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Foreword

This Highway Research Record contains six papers discussing the problems of transportation in developing countries. These papers were presented at Session 21 of the 44th Annual Meeting of the Highway Research Board in January 1965.

Five of the six papers were produced under the auspices of the Brookings Institution by men who had been connected with transportation studies overseas. Wilfred Owen, who was chairman of the session, contributed the paper, "Immobility: Barrier to Development," as a general introduction to the theme. He emphasized that transport is vital to progress in all fields and its improvement is justified only as it serves social, economic, and political needs. There should be a consistent and coordinated plan for the development of all modes of transportation.

In the paper, "Case Studies of the Effect of Roads on Development," George W. Wilson discusses field studies undertaken by the Brookings Institution in several Latin American countries and a number of cases taken from work done by other organizations in other countries. The major inference he draws is that, in terms of benefits to productive effort, the most immediate and probably greatest effects are to be found in areas where a dynamic situation involving potential development of other resources already exists.

Three of the papers utilize or deal with analytical methods for the solution of problems in technology and decision-making in underdeveloped countries. "The Structure and Requirements of the Transport Network of Syria," by Nuhad J. Kanaan applies measures derived from graph theory to the problem of connectivity between the regions and cities of Syria. The old caravan trails and railway network of the Ottoman Empire exerted only a waning influence after World War I, as Syria became oriented on its own development. The gradual rise in importance of highways has still further altered the relative importance of different regions and urban centers with resultant changes in the pattern of connectivity.

The Brown and Harral paper, "Estimating Highway Benefits in Underdeveloped Countries," is a plea for a more sophisticated procedure in estimating the benefits of highway projects than the conventional cost-savings approach. Using a simple example of primitive village economy, the authors show that transport cost savings resulting from a road improvement fail to account for the total change in the economy. They then proceed to a more general model of highway benefits in which the benefit calculation is contigent upon the investment in other sectors of the economy and upon factors favorable or unfavorable to growth. Thus, the investment decision becomes one of selecting among different investment packages the one making the greatest contribution to real income in relation to the size of the outlay.

The Soberman paper, "Economic Analysis of Highway Design in Developing Countries," also deals with economic models and gives an example of their application to problems of highway technology in Venezuela. Soberman is interested in the concept of substitutability, as exemplified by the alternatives of providing greater pavement thickness or greater subgrade strength to produce a given level of pavement load capacity, or the alternatives of annual outlay for fuel consumption against the annual cost of capital investment to reduce average rate of rise and fall. He develops isoquant and isocost curves, and through them, demonstrates the means of determining the optimum investment in these and other alternatives facing the decision maker. Finally, he shows that even with the inadequate data on vehicular and highway costs in Venezuela, it is possible to arrive at reasonable decisions among alternatives in the use of highway funds.

The closing paper is an interesting discussion of "The Passenger Car in the U.S.S.R.," by Holland Hunter of Haverford College. Mr. Hunter attributes the very small total stock of passenger automobiles in the Soviet Union (slightly over 1 million in January 1965) to deliberate policy of the Soviet government. The restrictions on free enterprise that are characteristic of the economy in that country are not the only reason for this attitude. It is apparently felt that unrestricted development of the automobile would constitute an inefficient use of the national resources. The author expresses a reluctant admiration for the relative effectiveness of rapid transit in the Soviet Union and remarks in his closing paragraph, "Our sympathies lie, of course, with the individual. And yet my own hope is that the Russian people and their government will find a way to harness the uncontrolled proliferation of automobiles and highways that has created such difficult problems for wealthy Western nations."

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Immobility: Barrier to Development

WILFRED OWEN, The Brookings Institution

•IN the complex process of development, transport plays a special role in facilitating other objectives: getting land into production, marketing agricultural commodities, making forest and mineral wealth accessible, developing industry, expanding trade, conducting health and education programs, and exchanging ideas. In recent years there has been a sharp increase in the availability of improved transport and in the impact of transport on levels of living.

Conversely, in large areas of the world lack of transport is a primary obstacle to economic and social gains. Poor transport is a major factor in world hunger; produce rots on the ground because it cannot be moved to the people. Much of the world's forest and mineral resources lie untouched because no one can get to it or move it to where it is needed.

Industrial activity is severely hampered by unreliable transport, leading to erratic supply schedules for essential fuel, raw materials, and spare parts as well as difficulties in marketing what is made. Traffic often has to wait for months for rail shipment, even with advance space reservations.

And on the political side, poor transport makes it exceedingly difficult to achieve national unity.

The size of the financial commitment to transport suggests its importance: transport generally ranks first or second in magnitude among all expenditures for national development and has accounted for as much as one-third of all loans by the International Bank for Reconstruction and Development.

How, then, does transport influence development? How can obstacles imposed by poor transport be reduced to further economic, social, and cultural ends? How does a country determine how much transport it needs when measured against other requirements? What kinds of transport would be best, how should they be financed, how administered? What role can foreign assistance play? In short, what must be done to achieve as quickly as possible the minimum standards of transport needed for rising levels of living in low-income countries?

THE SIZE OF THE PROBLEM

Today, in a few spots, there are dramatic examples of what transport modernization can do, particularly for the major cities of the developing nations. But despite these improvements, the gap between rich and poor countries and the distance still to be traveled by the underdeveloped nations are enormous. For example, if Latin America, Africa, and Asia (excluding the USSR) were to have just half as many miles of surfaced roads per square mile as the European Economic Community, 20 million miles of good roads would have to be built. Today, this huge area has scarcely one million miles of roads, mostly poor. For a similar upgrading in motor transport, the number of trucks would have to jump from less than 5 million to 26 million.

A variety of both natural and man-made obstacles will have to be overcome to narrow the transport gap between the immobile and the mobile nations. Poor countries generally have to cope with a formidable combination of physical obstacles—mountains, excessive heat, vast deserts, unpredictable rivers, and too much or too little rain. In addition, during colonial periods, transport was often developed primarily for military or export purposes, with little regard for internal growth requirements. Instead, the growth—and congestion—occurred in the port cities.

Paper sponsored by the Department of Economics, Finance and Administration.

TABLE 1

WORLD TRANSPORT TRENDS BY CONTINENT, 1950-60
(Freight in billions of ton-kms; all others in millions.)

Continent	Total Increase				Percent Increase			
	Rail Freight	Motor Vehicles[a]	Buses & Trucks[a]	Population	Rail Freight	Motor Vehicles[a]	Buses & Trucks[a]	Population
Africa	22	1.1	0.3	45	62	104	85	22
North America[b]	-14	24.1	2.6	31	-2	45	34	19
South America	10	2.1	0.8	43	16	86	72	26
Asia	264	2.4	1.7	290	261	250	293	21
Eastern Europe	916	n.a.	n.a.	65 (Eastern and Western Europe)	148	n.a.	n.a.	11 (Eastern and Western Europe)
Western Europe	48	16.9	1.9		28	166	50	
Oceania	3	1.5	0.3	3	26	76	42	27
World	1,249	48.1	7.6	477	65	80	102	19

[a]Increase, 1951-60—1951 was chosen as a base year since complete motor vehicle data for 1950 are not available.
[b]Canada and the United States.

Sources: United Nations, Statistical Yearbook, 1957 and Statistical Yearbook, 1961.

TABLE 2

WORLD MOTOR VEHICLES AND HIGHWAYS[a]

Continent	Motor Vehicles 1960			Percent Increase in Registration, 1951-60		Road Mileage[b]	
	Total (1,000's)	Per 1,000 People	Per Square Mile	Automobiles	Trucks	Total (1,000's)	Per 1,000 Sq Mi
Africa	2,573	10	0.2	101	81	241	20
North America[c]	79,163	398	10.6	45	26	2,737	367
Latin America	4,175	21	0.6	84	80	160	20
Asia	3,771	4	0.6	225	280	905	159
Europe	28,390	71	14.4	267	53	1,420	742
(EEC Countries	16,370	91	35.1	198	45	709	1,573)
Oceania	3,373	259	1.1	95	42	240	77
World total	121,145	60	3.2	68	46	5,700	150

[a]Motor vehicles include automobiles, trucks, and buses.
[b]Paved roads include miles of roads with gravel or crushed stone or stabilized soil surface.
[c]Canada and the United States.

Source: Motor Vehicle data from United Nations, Statistical Yearbook, 1957 and Statistical Yearbook, 1961. Highway data from International Road Federation, "World Highway Statistics-1960," Staff Report.

Poor maintenance of rolling stock has been an added problem. And in those countries where water transport might provide an important avenue of commerce, the potential is limited because of silting, absence of navigation aids, and seasonal interruptions due to weather.

Finally, there is general lack of well-trained personnel for the planning, management, or maintenance of an efficient transport system of any kind.

A good case can be made for transport as the key to national development, on the grounds that widening domestic markets is essential to economic growth. No country where there is a critical lack of transport facilities is moving ahead very fast, but some countries that have fairly impressive facilities also seem to be going nowhere.

BREAKING THE TRANSPORT BARRIER

It was not long ago that developed countries were just as immobile as the impoverished nations today; and one lesson to be drawn from their experience is that it took a

TABLE 3

THE MOBILE AND IMMOBILE NATIONS
(France = 100)

Country	Freight Mobility Index[a]	Passenger Mobility Index[b]
Canada	223.1	148.9
Australia	216.7	-
United States	189.0	147.2
Denmark	110.0	119.0
France	100.0	100.0
Sweden	93.0	104.5
United Kingdom	86.0	94.5
Argentina	63.8	68.0
Netherlands	58.2	69.3
Italy	45.3	53.2
Spain	33.2	34.8
Japan	30.5	46.3
Mexico	27.8	22.8
Israel	25.2	21.7
Brazil	19.7	19.8
Greece	17.8	18.7
Turkey	13.7	-
Colombia	11.3	9.2
Ecuador	10.2	8.7
India	10.0	11.5
Egypt	7.5	9.3
Thailand	7.2	8.0
Pakistan	6.7	8.3
Burma	5.3	5.5
Iran	4.7	4.3
Nigeria	4.0	3.5
Ethiopia	1.7	1.7

[a] Freight Index = Average index for rail lines per 100 sq miles, ton-miles per capita; and commercial vehicles per capita. Transport data based on 1957-58 figures.

[b] Passenger Index = Average index of the following: passenger miles per capita, passenger cars per capita, and rail lines per 100 sq miles, rail lines per 10,000 population, surfaced highways per sq miles, and surfaced highways per 10,000 population.

Source: United Nations, Statistical Yearbook, 1958 and Statistical Yearbook, 1959; highway data from The International Road Federation, "World Highway Statistics," Staff Report (1957 and 1958).

big push and large amounts of time and effort to make major transport improvements. In some instances the central government played the key role in planning, financing, and managing the endeavor, but in all nations there was some combination of public and private enterprise.

