocation? It is not surprising therefore, that those who become influential – professionally or position-wise – are averse to quantitative techniques.

The abstract complications of OR does not jibe with our general academic preparation. Computers have more appeal though it strikes fear among the uninitiated.

Data – where are you?

A third reason, though less formidable, is the lack of data. OR is data hungry. Computers, too. Only in the last couple of years have data collection about the buses and jeepneys been started. Origin-destination surveys have become more common but still limited to a few urban areas. I do not know if our data are richer in shipping or aviation, but there are unconfirmed reports of OR in air and sea transport.

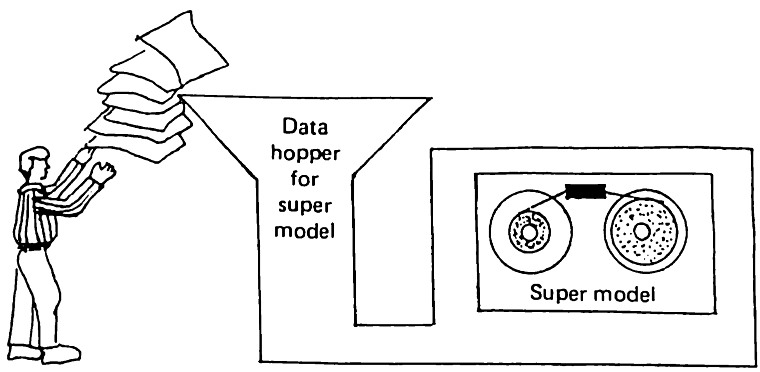


Figure 5

There was one messianic foreign professor who visited Manila a few months ago. He was preaching the value of OR and regaled us on the success story of one Western city's police department. The case had the familiar constraint of undermanned traffic force, and OR contributed to the search for optimal deployment of men and vehicles. In the process, costs and vehicular accidents were reduced. That professor left the country, wondering perhaps how backward we were for not latching on to a nice idea. What he did not know was no one could possibly be excited by a model whose data requirements (e.g., frequency and type of traffic accidents by street locations) appeared alien.

Climate for innovation

A fourth factor I would like to blame is the hostile climate for innovation in the country. How many of the few well-managed companies could claim their profitability on innovation? A transport operator who cultivated one particular route suddenly finds himself with a new competitor, thereby forcing him to revise schedules so that he could capture as many passengers as possible thru saturation tactics or skimming off of riders.

To be sure, the lack of sound proposals is not the issue. Pending before our transport regulatory agencies are numerous recommendations that are based on research and technical studies. While many are not strictly OR-based, they are nevertheless the result of scientific rigors, impartial analysis and objective considerations; hence, indicative of the prospects for OR in improving transport. The reason for their non-implementation is, perhaps, due to a different sense of priority that seems to animate our societal behavior – one that may be rational but not optimal, devoid of science but not of political respectability.

Do you know where we're going to?

Let me hazard a few guess. Without deliberate efforts at changing the way we do things, the state of transportation will remain unchanged for the next 10 years as they are now. Which is not much different from the situation 10 years ago. Except, perhaps, a more widespread use of computers in mundane applications and esoteric models which nobody understands. Being pragmatic is not the same as being pessimistic. Our transport system, in all its chaotic splendour and imperfections, merely reflects the kind of society we have. The tools of OR and computers are only as good as the people using them. And it takes several generations to make people beat to a different drum.

Unless the tail begins to wag the dog. Which is what the technology of computers is doing. As Jeremy Rifkin argues, in his book *Algeny*, the computer is drastically altering the way people think and behave as to recast the world in its own image – in the same terms that animate the operations of a computer system. Its discipline may yet infect us sooner than later.

SUGGESTIONS FOR RESEARCH

Applications I would love to see

Transportation is a fertile ground for OR, in general, and to our situation, in particular – given the small base we are in. Let me cite a few of them.

Have you ever wondered why buses or jeepneys tend to 'bunch' or 'clump' together at some points in their routes, even if dispatched at prescribed intervals? Analytical and simulation models have already been developed to discover ways to reduce the occurrences of bunching. Why not try them for size?