The appropriate mix in today's conditions will vary. It would hardly be fitting to suggest, for instance, that private enterprises vie with each other in the emerging nations to determine who could build the greatest mileage of railways or turnpikes in the shortest time for the greatest private gain. The days of the "robber barons" have passed. Yet it is difficult to say whether public enterprise can compensate for the disappearance of the pot of gold that rallied the pioneering spirit in the earlier days.

The question facing development planners today is whether—and how—the stages of transport progress from primitive immobility to 20th century aerial, highway, pipeline, and railroad mobility can be telescoped into a shorter time span. Although generally the underdeveloped areas are in the initial stage of primitive transport, many of them are operating in a mixture of all stages at once. Rural areas may be completely isolated, while major cities in the same country are served by modern diesel railways, jet airlines, superhighways, and motor buses. From this mixture, it is obvious that two dissimilar types of transport problems must be dealt with. The new nations do not have the leisurely time to develop and pay for their transport that older nations had; but at the same time, they can take advantage of the more sophisticated machinery to help them move more quickly. But if time is no obstacle, cost is. It is no longer feasible to allocate a major share of a nation's resources to transport. National planning bodies have emerged as essential mechanisms for progress. A key question is how far a country should go in dedicating resources to transport. It will be the growing capacity to establish transport requirements in relation to development goals that will keep the transport program within bounds, and it will be the potentials of science and technology that will reveal the best tactics to hold cost and time to a minimum.

CHOICE OF TECHNOLOGY

Similar trends in transport prevail throughout the world. In nearly all countries trucks are used for short hauls and small shipments. For low-value commodities that move in large volume, water transport and railways still provide the prinicipal methods of getting things moved. Other major trends include the long-distance movement of people by air, and the introduction of pipeline transport for shipment of oil and gas.

TABLE 4

PROPOSED OR PLANNED TRANSPORT INVESTMENT PROGRAMS, SELECTED COUNTRIES[a]
(Currency items in millions)

Country	Total	Railways	Highways	Trucks and Buses	Water Transport	Ports	Air Transport
			(a) Investment				
Argentina (in pesos)	182,427.0	100,204.0	69,874.0	-	12,349.0	-	-[b]
Chile (in escudos)	1,389.0	300.2	498.0	399.2	95.2[c]	44.8	51.6
Colombia (in pesos)	2,467.6	326.3	1,822.5	-	7.5	129.3	182.0[d]
Iran (in rials)	34,900.0	4,300.0	23,700.0	-	-	2,900.0	4,000.0[d]
East Pakistan (in U.S. dollars)	269.4	104.7	54.8	29.9	77.3		2.7
West Pakistan (in U.S. dollars)	529.2	186.0	128.7	162.0	44.3		8.2
Philippines (in pesos)[e]	632.5	186.0	295.0	-	-	73.5	78.0
Senegal (in francs)	15,720.0	2,172.0	11,235.0	-	1,225.0		1,088.0
			(b) Percentage Distribution				
Argentina	100.0	54.9	38.3	-	6.8	-	-
Chile	100.0	21.6	35.9	28.7	6.9	3.2	3.7
Colombia	100.0	13.2	73.9	-	0.3	5.2	7.4
Iran	100.0	12.3	67.9	-	-	8.3	11.5
East Pakistan	100.0	38.9	20.3	11.1	28.7		1.0
West Pakistan	100.0	35.1	24.3	30.6	8.4		1.6
Philippines	100.0	29.4	46.6	-	-	11.6	12.3
Senegal	100.0	13.8	71.5	-	7.8		6.9

[a]Proposed expenditures are for the following periods: Argentina, 1962-67; Chile, 1961-70; Colombia, 1962-71; Iran, 1962-66; East and West Pakistan, 1960-65; Philippines, 1963-67; Senegal, 1961-64.
[b]Air transport was not included in the Argentia transport survey.
[c]Includes shipping only.
[d]Includes airports only.
[e]When the private sector is added, the transport expenditures are as follows:

Purpose	Millions of Pesos	Percent
Railways	186.0	5.5
Highways	295.0	8.7
Ports	73.5	2.2
Airports	78.0	2.3
Airplanes	157.4	4.7
Trucks and Buses	1,953.3	57.7
Shipping	642.6	19.0
Total	3,385.8	100.0

[f]When oil pipeline expenditures are included, the percentage distribution is as follows:

Purpose	Percent
Highways	59.4
Railways	10.8
Ports	7.3
Airports	10.0
Oil pipelines	12.5
Total	100.0

Sources: Argentina data from A Long Range Transportation Plan for Argentina, Transportation Planning Group, Republic of Argentina, Buenos Aires, 1962, Main Report, p. 75. Chile: National Economic Development Program for Chile, 1961-70, Government of Chile, 1961. Colombia: Ministry of Public Works, Republic of Colombia, Plan for Improvements in National Transportation (Report prepared by Parsons, Brinckerhoff, Quade, and Douglas, December 1961); 1962-71 expenditures based on the table, "Summary of Recommended Investments—All Modes of Transportation." Iran: The Plan Organization, Transport and Communication—Third Plan Frame, Teheran, 1961, based on Table I, p. 11. East and West Pakistan: Corps of Engineers, Department of the Army, Transport Survey of East Pakistan, Washington, 1961, Vol. 1, p. 23, and Transport Survey of West Pakistan, Washington, 1960, Vol. I, p. 29. Philippines: The Republic of the Philippines, Five-Year Integrated Socio-Economic Program for the Philippines, 1963-67, based on the table on p. 88. Senegal: Le Plan Quadriennal de Developpement, 1961-64, Dakar, 1961.

The United States, as an affluent society, has shown a markedly greater expansion in truck and pipeline freight traffic in the past two decades of enormous growth of freight movement by all methods. But in the underdeveloped nations, those with dense populations have been emphasizing railroads, and those with sparse populations have been emphasizing roads. Whatever the proportion, however, the combination of road and railway investment has absorbed most of the transport resources in the developing countries in recent years.

TABLE 5

DISTRIBUTION OF FREIGHT TRAFFIC, SELECTED ASIAN COUNTRIES, 1957

(Freight traffic in thousands of ton-km)

Country	Total (ton-km)			Percent Distribution		
	Rail[a]	Road	Water[b]	Rail	Road	Water
India	73,415	4,550	5,950	88	5	7
Japan	48,991	13,724	41,000	47	13	40
Pakistan	6,684	438	4,960	55	4	41
Thailand	1,025	780	500	44	34	22
Burma	621	388	1,400	26	16	58
Indonesia	1,044	1,568	3,491	17	26	57
Philippines	190	1,558	300	9	76	15
Vietnam (S)	82	350	1,210	5	21	74
Cambodia	62	126	400	11	21	68

[a] Road traffic is estimated by multiplying the following assumed annual performance to the numbers of registered vehicles by type:

Year	Type of Vehicle	Capacity	Rate of Performance	Avg Annual Distance Traveled	Annual Performance
1957	Bus	30 pass.	0.80	40,000 km	960,000 pass.-km
	Pass. cars	5 pass.	0.40	12,500 km	24,000 pass.-km
	Truck	$2\frac{1}{2}$ tons	0.50	20,000 km	35,000 ton-km

[b] Except in the case of Japan, Indonesia and the Philippines, water transport refers to inland waterway traffic only, figures of which are worked out largely on the basis of the estimates of the number of vessels, inland country-boats, the average load factor and informed opinion regarding the average length and number of journeys performed annually. For Japan, Indonesia and the Philippines figures refer to interinsular freight traffic. In the case of Indonesia and the Philippines, estimates are made by multiplying actual tonnage carried by an average haul of 500 km for Indonesia and 200 km for the Philippines.

Source: Economic Development and Planning in Asia and the Far East, VI. Transport Development, U.N. Economic Bulletin for Asia and the Far East, Vol. XI, No. 3, December 1960, pp. 6-7.

In early stages of development, when low cost movement of bulk commodities is especially important, waterways can provide excellent cheap transport for both short and long hauls. Improvement of the navigability of waterways and use of newly developed diesel-powered tow boats—or even putting small motors on country boats, as the Thais have done in Bangkok—could help expand the usefulness of water transport in many places.

In the absence of water transport, of course, railways provide the most economical way of carrying bulk materials long distances, and in many countries they are the principal method of mechanized transport. Railway mileage is actually very small in much of the underdeveloped world, however, and the question is arising as to whether industrialization will result in a new railway age for Africa, Latin America, and the smaller countries of Asia.

Rail movement, to be economical, requires sufficient traffic moving over a given route to permit the economy of large-scale operations; both traffic density and length of haul are key factors in judging whether a heavy investment in rail transport is justified. Short hauls and/or light traffic make for high unit costs for rail freight.

Three main facts have led to the recent worldwide emphasis on roadbuilding, instead of railway building, for transport needs. One is that, along with better roads, the economy and reliability of truck haulage has vastly improved; secondly, where traffic is light, this is the only feasible method of mechanized transport; and thirdly, the service can often be faster and more flexible than rail operations with their complicated schedules, fixed routes, and loading problems.

In some countries, where the terrain is rough and difficult to cross, moving cargo by air has proved to be relatively economical. But to perform efficiently, an air vehicle is needed that moves at relatively slow speed, in order to reduce the cost of ground and navigation facilities, increase safety, and reduce operating complexity. If such an aircraft could be built at low cost, it might appreciably alter the character of the transport investment program in many developing nations.

The use of pipelines also offers interesting possibilities, particularly since it may be feasible to move some solids as well as liquids and gases by this method. The practicality of pipelines for developing countries lies in the ability to traverse even the most difficult terrain, to be almost unaffected by weather, and to furnish transport of petroleum products at low unit costs. Maintenance is also simple and does not require a large number of highly trained personnel.

In addition to the cost and service characteristics of transport methods, another factor to be weighed in making a wise choice of alternatives is the effect it will have a on the economic activity and living standards of the country. Different methods require different inputs of capital, foreign exchange, managerial talent, and technical skills. They take different lengths of time for completion, and afterwards have varied requirements for maintenance and operation. The outputs will also differ, including the ability to create capital, earn foreign exchange, train entrepreneurs, foster supporting economic activities, and provide jobs.

A major shortcoming in the process of selecting among transport technologies is the hesitancy to adopt innovations, owing to traditional attitudes in developing countries. As a result, many of the plans for future development seem to deny the transport revolution and favor instead a reconstruction of the past.

CARRYING OUT THE PROGRAM

Every country, regardless of its state of development, is burdened by the high cost of moving. Virtually all nations operate their transport at a deficit, and often rates are below out-of-pocket costs. While to some extent this can be corrected by more realistic rate structures, it is also necessary to avoid the opposite danger of achieving self-support by putting rates so high they discourage use of facilities and thereby interfere with the goal of generating new economic activity.

User taxes are one acceptable way to help pay for transport, but the extent to which they can be adopted varies with the type of transport. It can only be said, therefore, that different circumstances make it necessary to tailor price and tax polices to the particular economic and social environment served.

The cost problem is especially acute for roads and railroads, which account for two-thirds of all expenditures for transport. In the railway field, the global picture is one of chronic deficits stemming in part from the persistent idea that railways are capable of providing every type of transport service with maximum efficiency and economy. The result is that they carry too much unremunerative traffic.

It is important, therefore, that railway managements be empowered to determine what price policy is appropriate in the light of the overall circumstances in a particular country, and that public policies take into account the economic advantage of carrying part of the freight by road. Road deficits may also be expected to persist, however, because the economic returns from road use are often difficult to reflect in prices paid for service. But roads are needed, regardless of whether there is a railway, because they serve the unique function of providing access to land and resources throughout their length, and accommodating all kinds of traffic, from primitive to mechanized.

The problem of financial support is closely related to the organization and administration of the transport program. Unfortunately, in developing countries as in many developed nations, neither physical nor financial problems are viewed in relation to a "coordinated" transport system for highways, rail, water, and air. Typically, each method of transport is studied separately because most experts are specialists in one aspect of transport only. The focus should be on the economics of alternative technologies.

The desire to provide a better organizational and administrative environment has led some countries—with prodding from the World Bank—to alter their administrative approach to transport. One trend has been toward a public authority, especially for the operation of railways and ports. Another has been to lodge all public transport

TABLE 6

CUMULATIVE AID FOR TRANSPORT, UNITED STATES AND INTERNATIONAL AGENCIES[a]
(In millions of U. S. dollars)

Aid	Total	Percent
I. By Source		
IBRD and IDA	2,508.2	38.3
Export-Import Bank	2,136.2	32.6
ICA	979.9	14.9
DLF	561.9	8.6
AID	173.9	2.7
EEC (European Development Fund)	195.7	3.0
Total	6,555.8	100.0
II. By Method of Transport		
Railways	2,537.4	38.7
Roads	2,080.9	31.7
Ports and inland waterways	562.0	8.6
Shipping	88.1	1.3
Air	671.7	10.2
Pipelines	64.0	1.0
Miscellaneous	377.8	5.8
AID	173.9	2.7
Total	6,555.8	100.0
III. By Region		
Africa	862.0	13.2
Asia and Middle East	2,826.9	43.1
Western Hemisphere	2,016.2	30.8
Europe	690.7	10.5
Oceania	159.6	2.4
Non-Regional	0.4	-
Total	6,555.8	100.0
IV. Transport Equipment—AID	700.0[b]	
Grand Total	7,255.8	

[a]Over the life period of the aid organization to June 1963, except for the AID data which cover only through June 1962 and the European Development Fund figures, as of January 1963.
[b]Transport equipment aid expended by AID and its predecessors under non-project type aid between June 1952 and June 1963.

Source: "European Development Fund: Balance Sheet 1958-62," Information Memo, European Economic Community, Brussels, January 1963; W. Owen, Strategy for Mobility, Brookings Institution, 1964, Appendix tables A.9, A.10, A.12, and A.13, and Tables 6.1 and 6.4.

responsibilities in a ministry of transport, with its own research and planning staff. Or if neither of these is adopted, then the national planning agency, if there is one, may be left to coordinate various plans. But the function of a planning commission is to help relate transport projects to development goals, and it is generally too late at this stage to weigh individual project decisions.

With respect to transport operations, another type of administrative problem arises. Experiences in Canada suggest that a key element in improved and efficient operation is to view the several carriers as an integrated system, rather than as a series of component or unrelated parts. Such an approach could lead to rate policies and traffic allocations that would encourage movement by the most economical channels. Various mixes of public and private enterprise can be involved in the resulting system.

FOREIGN AID

Whatever the domestic efforts, most developing countries will need help from the outside—more capital, foreign credits, entrepreneurs, and technical skills. How much of this help is now being provided? And what more is needed?

In this decade of development, it can be said that extensive assistance has been provided, and that many of the results have been impressive. The principal agencies have been the World Bank, the International Development Association, the European Development Fund of the Common Market, the Export-Import Bank of Washington, and the United States Agency for International Development. In the postwar years, these agencies have given or loaned a total of $7.3 billion for transport development, with the World Bank and IDA providing the largest segment of the total. Most of this has gone for railroads and highways.

With all this help, scarcely a dent has been made in the transport barrier. If the growing challenge of meeting the needs for money and materials is to be met, the necessity for larger amounts of financial support is clear, And equally clear is the need for the transfer of knowledge and experience from the rich nations to the poor.

Students of foreign aid objectives have identified six discernible motives at work among donor nations, including the pursuit of humanitarian purposes, provision of subsistence aid, furtherance of military objectives, offering of political rewards, granting of prestige foreign aid, and the promotion of economic development.

In the transport field, as in others, the first five may continue to be provided on a bilateral basis, or through international agencies. But the sixth, which is most important, should be granted on the basis of an overall economic strategy adhered to by both recipients and donors, regardless of the selfish interests of the latter. Aid for this purpose should be judged in terms of what is best for the aided country.

A good case can be made for funneling a much higher proportion of loan and grant programs through international arrangements that remove mixed motives and make it easier to impose performance standards on the recipient nations. Such a consolidation would also help alleviate the acute personnel shortage problem through pooling information and experience. Pre-investment surveys, in particular, should be accomplished through international auspices, with the goal of achieving a standard acceptable to all agencies that might be called upon for money.

Another new direction for improved foreign assistance efforts lies in viewing the task as a long-term operation which includes maintenance, good management, and sound financing as well as initial construction. Closer controls over financial assistance through international agreements would also make practical a system of grants instead of loans.

This use of grants offers the only promise of stepped-up efforts without prohibitive debt burdens for the developing nations. They can be made on a businesslike basis if matched by the recipients on a sliding scale determined by financial capacity. The European Development Fund of the Common Market, used principally for African nations, suggests a pattern for applying an agreed-upon percentage of the gross national product of the donor nations for such aid to the underdeveloped world.

One major step toward improving transport planning would be the establishment of a World Transport Center to serve the United Nations as a focal point for research and education. This could provide for an interchange of experience among member countries in various parts of the world, would promote regional transport solutions, and would direct research and training efforts toward the solution of common problems.

A TRANSPORT STRATEGY FOR DEVELOPMENT

Global transport and communications have set the stage for man to think his way as well as work his way out of bondage. But to date, the transport revolution has been contained in scattered economic islands where mobility and some degree of prosperity go together. There are still vast areas where immobility and poverty persist.

There are no easy guides for the transport policymaker. The most urgent need may be simply to create a state of mind in which transport decisions are clearly seen as an integral part of other policy decisions. And this will mean giving up some long established misconceptions.

The misconception that causes the most trouble is that transport is a separate sector of the economy, where in reality it is a link among sectors. Improvement of transport is justified only if it serves other purposes. Another misconception is that each method of transport can be planned separately, for clearly what is done in one part of the transport system has important bearings for the whole.

One cannot establish a simple goal for transport, such as for steel production or food consumption. It is up to those responsible for the development of agriculture, industrialization, and other targets to say how much transport will be required.

Thus, within the poor nations, the strategy for mobility must start with a thorough knowledge of the country's resources, its development potentials and objectives, whatever transport plan it may have in existence, how various types of transport would serve the national purpose, how transport can be paid for, and how it should be managed and operated effectively.

Improvement of transportation in the United States, for example, requires many of the same approaches called for in less developed countries. This includes the formulation of desirable goals for the nation and for the community, based on a consensus as to both needs and priorities. In establishing a clearer set of goals, whether at the national or the community level, there will be a better understanding of how transport can help to achieve these objectives as an integral part of the physical developments proposed in other sectors. For example, there is a close relation between urban transport facilities and the design of the city, and between transport services and the functioning of the city. Similarly, effective distribution facilities for industry have important implications for industrial location, costs, and markets.

In the United States, as elsewhere, there is pressing need for viewing transportation problems as a whole, to assure that maximum advantage is taken of all available technologies. Physical interrelations among the several methods of transport are needed to permit all forms to play their appropriate roles in a total system. And the conduct of research and development to apply the fruits of scientific innovation presents a continuing challenge and opportunity.

Both the rich countries and the poor have much to learn from each other. The great need today is for a global interchange of information and experience, greater support of transport research and training, and continuing efforts to overcome the world's transport barriers through cooperative action. For if the world's idle resources can be put to effective use through easier access and low-cost movement, the result may be a key to improving living conditions everywhere.

As the dimensions of the world community continue to grow smaller with advances in transport and communications, higher standards of living on one continent cannot fail to have a desirable impact on all the others. An effective strategy for transport and communications may prove to be the most important single factor in the global effort to bridge the gap between physical resources and human needs.

Case Studies of Effect of Roads on Development

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•A SERIES of case studies has been conducted in Latin America to indicate the impacts of road construction on economic development. The purpose of these field studies, undertaken by The Brookings Institution, was to shed light on the actual results of better transport, as a basis for improving techniques of evaluating future transport project proposals.

The countries included in the case study work were El Salvador, Guatemala, Nicaragua, Venezuela, and Bolivia. In addition, analysis was made of a number of other cases previously studied by other organizations in India, Thailand, North Borneo, Uganda, and Peru. The following sections provide a broad survey of the impact on the regions influenced by the new roads. (For further details and an analysis of the implications for theory and policy, see Ref. 1.)

EFFECT ON TRAFFIC

In every case there was a rise in traffic along the new facility, representing in most instances a net increase in total mobility, not merely a diversion. Where no previous connection existed, the traffic on the highway represented a net increase in movement. But in most instances, even where rail connections were paralleled, the rise in highway movement implied a net increase. For example, only 12 percent of the total traffic along the Friendship Highway in Thailand was believed to have been diverted from the railway, and along India's Ramnad-Mandapam road, and the coastal highway in El Salvador, rail traffic increased following its completion. The same is true of the autopista in Venezuela. In Nicaragua, rail traffic declined along the portion of the highway closely paralleling the railroad, but this was more than offset by the rise in trucking. Even in the case of the Guatemalan road, some net increase in mobility was recorded although this was slight and mainly attributable to other factors.

In general, however, the total volume of traffic in the region or country increased, and the extent of diversion from parallel facilities, other than indigenous forms of transport, was not significant compared to the growth along the new capacity. Even where diversion occurred, this proved to be a more rational allocation of traffic.

In every case, local traffic was almost completely captured by truck transport except for heavy, bulky low-valued commodities such as bricks, tiles, gravel, and timber, which continue to move by rail where this is a possible alternative. In Guatemala, for example, local traffic by rail is estimated to have declined by almost 50 percent. In Nicaragua local traffic by rail fell sharply between 1954 and 1962. During this period it accounted for only one-third of total rail and truck short-haul or local traffic. With respect to indigenous forms of transport, which were entirely short-haul, the volume of traffic similarly decreased substantially.

Longer-haul or through traffic also showed a shift to truck from rail but for the most part this represented movement of the increased production in the region, and the extent of diversion from alternative forms of transport was relatively small.