Optimal routing of school buses is another problem with an OR solution that has not yet gained adherents. The number of bus runs and amount of transport costs can be reduced, at the same time improving the quality of service to the students. Freight distribution is similarly situated. Both problems are analogous to the traveling salesman problem, which has been the subject of literally hundres of scientific reports and papers.

Another routing problem is the collection of garbage (Metro Manila spends about ₱400 million/year on solid wastes disposal) and the delivery of mails. Do the city's refuse-collection trucks spend more time in moving back and forth between the urban centers and a few remote garbage dumping sites than in collecting garbage from city streets? The collection pattern can be redesigned so that travel distances are reduced drastically, or the best location(s) for dumping site chosen. They fall under that class of routing problems known as the Chinese postman's problem, the analysis of which dates back to 1736 when the Swiss mathematician Euler sought to find a way in which a parade procession could cross all the seven bridges of Konigsberg exactly once.

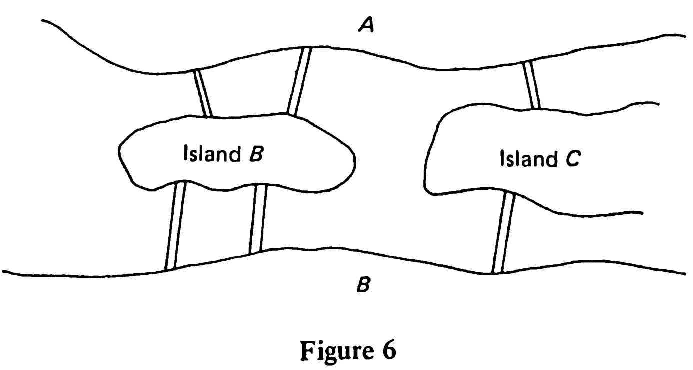


Figure 6

International air travellers would find the Manila International Airport as one of the most irritating and exasperating in the Asian region in terms of service delays, congestion at the arrival and departure lounges, and chaos in vehicular traffic at the parking lots and access roads. We can either build another terminal building or apply OR techniques. A decision in favor of the former might be 'rational' though not creative nor optimal.

Another sad commentary is the limitation on the mobility of enforcers because of budgetary restrictions. The police force of Metro Manila are equipped with cars and motorcycles but are given only a gasoline ration of five liters a day. OR could provide a better way to allocate a resource (i.e., gasoline) to maximize the objective of area coverage subject to the constraints of supply (i.e., x number of liters).

The capacity of our major ports could also be increased via queueing theory, instead of building another pier to handle shipping traffic. I do not know to what extent this 'operational' exercise has been done whenever our ports agency complained about cutback in investments and shortage of berthing capacity. The sequence of arrivals of vessels often are random and follow a Poisson probability function. When they arrive, they may be able to move directly onto a berth or they may have to wait until other ships clear the port. The amount of cargo which each ship carries and the time required to handle it will also vary so that the delay to vessels waiting for berths will be the resultant of two variable functions. With respect to servicing time, it is usually possible to describe berth occupancy as an Erlangian function. The cost of the delays to ships waiting for berths can be used in the cost benefit analysis for comparing the economics of developing additional facilities, or of continuing to operate existing facilities with increasing congestion.

Some brave recommendations

The following recommendations may not be glamorous. They do not provide officials with opportunities for making bold decisions or unveiling impressive plans.

The most cost-effective step to take is to get all the microcomputer-based software already developed elsewhere and adapt them to local conditions. We cannot afford to reinvent the wheel. However, these carry the national perspective of developed countries and should therefore be evaluated to discriminate between the concepts and solutions which can be helpful and which are not. With their availability, let us then promote their understanding and use in the local context. OR may just get in via the backdoor simply because the computer is there.