Passenger traffic, however, shifted more dramatically to bus service once the road was completed. In Guatemala, bus service even replaced an airline between Guatemala City and Puerto Barrios. Large reductions in rail passenger traffic were generally reported despite a rise in total passenger movement. It is clear from the cases that bus transport captured much of the previous passenger business and was responsible for practically all of the increase.

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CHANGES IN PRODUCTION

The net increase in mobility implied an increase in both the tonnage of freight and number of people moved during any time period and, in some instances, a lengthening of the average distance traveled. As both cause and consequence of this, a sharp rise in production (mostly agricultural) took place with a growing emphasis on production for the market rather than for subsistence. In other words, the rise in mobility was not simply more movement over longer distances of existing annual volumes of production. In virtually every case, the greater mobility represented a net increase in physical output as well as a higher value of output per unit of weight, as substitutions for both low-valued cash crops and subsistence crops ensued. The extent of growth of new output was particularly striking in the area affected by the Friendship Highway, and the Nicaragua and El Salvador Littoral Highways. (The 1962 decline in upland crop production in Thailand is believed to have been a result of locust plague and does not represent a reversion to production levels before the highway.) In the Department of Chinandega, Nicaragua, the area cultivated increased by over 70 percent because much pasture land was converted to crops, while the estimated value of output almost tripled between 1951-1952 and 1962-1963. The sharp rise in value per unit of cultivated land is attributable to a substantial shift from low-value crops to cotton and sugar cane as well as rising yields, especially in cotton. For example, while the total number of manzanas (1 manzana = 1.73 acres) cultivated increased by about 40,000, the area devoted to cotton alone increased by over 52,000 manzanas. The area devoted to such lower-yielding crops as rice, beans, corn, and sesame declined between these two dates. Physical yields in cotton increased steadily from about 6 quintales per manzana (1 quintal = 100 lb) in 1952-1953 to over 12 in 1962-1963, with the result that a ten-fold increase in the value of cotton output occurred. A similar though less-pronounced pattern of new lands and substantial substitution of cotton for other crops also typified the Department of Leon.

Even in Guatemala, where the area affected by the road was not extensive and conditions along the right-of-way were not propitious, some net increase in cash crop production for sale in Guatemala City was reported, which implied a substitution for subsistence crops.

But the most dramatic change occurred in the El Salvador case where cotton output increased more than seven times in the decade following 1953-1954. Indeed, the conversion of a relatively substantial region from subsistence to market-oriented production probably went further in El Salvador than in any other region examined in this paper.

There was a sharp response in timber production following completion of penetrating transport facilities (and negatively when they collapsed as near Satipo, Peru, in 1947) in Peru and the Pasak Valley in Thailand. Slightly less dramatic were the production increases in the Ramnad-Mandapam area of India, North Borneo, Uganda, and the Aragua Valley in Venezuela. Only the Guatemalan road and the Cochabamba-Santa Cruz highway in Bolivia have failed to trigger much new production. Most of the increases in output constituted a net growth for the economy as a whole and did not simply represent a relocation of productive activity.

The substitution of cash for subsistence crops was especially apparent in North Borneo, El Salvador, Nicaragua, Thailand, the Santa Cruz area in Bolivia, and the Western Montaña in Peru. This implies not only a greater volume of output but a higher unit and total value as well. More importantly it permits greater specialization and provides an essential integration of market-oriented economic activity over a more extensive area.

In most instances the transport facility served directly or indirectly to bring more land into productive use, although the extent of this varied widely. It was obviously dependent on the type and length of road as well as the quality of the soils or forests through which the road went or to which it provided easier access. Yet there is no relationship between the cost of the highway per mile and the developmental impact.

With the exception of the autopista in Venezuela, which is a very special case, the most expensive road was that constructed in Guatemala which cost over $26,000 per mile. The East-West highway in Thailand cost about $210,000 per mile, and the others

TABLE 1

SELECTED DATA FROM THE CASES

Country	Vehicles per Day, 2 to 5 Yr after Construction	Avg. Annual Change in Production in Areas Affected[a] (%)	Approx. Cost of Road per Mile (U.S. $)
Bolivia	102 to 120	20	134,000
El Salvador	150 to 1,200	80	165,000
Guatemala	400 to 700	5	261,000
India	<100	5	14,000
Nicaragua	770 to 1,500	45	100,000
North Borneo	N. A.	35	10,000 to 17,000
Peru	N. A.	75	N. A.
Thailand: Friendship	700 to 1,000	40	150,000
East-West	40 to 470	50	210,000
Uganda	N. A.	65	N. A.
Venezuela	>5,000	30	1,600,000

[a]Data refer to simple average annual increases, not compound rates of growth, rounded to the nearest 5 percent. The production estimates were derived as follows:

Bolivia: tonnage of rice and sugar production 1950-1958.
El Salvador: tonnage of cotton production, 1953-1954, 1963-1964.
Guatemala: estimated from tonnage handled at ports influenced by highway, 1953-1962.
India: weight of agricultural output excluding paddy, in study area 1954-1955 to 1958-1959.
Nicaragua: average weight of cotton and sugar output for Departments of Chinandega and Leon, 1951-1952, 1962-1963.
North Borneo: land demand, 1953-1960.
Peru: board feet of lumber production in Chinchamayo-Oxapampa area, 1942-1951.
Thailand: Friendship, weight of output of upland crops and vegetables, 1957-1961, in provinces affected;
East-West, weight of output of upland crops and vegetables, 1957-1962, in provinces affected.
Uganda: avg. of weight of cotton output for Madi and Jonam, 1948-1949, 1955-1956.
Venezuela: production index average for Departments of Aragua and Carabobo, 1954-1960.

in Latin America cost between $100,000 and $150,000 per mile. The Ramnad-Mandapam road and the unpaved roads in North Borneo cost less than $20,000 per mile. There is no relationship between these amounts and traffic estimates several years later which varied from less than 150 veh/day for the highway in Bolivia and the roads in North Borneo and Uganda, between 400 to 700 on the Guatemalan and East-West highways to almost 1,000 on the Friendship Highway and portions of the coastal highway in El Salvador (Table 1). There are obvious features of noncomparability in these cost estimates such as the degree of inflation (since the highways were constructed at different times), the variations in the exchange of rate of local currencies for U. S dollars, and, of course, the nature of the terrain and standard of road built. But even considering these sources of cost variations, the kind of road and its cost per mile is not associated with the degree of success, however measured. For comparison, data for Tanganyika are given in Table 2. If these figures have any relevance at all outside of Tanganyika, the construction costs in the Latin American and Thailand cases are clearly excessive. Independent of the general applicability of these estimates, however, the point is that road costs and standards vary considerably and without any apparent relationship to the subsequent economic effects.

There is no single answer to the question of what type of road is needed to stimulate development. Differing circumstances require different transport solutions. For instance, the Uganda case shows that when harvest time coincides with the dry season or a time of year when dirt roads are passable, all-weather or surfaced facilities are not essential for inducing sustainable increases in output of crops, especially if they are not subject to serious damage through rough transport (e.g., cotton). On the other hand, all-weather roads are important where these circumstances do not exist. The only specific example of this is in North Borneo where a positive relationship exists between all-weather roads and the value of crop production at varying distances from the market. It is reasonable to assume that a similar, though less pronounced, relationship

TABLE 2

ESTIMATED ROAD CONSTRUCTION COSTS, TANGANYIKA[a]

Vehicles per Day	Type of Road	Construction Cost per Mile (U.S. $)
<60	Earth feeder roads, permanent bridges	1,400 to 7,000
60 to 150	Earth or gravel	14,000 to 22,000
150 to 1,200	Bituminous surface 20 ft wide	33,600
>1,200	Bituminous surface over 20 ft wide	56,000

[a]Data denied from International Bank for Reconstruction and Development, The Economic Development of Tanganyika, Baltimore, Johns Hopkins Press, p. 279, 1961.

holds for improvements up to and beyond paved facilities, although the data available do not permit specifying its precise nature.

Furthermore, where constant attention must be paid to crops during the growing season, accessibility at all times during the year, and not merely to transport the harvest from the fields, is important as the Nicaragua and El Salvador cases suggest. This is especially true when landowners or their agents reside in towns or villages more or less remote from the growing area.

RATES AND SERVICE

The mechanism that served to stimulate additional output, cultivation of new lands, and more passenger travel was in every case except that of El Salvador a rather sharp decrease in freight and passenger charges from levels prevailing before the new facility as well as improved service. This, however, did not happen spontaneously. Moreover, some commodities and segments of the region benefited more than others. Nor was there much uniformity in the extent of average rate decreases among the cases as would be expected. (As far as penetration facilities are concerned, it is not possible to speak of rate decreases since no previous service existed.)

Rough estimates indicate that rates for most of the commodities involved dropped by about 50 percent in the Guatemalan, Bolivian, and Indian cases and by even more than this on the Friendship and Nicaraguan Pacific Littoral highways. However, in El Salvador, both passenger and freight rates on the railroad which paralleled the road for part of its distance did not drop. Furthermore, for the Friendship Highway it is estimated that the cost of moving maize from Korat to Bangkok is about the same whether by rail or road. It is not clear whether the rail rate before the highway was much higher than at present. Data on rates for the other cases are either not available or indicate a mixed pattern. Even these rate changes hide a wide variety of changes, for instance among commodities with import rates, where relevant, falling more than export rates, and rates for local traffic declining more than for through traffic.

The difference in the extent of rate reduction between imports and exports reflects the typical situation of an underdeveloped country. Bulky, low unit-value agricultural commodities predominate among export commodities; and high unit-value manufactured goods constitute the major proportion of total imports. This meant that before road competition, the rail rate from the ports was significantly higher than the rate to the ports, since "value of service" rate-making principles typify most rail networks. Furthermore, the import traffic in general is more suited to truck transport than is the export traffic. Thus, the import rate by rail was especially vulnerable to truck competition. It is not surprising that when road facilities were made available, the prime target was the import traffic. In the Nicaraguan case, rail rates on imported goods from Corinto to Managua declined by well over 50 percent while export rates on cotton and coffee were reduced by only 11 and 19 percent, respectively. The rail rate from Puerto Barrios to Guatemala City in the Atlantic Highway case exhibited a somewhat similar pattern. The export rates for sugar and coffee were reduced by about 10 and 50 percent, respectively, between 1958 and 1963, whereas import rates on truck-competitive traffic were generally halved.

On the other hand, the even more drastic rate reductions for local traffic were less a result of excessive rail rates, where rail transport was an alternative, than the high cost of indigenous forms of transport and vigorous competition among the large number of independent truckers who suddenly emerged.

For example, the short-haul cotton traffic from the field to the cotton gin in Nicaragua was estimated to cost $0.35/ton-kilometer by oxcart and only 10 cents by truck. In the Western Montaña of central Peru, costs by mule per ton-mile are more than double those by air and many times higher than truck where these forms of transport are possible.

Except for El Salvador, in places where rail competition existed, rates on local traffic declined very sharply. (In the Guatemala case, the rail rate for general merchandise was reduced from almost $2.00 per hundredweight in 1957 to $0.40 in 1963.) This put additional pressure on truck charges aside from the vigorous competition among the truckers themselves. However, the marked service advantage of motor transport over rail, especially for short hauls, meant that a substantial diversion from rail to truck could not be prevented. Indeed, the railway in Guatemala acknowledged that shippers definitely prefer truck service for export of cotton (2, p. 38). Short-haul truck rates up to 50 percent above the corresponding rail rate did not prevent the loss of local traffic to trucks.

But no rate change was possible without the creation of excess capacity in transport and relative freedom to set whatever rates seemed necessary to utilize this capacity. Where some type of restriction on entry into the trucking business was in force (e.g., Guatemala), the results were among the poorest of all the examples given, although some evasion of the law and lack of enforcement offset the importance of the restrictions. Again, in the Bolivia case, part of the lack of success, at least during the early years, has been attributed to monopolistic tariffs due to "restrictive practices of the Cochabamba and Santa Cruz road haulers' federations" (3). The income from a round trip, Cochabamba to Santa Cruz in 1958 was estimated at $185, while costs were only $110 (4).

The excess capacity was a direct result of a rather sudden influx of trucks and buses on a for-hire basis. In other words, one precondition for rate changes was the rise or expansion of entrepreneurial activity in the provision of transport service and an absence of direct or indirect restrictions. Despite a sharp decline in rates charged, new or existing transport firms still found it sufficiently profitable, at least in the short run, to initiate or expand service to the area served by the new right-of-way. In all cases, the transport industry received an influx of small-scale operators in response to the new economic opportunity, and the low-level instability of rates and service typical of this kind of operation naturally ensued. Vehicle registrations in the areas directly affected increased more rapidly than the national average, and the number of vehicles using the highway rose even faster as trucks, buses, and automobiles were diverted from other more costly routes.

In Nicaragua an economic slump occurred between 1957 and 1962, occasioned by declining coffee and cotton prices. Despite the fact that the slump led to a contraction in the purchase of vehicles, traffic along the completed portion of the Pacific Littoral Highway rose steadily from 277 vehicles per day (counted at a station 30 kilometers north of Managua) to 1,200 in 1963. This suggests some diversion from other routes as well as increased use of the existing stock of vehicles.

In the Santa Cruz area of Bolivia, it is reported that campesinos were entering the local trucking business in response to agricultural growth. These new truckers purchase Japanese trucks with two-year loans which suggests that financing is readily available. Partly due to the increased production in Santa Cruz, traffic along the Cochabamba-Santa Cruz highway is believed to have risen from 102 vehicles per day in 1959 to 120 in 1962 (4; the data are subject to some serious shortcomings; a "most conservative estimate" covering the period from December 1961 to September 1962 puts the vehicles per day at only about 80 [p. 20] while another estimate for 1960 suggests a figure of 135 [p. 36]).

Even in the less successful Guatemala case, it is reported that "as soon as the paved highway . . . was completed, trucking interests commenced to operate to and from the port," (2, p. 26) precipitating a serious rate war. Since there was no significant increase in the size of the country's vehicle fleet, this represented mostly a reallocation of motor transport in reponse to the increased profit potentials created by the highway. That the response was substantial is indicated by the fact that 18 bus companies (during 1963) were operating over the entire length of the highway while 89 others were licensed to operate over routes which require the use of portions of the road. Thirty-seven larger trucking firms used the highway, and although data are lacking, it is believed that several times this number operate as small independent or owner-operators (2, pp. 40 and 87).

Vehicle registration in the provinces directly affected by the Friendship and East-West highways in Thailand, showed markedly faster rates of growth than for all of Thailand. Available evidence also suggests that the number of vehicles per day is continuing to rise, although no data are presented regarding the number and type of transport firms operating along these highways.

Although similar data are not available for all of the other cases, it is clear that something of the same type of phenomenon must have occurred in response to the production increases.

At the same time that rates decreased, the service became faster, and accommodations for small shipments over relatively short distances were improved.

Time in transit was sharply reduced compared with previous alternatives in almost all cases. Before the road in Bolivia was completed, travel between Cochabamba and Santa Cruz even during the dry season took from two to four days. It is now a matter of about one-half day to one day during all seasons. On both the East-West and Friendship highways in Thailand, time savings of over 50 percent, compared to the next best alternative between important points, were recorded. The same is true of the several areas in the Peruvian Western Montaña with respect to travel time to Lima. Time savings in the Nicaragua case amount to about one-third although this was not directly attributable to the road since the railways had installed better equipment in 1955 which improved speeds by this amount.

But of greater importance, especially to local traffic and small holders, are both the increased flexibility of service and the ability to transport smaller amounts at reduced rates. Average loads with few exceptions run from barely four to ten tons, depending on the country and nature of the vehicles, and these are well below the cut-off points for carload rates by rail. Door-to-door service also eliminates the time and extra cost of transshipment.

Furthermore, truck transport is inherently more capable of tailoring service to specific needs, especially of small-scale producers. This refers not only to more frequent scheduling of service or providing service on demand, but also to the fact that truck drivers sometimes assist in loading and perform other services for small individual producers that a railroad could not. It is not surprising that the bulk of short-haul, local traffic now moves by truck in virtually all the cases examined which is, of course, consistent with the technology and economics of road vis-à-vis rail transportation.

Because of the nature of these changes, substantial benefits accrued to smallholders located near the highway relatively close to the market as well as to middlemen who handle small quantities at any one time. Where the highway paralleled a rail connection, the relative advantage was even greater since there was no need to transship and small loads could be moved more efficiently. In all such cases a more rational traffic allocation ensued. The less-than-carload, short-distance traffic which was highly rated by rail was captured by the trucks. This permitted, or forced, the railroad to concentrate more on the type of traffic for which it has an inherent advantage. The importance of this traffic shift was particularly pronounced in those instances where the railroad was operating at or beyond full economic capacity.

In short, the effect of a net increase in mobility was to bring about an improved use of an expanded transport capacity. Both the former users of alternative modes of transport as well as the new users benefited. At the same time fewer resources were used up than would otherwise have been the case. More traffic was carried at lower per unit real costs (as well as rates) as a result of the new facility and increased number of vehicles.

TRENDS IN POPULATION

Even in the absence of information concerning regional demographic trends, a positive relationship between new transport capacity and population was evident. This does not imply any relationship at the aggregative level where, in fact, transport would represent more of a response to population growth. But for particular regions, transport facilities are both cause and consequence of population growth. When transport creates new economic opportunity, it attracts people to the area. Increases in output usually require more labor; higher incomes attract new settlers; and a demand for services, shops, etc., emerges. So long as markets remain favorable and the resource base undepleted, this process becomes self-reinforcing and the rate of population growth in the region affected is accelerated.

One of the most striking illustrations of what improved access means in terms of population growth is provided by Drewes' comparison of the four areas in central Peru, although cause and effect are not readily separated. The slowest and steadiest growth of population was recorded in Pozuzo which has been virtually isolated since 1900 and grew almost entirely without immigration. On the other hand, population grew sharply in the Tingo Maria-Pucallpa area after completion of the road connection to Lima. Satipo indicates the volatility induced first by improved access in 1940 when the population increased sharply after decades of stagnation and then decreased just as sharply after the road was destroyed in 1947.

But the complexity of the interrelationships between improved access and population growth is suggested by the Bolivia and Guatemala cases. It is true that the city of Santa Cruz grew at a rate well above the national average between 1950 and 1962, but this is due to a complex of factors only one of which is the Cochabamba-Santa Cruz highway. Furthermore, the Department of Santa Cruz recorded a rate of population growth below the national average and only one-fourth that of the city of Santa Cruz. In the Guatemala case, little migration has occurred and the overall demographic impact has been negligible.

Improvements in health, resettlement schemes, and relative economic potential of particular areas are more significant than access, per se, regardless of the fact that access of some sort is a necessary condition for effective attacks on disease and resettlement (e.g., El Salvador) as well as exploitation of economic opportunity. Just as in the case of the growth of production, population responds differently to new transport capacity depending on a complex of conditions.

CONCLUSION

In every case, the extent of new traffic generated depended mainly on the availability of easily exploitable natural resources. The lowest levels of traffic, omitting the earth roads in Uganda and North Borneo for which traffic estimates are lacking, were associated with highways traversing a territory poor in resources. The Guatemalan, Bolivian, and Indian experience typifies this situation. The largest traffic volumes or those growing most rapidly involved highways through areas rich in forest reserves or with good soil conditions for cash crops. This was especially true in Nicaragua, El Salvador, Venezuela, Peru, and Thailand. Additional inducements to open up new lands were population pressure, rising prices for the crops concerned, reduced transport charges, and improved service. In short, the highest traffic volumes were fairly consistently associated with rising net receipts to producers of agricultural products.

No adequate details of actual or possible profit prospects were provided, but the inference is clear that they created a powerful inducement to raise output and sell a greater proportion of it in local, sectional, or world markets. Some of the evidence on production changes is given in Table 1. The data are not strictly comparable nor can they be assumed accurate in all cases. But with all their weaknesses, they do suggest the radically different impact on production between the Guatemala, India, and to some extent Bolivia cases and all the others. With appropriate qualifications, these data may be construed as rough indicators of the relative degree of success. Using this criterion, even considering the costs per mile and amount of traffic, the least successful roads, up to the present, are those in the three countries just mentioned. It cannot, however, be stressed too much that this evidence by itself is inconclusive. Nor has it been possible to deduce a consistent set of calculations yielding a meaningful and comparable benefit-cost ratio. But the inferences deduced from the behavior of production in the affected areas are consistent with the impressionistic evidence concerning relative profitability which itself is closely associated with the availability of natural resources in the regions.

As far as causation is concerned, we have noted the role of the highways in Bolivia, Guatemala, and India (even if there was not much in the way of development according to production indicators), as well as in both areas in Thailand, Peru and El Salvador. For the other cases, the highway or road is best construed as a response to a development that would probably have occurred in any event although not necessarily in the same manner nor to the same extent. The role of transport in the latter cases was more one of facilitating a dynamism already under way. In the former group the road was at least a partial initiator, inducing a development that would not otherwise be expected to occur. The relative lack of success to date in three of these instances does not detract completely from the importance of the road. Indeed, in Guatemala, not only was there a large expansion in truck transport, but a new type of transport using refrigeration equipment appeared, and its future prospects seem bright. In Bolivia, the future success of the colonization scheme lies partly in the existence of a good connection between the highlands and the Santa Cruz area, to say nothing of the political significance of tying together two regions of a country hitherto separated physically and psychologically. Furthermore, recent evidence on domestic production of rice and sugar, most of which comes from the Santa Cruz area, suggests a continued acceleration. From 1950 through 1962, the average rate of growth of these products combined is more than double the figure given in Table 1. Preliminary data for 1963 show an even more rapid increase. Even in the India case, the growing number of market areas, a narrowing of regional price differentials, and the rapid expansion of some key products might well pave the way for accelerated growth in the future. However, data are not available to demonstrate what in fact has occurred more recently in the Ramnad-Mandapam area.