For the 'purist' among our researchers, the best area to work on is in network models or graph theory. This is still a rapidly developing area of applied mathematics that has attracted a great deal of attention during the last 15 years. The stimulus has been provided by the computers which could handle computationally difficult problems thru powerful algorithms. I am afraid that without our own research in this field, the development of algorithmic approaches suitable for our own peculiar conditions would take second priority to those addressed by Western academics. The graph-theoretic approach is a most natural one for transportation. As of yet, only a few tools exist for examining the full interaction of the demand for services with their supply, or even the interaction of different transport modes. Considerable work is needed on the behavior of transport networks, especially for the situation where intra- and inter-modal competition exists.

Another research area that might be useful is the development of our own quick response methods for transport planning. Simple, approximate, analytical models that are not data-hungry and relying on microcomputers should be very useful. Local environment is more wanting in methods for quickly estimating travel volume, demand for public transport, corridor diversion, intersection capacity analysis and the like, since more complicated techniques are not readily understood nor accepted. How many of our prospective users hear music when they hear of probabilities, Poisson distribution functions, or hypercube queueing models? Besides, we need our own set of coefficients, nomographs, and heuristics. If transport planning is to be responsive to the aspirations of our country, its techniques must be sensitive to the prevailing conditions.

In an activity that is strongly model-oriented, one must build a constituency for the model itself. This is often difficult. In private or government organizations, 'bilingual persons' – those who can speak model language as well as agency language – are rare and highly-valued. Professionally mobile, these persons are apt to be kick upstairs or to transfer elsewhere. Developing a broader constituency through sponsored workshops, training sessions, and shared publications is therefore an important research program by itself. A strong model constituency, however, is no guarantee against the vanishing advocate syndrome. OR and computer applications can be associated with a particular regime; viewed as instrument of reforms, they can develop political attributes with consequent risks. What is needed is to push as many 'publics' as possible to climb their own learning curves.

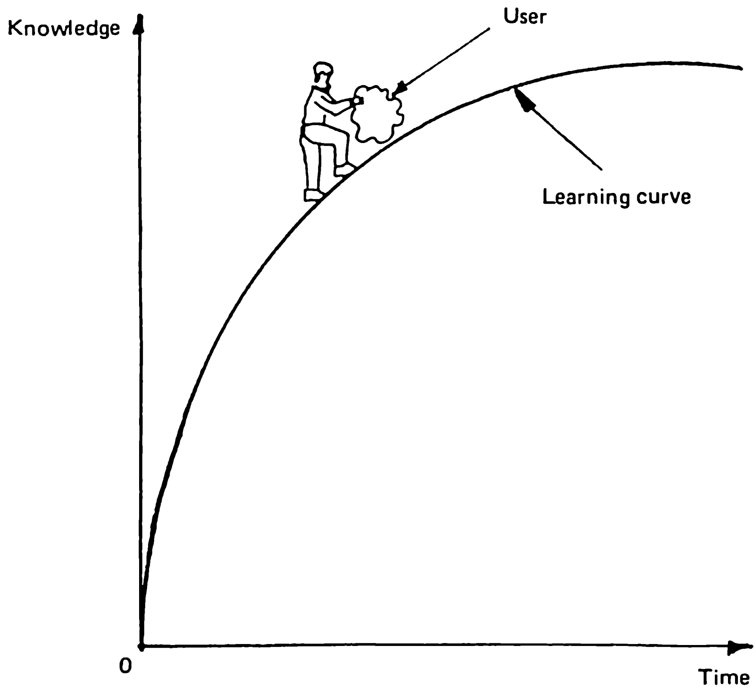


Figure 7

Ending with a Question

Well-established relationships between transportation and ultimate goals as well as between transportation supply and demand tell us that transportation facilities should not be designed as an end in themselves. True planning is for posterity. The real challenge lies in steering development over the next 50 years rather than trying to correct the mistakes of the last 100. On this, we need to rely on our intellectual tools.

Civilization is known by the tools it used.

Is our transport system backward because we still have bullcarts, calesas, dugout canoes, and jeepneys? Or is it backward because inefficient and parochial methods persist, despite the liberating influence of OR and computers?

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