What these three examples suggest is that, given a relatively static or deteriorating situation before the new transportation capacity, along with few readily exploitable natural resources, the task of initiating sustainable growth is both more difficult and protracted, which implies the necessity of combining transport investment with other policies if important changes are to occur.

Furthermore, the three countries with the slowest rates of overall growth coincide with the three relatively unsuccessful cases just mentioned. This would suggest that where there is a general lack of dynamism there is also a greater probability that a specific investment will not become much of a success. Where there is a high degree of overall dynamism, on the other hand, a specific investment is apt to become an apparent success for two reasons: (a) the greater the general rate of growth, the more likely it is that any investment will appear as a necessary reponse to prevent or alleviate a bottleneck situation; or (b) even in the absence of an actual or incipient bottleneck, a rapid rate of expansion is associated with an environment where additional economic opportunity is not only more assiduously sought but more rigorously exploited. The opposite typifies a situation of persistent overall stagnation.

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Structure and Requirements of the Transport Network of Syria

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•THIS STUDY examines the relationship between the spatial structure of a transportation network and other basic distributions reflecting the demands for transport facilities. These ideas are examined within the regional setting of Syria, a country carved out from the age-old Turkish Empire after World War I by somewhat arbitrary international boundaries, which disrupted old functional or nodal patterns and the well-developed flows of commodities and people associated with them. Measures of transport network structure are derived from graph theory, and are related by multiple regression methods to spatial variations in the distributions of population, economic activity, and the physical base. In this fashion the variables having a significant effect on transport network development are identified, and the variation in the growth of the network from place to place within Syria is described. This is followed by the identification of areas where a lag in the network development exists, based on the foregoing assumptions. These may be the areas where future development ought to be undertaken, especially in places where a high degree of growth in population and economic activity is taking place.

Graph theory techniques are also applied in the examination of changes through time of the total connectivity of a transport network and the relative connectivity of major urban centers. In this fashion, the important centers which decreased in connectivity due to the realignment of the network are identified, as well as newly emerging urban centers whose relative connectivity increase places them in an advantageous location on the major trunk lines of the developing network. This method of analysis is especially useful when examining increases or decreases in connectivity, or accessibility of urban places through time, due to the effects of superimposing an international boundary which severs the network at critical points, as is the case with a large number of developing countries, making it necessary to realign the network to meet the national demands of the country.

GRAPH THEORY MEASURES

In its natural form, graph theory is a body of mathematics which examines the relationship of points and linking lines. (For a detailed study of graph theory see Ref. 1.) In its adaptations to transport network analysis, the points may be considered the nodes of the network, and the lines as the road segments connecting the nodes. In this fashion, any network under consideration is reduced in shape from its actual form (Fig. 1a), to a simplified form, with its significant properties left intact (Fig. 1b). Thus graph theory, as applied in the area of transport network analysis, is a mathematical tool relating the vertices of the network to its edges. Since edges and vertices may be represented in a variety of ways, depending on the aim of the study, they have to be defined before the investigation. The vertices may represent urban centers in one study, whereas in another they may include any point where two lines intersect. Similarly, edges may be represented in many other ways. In one case they may represent the road (physical) connections, whereas in another they may represent distance or travel time between two points, whereas in still other cases they may be considered in terms of traffic flow.

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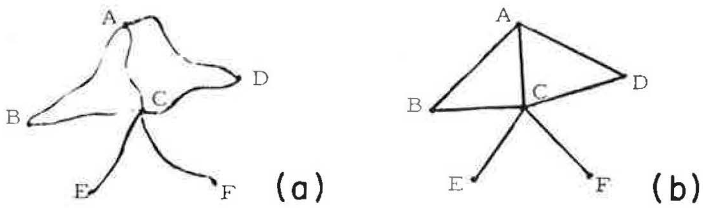
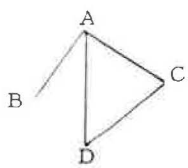


Figure 1. Transportation network: (a) actual form, (b) simplified form.



	A	B	C	D
A	0	1	1	1
B	1	0	0	0
C	1	0	0	1
D	1	0	1	0

Figure 2. Matrix of connectivity.

Measures of Network Structure

The graph theory measure used in this study is the iota (2) index

$$i = \frac{M}{W + W_e}$$

where M is the total mileage of the network, W is the total number of vertices with weights assigned to them, and W_e is the number of weighted vertices in surrounding areas directly linked to the network. Two underlying factors are believed to influence the structure of the network: the first incorporates the idea that a connection to a first order vertex has a different effect on the system than a connection to a second or third order vertex. The second brings in explicitly the idea that the connections crossing the boundary lines from the surrounding units influence the structure of the network within the specific area under consideration. The weighting of the vertices is done arbitrarily with a value of 1 assigned to a first order vertex, a value of 2 assigned to a second order vertex, etc. The vertices, W_e, are similarly weighted.

Measure of Network Connectivity

Another fashion in which graph theory concepts are used in network analysis is to reduce the graph to a matrix of connectivity. This is done by constructing a matrix in which the vertices which are connected to one another are indicated by unit elements, and vertices that are not connected are indicated by zero (Fig. 2). The matrix may then be powered to the diameter of the graph, which is the minimum number of one-step connections required to join the farthest pair of nodes, and the connectivity of the different vertices is then calculated by totaling the rows of the matrix, and the hierarchy of the connectivity is determined.

This technique indicates the changes in connectivity over time, by examining basic measures of the structure of the network for any desired date, past, present, or future. This is based on the fact that as new connections are added to the graph, the value of the connectivity indices changes, not only that of the two vertices concerned, but those of the whole system.

Road Network Demands of Syria

For the purpose of this analysis, the 42 administrative divisions (Qada) of Syria are used as units, since all the statistical information gathered uses these units as the basis for data collection. Using the i index two sets of graph theory measures were obtained for each unit, one set representing the structure of the primary road network, and one set representing that of the road network as a whole. In addition to these dependent variables, the following eight independent variables, considered related to road network demand, are obtained: population index, agricultural index, industrial index, transit movement index, railroad competition index, size index, and slope index.

Multiple regression analysis is applied to the two dependent and eight independent variables after common logarithmic transformation was applied to the data. Table 1 gives the result of the multiple regression analysis, which is the relationship between each dependent and the eight independent variables, added one by one.

For example, the first row from left to right indicates that 1 percent of the total variation in the road network structure is statistically explained by the population distribution, 40 percent by agricultural production, etc., and, finally, 84 percent of the total variation is explained by the eight variables. One of the surprising results of the analysis was the low correlation between the structure of the network and the distribution of population. Investigation of this fact, however, reveals that in Syria there is a low degree of mobility among the majority of the people, which is one of the general characteristics of transportation in developing countries (3).

Agricultural production is highly correlated with road network reflected by the significant increase in R^2 when agricultural index is introduced to the analysis. This indicated the strong relationship between the agricultural sector, the most important economic activity in the country, to the pattern of the road network which links the areas of production to the local, national, and international markets.

The introduction of the index representing the industrial activity of the country provides a significant increase in the case of the primary network measure, but yields a relatively low increase for the total network measure. This result indicates that industry, in general, depends on primary roads more than it does on secondary and tertiary roads. However, this correlation is not as strong as in the case of agriculture, indicating that industrial production in Syria is still in its early stages of development.

The introduction of the index representing the movement of transit goods across the country has a very small effect on the coefficient of determination, reflecting the small correlation between movement of goods in transit, and network structure. This is mainly due to the fact that most of the transit goods passing across Syria are transported by rail, and have very little relationship to the development of the road network. Another reason for the low relationship may be due to the fact that Syria did not take the pattern of flow of transit goods into consideration in its recent development plans.

The index representing railroad competition results in a negative value of the regression coefficient which means that the presence of railways within a certain area is inversely related to road structure, portraying the competitive nature of roads and railroads. However, the inverse relationship is very weak, which may be due to a number of reasons:

1. Since the railroad system in Syria is very limited in extent, and is fragmented by political boundaries, competition is very small.
2. The measure of railway competition which took into account the presence or absence of rail lines may not have been the best way to examine the effect of railroads.

The introduction of the area index to the analysis brings about a large increase in the value of R^2 in both cases. This supports the fact that the size of a given area has a high relationship to the complexity of the network that develops within that area.

The shape index produced a negative value of the pertinent regression coefficient showing that a circular area, which has a low index value, requires a simpler network structure than an elongated area to serve its transport demands, other things being equal. However, once again the relationship was very weak and the value of R^2 did not increase much with the introduction of the index of shape.

The index of surface configuration is inversely related to the structure of the road network, which means that a rugged area has a simple network, whereas a flat area has a relatively more complex network. The increase in the value of R^2 after the introduction of the surface configuration index is significant, reflecting the importance of slope on the structure of a transport network.

Summarizing the results of the relationship of the network to the three major factors, i.e., population, economic activity, and physical base, it is evident that in the case of

Syria the economic and the physical factors are strongly related to network structure, whereas population distribution is weakly related to the country's network structure.

Analysis of Residuals from Regression

The expected values for each of the dependent variables were calculated, and then compared to the actual values of each entry. The difference between the two represents the residuals from regression. In the cases where the expected values are less than the actual ones, the residuals are negative, whereas in the cases where they are larger than the actual, their values are positive. The residuals are then broken down into five groups, using the standard error of the estimate as a criterion of classification, and plotted on maps (Figs. 3 and 4).

As the correlation between the dependent and the independent variables is high, it is appropriate to say that most of the important variables that are related to the structure of the road network in Syria have been identified, and incorporated into the study. Based on this assumption, the places that have low negative residual values can be identified as those places where there is a lag in the development of the road network structure, whereas the areas that have positive residuals are the ones that have a lead in the development of their road network. Analysis of the two residual maps reveals that there are a number of important districts which have a lag in both their primary and their total road network structure. Examples of such places are Al-Kamishli, Ain-en Arab, Ifrin, Banias, Feek and Homs. Other places have a lag in the development of their primary network, whereas still others have a lag in their network developments. Examples of the former case are Al-Latiquiya, Harem, and Ad Dijlah, and examples of the latter are Al-Hasakeh, Jarablus, Tartous, and An-Nabak. These results suggest that to enable the network to meet its transport demands, improvements in the structure of the road networks in these areas should be undertaken.

CONNECTIVITY OF TRANSPORT NETWORK OF SYRIA

Analysis of the connectivity of the transport network of Syria and changes in the accessibility of urban places through time is conducted in two parts: (a) connectivity of the railroad network; (b) connectivity of the highway network.

Connectivity of Railway Network

The first part of the analysis of the connectivity of the railway network is applied to the system as it originally developed, and the original important rail centers are identified. The second phase of the analysis examines the condition of the network after the introduction of political boundaries to the area, and the effects of this fragmentation on the individual centers. The third step analyzes the connectivity of the railway network by 1975, which includes the lines planned and under construction.

The matrix of connectivity is constructed and solved, and the percentage values for the relative connectivity of the major urban centers are obtained (Table 2). Homs, Damascus and Riyak have the highest indices of connectivity making them the most accessible urban centers to the network as a whole. These are followed by Dar'a, the main rail center in the south, and Hama and Aleppo, the important rail centers of the north. The rest of the centers have low indices of connectivity indicating their relative isolation from the overall network.

The international boundaries that came into being after World War I dissected the rail network leaving Syria with small sections (or in graph theory terms, sub-graphs) of the whole network.

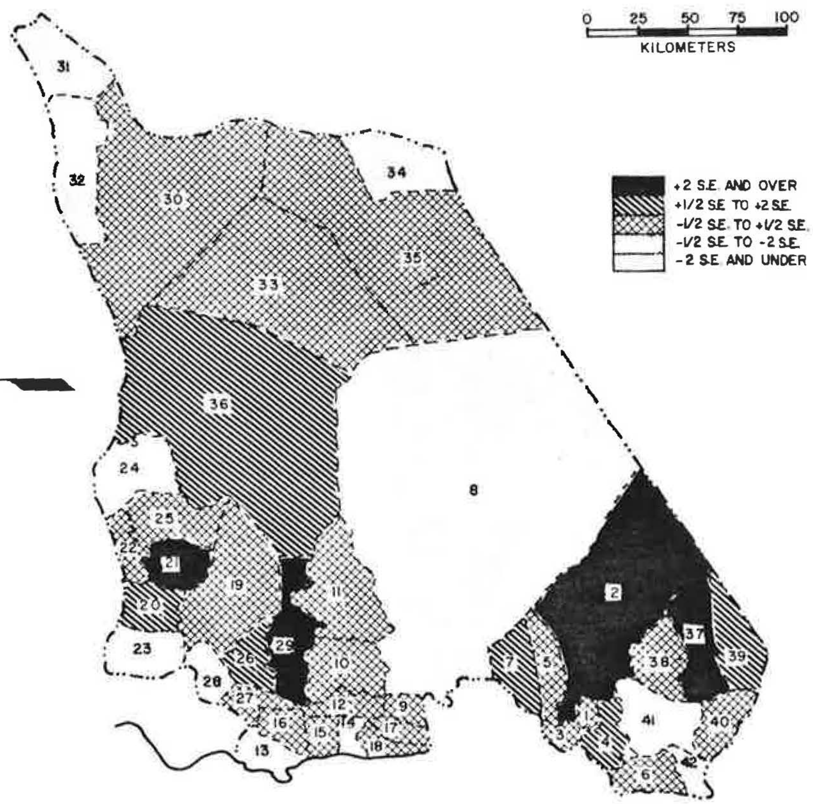
The matrix of connectivity for the present day rail network in Syria is constructed, and the connectivity values for each individual center obtained (Table 3). Aleppo and Hama became the best connected centers on the rail network, followed by Midan Ikbis and Choban Bey, then Homs, with the rest of the centers mostly isolated from the main system.

The connectivity of the rail network should increase significantly once the Aleppo-Al-Kamishli line, which is now being built, is completed, and when the proposed con-

TABLE 1

CUMULATIVE MULTIPLE COEFFICIENTS OF DETERMINATION

Dependent Variable	Population	Agriculture	Industry	Transit Movement	Railroad	Area	Shape	Slope
i(Primary network) R^2	0.01	0.40	0.46	0.46	0.47	0.79	0.80	0.84
i(Total network) R^2	0.003	0.34	0.37	0.38	0.38	0.80	0.81	0.88

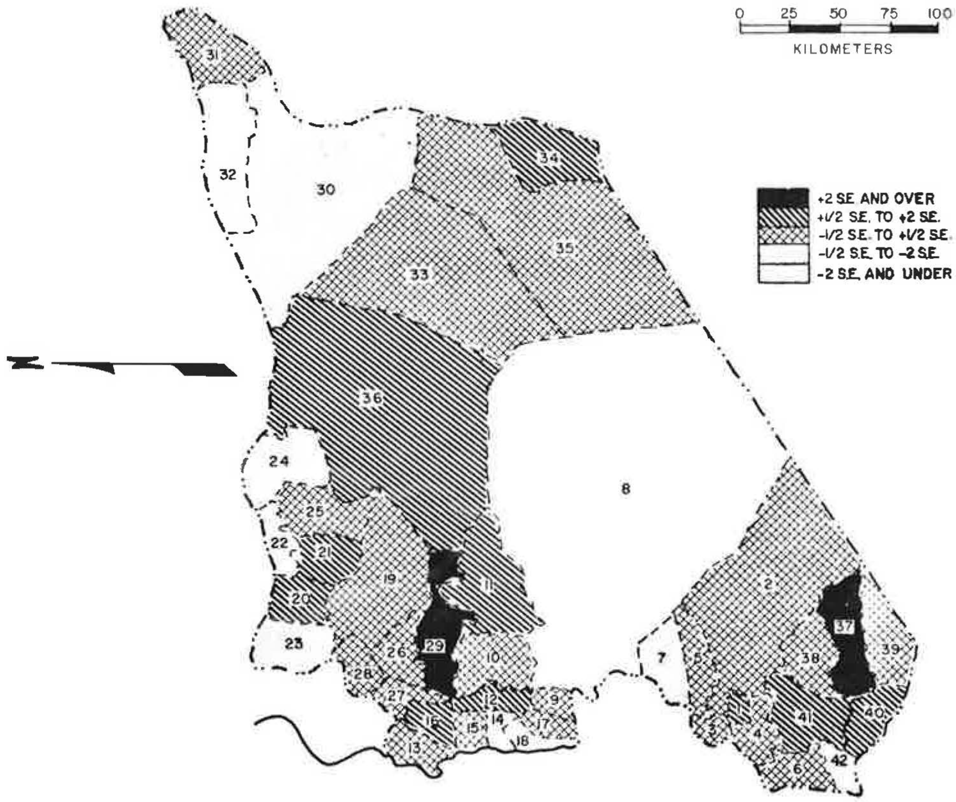


1. Damascus
2. Douma
3. Zabadani
4. Katana
5. Al Kteifeh
6. Al Qneitra
7. An Nabak
8. Homs
9. Tall Kalakh
10. Hama
11. Salamiya
12. Misyaf
13. Al Latiquiya
14. Banias
15. Jableh
16. Al Haffeh
17. Safita
18. Tartous
19. Aleppo
20. Izaz
21. Al Bab
22. Jarablus
23. Ifrin
24. Ain-el-Arab
25. Manbij
26. Idlib
27. Jisr-esh-Shaghour
28. Harem
29. Maarrat-en-Nouman
30. Al-Hasakeh
31. Ad Dijlah
32. Al Kamishli
33. Deir-ez-Zor
34. Abou Kamal
35. Al Mayadin
36. Ar-Rashid
37. As Suweida
38. Shahba
39. Salkhad
40. Dar'a
41. Izra
42. Feek

Figure 3. Residuals from regression for the i measure of the primary road network.

nection linking Homs and Damascus is constructed. Table 4 indicates the connectivity values for the completed rail network.

Table 4 indicates that by 1975, Aleppo will have become the best connected center in Syria, lying between the important agricultural area of the northeast, the port of Al-Latiquiya and the large urban centers to the south. At that time, Rakkah, the second highest place of the connectivity scale, may very well become the regional center on the agricultural northeast, due to its favorable location between the small but important centers of Deir-ez-Zor and Al-Hasakeh on the one hand, and Aleppo on the other. The



1. Damascus
2. Douma
3. Zabadani
4. Katana
5. Al Kteifeh
6. Al Qneitra
7. An Nabak
8. Homs
9. Tall Kalakh
10. Hama
11. Salamiya
12. Misyaf
13. Al Latiquiya
14. Banias
15. Jableh
16. Al Haffeh
17. Safita
18. Tartous
19. Aleppo
20. Izaz
21. Al Bab
22. Jarablus
23. Ifrin
24. Ain-el-Arab
25. Manbij
26. Idlib
27. Jisr-esh-Shaghour
28. Harem
29. Maarrat-en-Nouman
30. Al-Hasakeh
31. Ad Dijlah
32. Al Kamishli
33. Deir-ez-Zor
34. Abou Kamal
35. Al Mayadin
36. Ar-Rashid
37. As Suweida
38. Shahba
39. Salkhad
40. Dar'a
41. Izra
42. Feek

Figure 4. Residuals from regression for the i measure of the total road network.

port of Al-Latiquiya, now without any rail connections, will have a relatively high connectivity value on the projected rail network. This will increase its accessibility to the rest of the country, both to the east and to the south, and will put it in a much better position to serve the shipping movements of the country. This will also give it a strong locational advantage over the port of Tartous, which is being renovated and enlarged, as this newer port will not have a rail line linking it to the rest of the country.

The connectivity of the rail centers in the south remains quite low and especially that of Damascus, the important urban and economic center of the area. This is in contrast with the position of Aleppo, the chief rival of Damascus, whose position relative to the developing rail network is very advantageous in its accessibility to Al-Latiquiya, the country's main port, and to the important agricultural region of the northeast, where the country's largest portion of export commodities comes from.

Connectivity of Road Network

This section analyzes changes in the connectivity of the road network in Syria and in the relative importance of the connections of urban places through time. This is done by first examining the network as it existed in the early 1920's, the first decade of mod-

TABLE 2

CONNECTIVITY VALUES OF MAJOR RAIL CENTERS

Center	Total Connectivity (%)
Islahiyeh	2.08
Midan Ikbis	4.78
Aleppo	8.27
Choban Bey	5.36
Nusaybin	3.25
Al-Kamishli	2.01
Tell Kotchek	0.90
Hama	8.31
Homs	11.22
Tripoli	4.52
Rivak	10.04
Beirut	5.21
Damascus	10.33
Dar'a	8.40
Haifa	5.11
Mafrak	5.11
Bosra	5.11

TABLE 4

CONNECTIVITY VALUES OF THE MAJOR RAIL CENTERS, 1975

Center	Total Connectivity (%)
Midan Ikbis	10.12
Aleppo	15.25
Al-Latiquiya	10.12
Choban Bey	10.12
Nusaybin	1.74
Al-Kamishli	2.61
Tell Kotchek	1.74
Al Hasakeh	5.16
Deir-ez-Zor	5.14
Raqqa	13.54
Hama	13.23
Homs	4.73
Damascus	4.06
Dar'a	1.48
Bosra	0.95

TABLE 3

CONNECTIVITY OF MAJOR RAIL CENTERS, 1963

Center	Total Connectivity (%)
Midan Ikbis	16.94
Aleppo	23.95
Choban Bey	16.94
Nusaybin	1.36
Al-Kamishli	1.36
Tell Kotchek	1.36
Hama	23.95
Homs	9.92
Damascus	1.36
Dar'a	1.36
Bosra	1.36

ern transport in the country, and by analyzing the present day network, and then interpreting the changes that have taken place.

In 1920, the beginning of the modern road network in Syria began to evolve. The network existing at the time had not been designed for motor use, but was a combination of improved caravan and wagon routes. The condition of the individual roads did not differ much from one another, so that in this phase of the analysis all connections will be assigned equal weights.

The matrix of connectivity for the road network existing in 1920 is constructed, and the percentage value of the 48 individual centers under consideration is then obtained (Table 5). High connectivity values are obtained for the major urban centers of Damascus, Homs, Hama, and Aleppo, and for the intermediate points of Jisr-esh-Shaghour, Idlib, and Maarrat-en-Nouman. It also shows the importance of Palmyra, Deir-ez-Zor and Rakkah, the eastern centers located on the important routes joining Syria and Turkey to places further east, such as Iraq, Iran, and then India.

Other results show the high connectivity of the southern centers where early economic growth, especially in the field of agriculture, took place. Most of the northern and northeastern centers, where very little development had taken place, had low connectivity values as did the port cities of Jableh and Tartous, whereas the port of Al-Latiquiya showed a moderate degree of connectivity.

TABLE 5

PERCENTAGE VALUE OF CONNECTIVITY OF URBAN CENTERS, 1920

Ain Deiwar	0.006
Karatchok	0.001
Tell Kotchek	0.006
Dmir Kabou	0.028
Al-Kimishli	0.127
Al-Hasakeh	0.562
Ras-el-Ain	0.201
Abou Kamal	0.517
Deir-ez-Zor	2.306
Rakkah	4.083
Tell Abyad	0.018
Ain-el-Arab	0.078
Manbij	0.331
Jarablus	0.313
Al-Bab	1.392
Aleppo	5.564
Izaz	1.318
Ifrin	0.312
Rajou	0.070
Harem	1.248
Idlib	5.809
Jisr-esh-Shaghour	5.023
Maarrat-en-Nouman	5.809
Al-Latiquiya	1.266
Al-Haffeh	0.285
Jableh	0.332
Banias	0.210
Kadmous	0.552
Misyaf	2.253
Hama	9.458
Salamiya	6.720
Homs	7.367
Safita	0.011
Tartous	0.049
Tell Kalakh	1.650
Palmyra	9.158
Douma	5.322
Damascus	7.095
Zabadani	1.609
Sab Biar	1.609
Shahba	2.011
Suweida	2.204
Salkhad	0.125
Bosra	0.547
Dar'a	0.125
Feek	1.609
Qneitra	1.609
Sheikh Miskin	1.609

TABLE 6

PERCENTAGE VALUE OF THE CONNECTIVITY OF URBAN CENTERS, 1963

Ain Deiwar	0.021
Karatchok	0.036
Tell Kotchek	0.133
Dmir Kabou	0.139
Al-Kamishli	0.323
Al-Hasakeh	0.657
Ras-el-Ain	0.319
Abou-Kamal	0.310
Deir-ez-Zor	0.874
Rakkah	1.514
Tell Abyad	0.644
Ain-el-Arab	0.311
Manbij	0.603
Jarablus	1.719
Al-Bab	0.886
Aleppo	5.783
Izaz	0.208
Ifrin	3.180
Rajou	0.075
Harem	1.327
Idlib	2.696
Jisr-esh-Shaghour	4.732
Maarrat-en-Nouman	3.606
Al-Latiquiya	2.570
Al Haffeh	2.020
Jableh	1.963
Banias	3.731
Kadmous	3.068
Misyaf	5.529
Hama	5.999
Salamiya	2.368
Homs	8.651
Safita	4.970
Tartous	7.304
Tell Kalakh	5.542
Palmyra	1.662
Douma	2.372
Damascus	3.321
Zabadani	0.818
Sab-Biar	0.464
Shahba	1.246
Suweida	1.583
Salkhad	0.650
Bosra	0.826
Dar'a	1.013
Feek	0.144
Qneitra	1.891
Sheikh Miskin	2.023

Between 1920 and 1963 the road network of Syria developed on a national rather than regional basis. The connections considered important were widened and improved, so that by 1963 the network was composed of primary, secondary and tertiary connections.

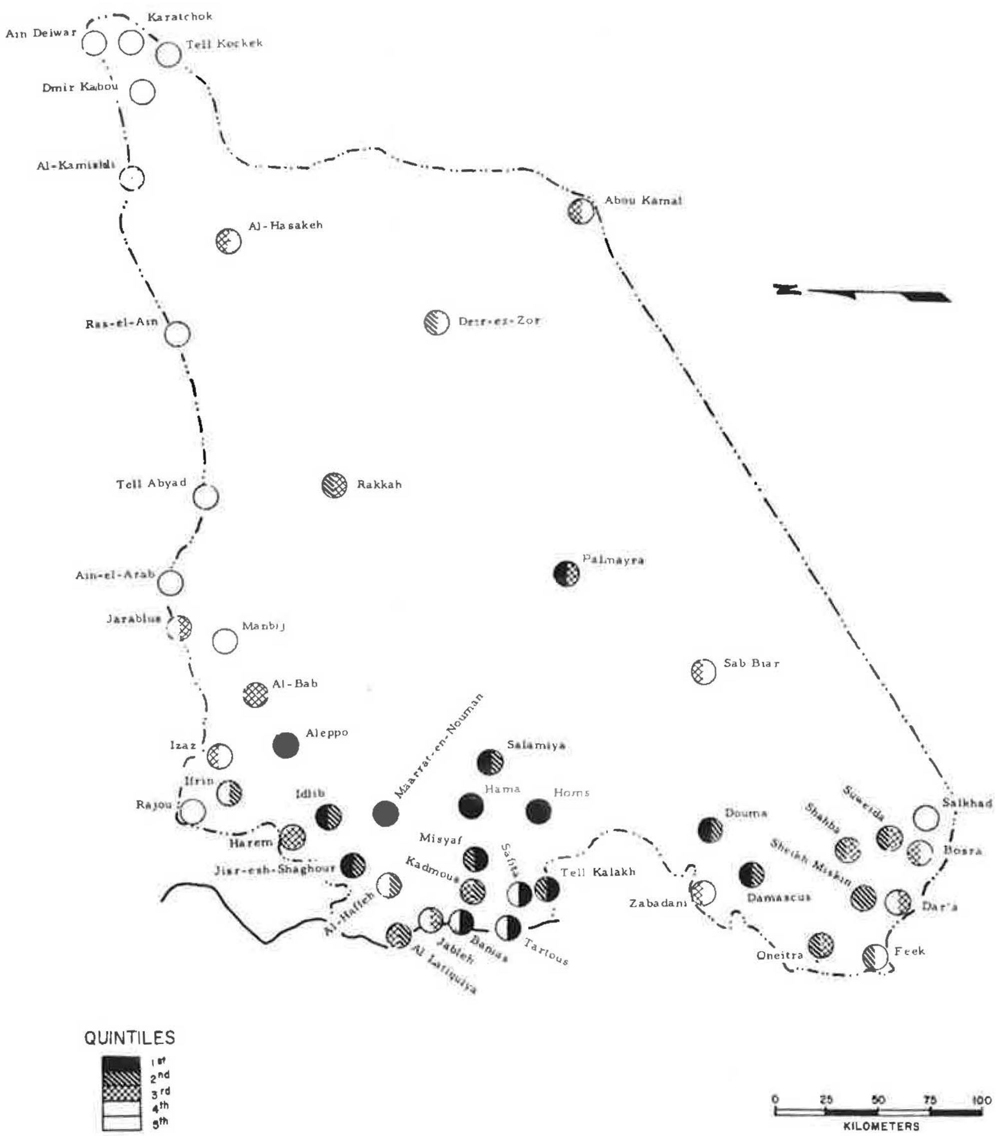


Figure 5. Connectivity value of the road network, 1920 and 1963.

In this phase of the anaylsis, weighting of roads is undertaken, so that a primary connection which is more important than a secondary or tertiary one, also has a higher index. The value assigned is done arbitrarily with a value of 3 given to a primary connection, a value of 2 given to a secondary connection, and a value of 1 given to a tertiary connection. Again the percentage values for each of the urban places is obtained (Table 6).

The first result obtained from the analysis is the large increase in the total connectivity of the network from 1920 to 1963. The second result is the fact that the connectivity of a number of urban centers increased between 1920 and 1963, whereas the connectivity index of certain other centers decreased in relative importance. This change is shown in Figure 5, where the left half of the circle shows the value of the relative weight of the center in 1920, and the right half shows the value of the relative weight of the center in 1963. One of the significant results in the analysis is the decrease in the connectivity in a large number of the urban centers in the southern part of the country, especially in the case of Damascus which went down from the first to the second quintiles. Another result shows the increase in the connectivity of the port cities of Al-Latiquiya, Jableh, Banias and Tartous, with Tartous having the highest degree of connectivity among the ports, even though Al-Latiquiya is the country's main port. Two significant facts were obtained from this information: (a) that Al-Latiquiya, which has become a busy port since its completion in 1960, handling over one million tons per year, is not as well connected to the areas that it serves as it ought to have been; and (b) the port of Tartous, in the process of being modernized and expanded, is well connected to the network, and would thus be in a relatively good position to serve the economy of the country and to provide the port of Al-Latiquiya with competition for handling the country's foreign trade.

Another result which is obtained from the analysis is that the connectivity of the eastern centers of Deir-ez-Zor, Rakkah, Abou Kamal and Palmyra decreased in the past 40 years. This is due to the fact that their early role as mid-points on transport lines linking the Mediterranean Sea to the regions further east, such as Iraq and Iran, was curbed and that they had become peripheral centers on a road network that developed on a national basis within the last two decades. The northeastern region as a whole is poorly connected to the rest of the country. This is a newly developed agricultural area where a large amount of the country's food supply, as well as most of its wheat and cotton for export, come from. Therefore, the regional urban centers where the agricultural products are gathered and then exported should become better connected to the areas of demand and to the port of export, so that speed of movement and decrease in transport cost could occur.

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Estimating Highway Benefits in Underdeveloped Countries

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•TRANSPORTATION is frequently considered an area in which new investments can substantially increase output. Underdeveloped countries need techniques to identify which of the many investment alternatives have the highest potential benefits in relation to their cost. The problem is especially acute in the case of highways because their potential benefits are notoriously difficult to measure not only before an investment is made but also afterwards. Since highway benefits cannot be sold in the marketplace as are the products from industrial investments, it is exceedingly difficult to devise methods of estimating these benefits on a basis comparable with the benefits of other investments. The importance, furthermore, of improving techniques for estimating highway benefits goes beyond the desire of underdeveloped countries to assure an efficient use of their own limited investment capital. International lending agencies such as the International Bank for Reconstruction and Development have shown their willingness to make loans for highways provided the potential borrowers can demonstrate that worthwhile projects have been selected.

The importance of estimating benefits from alternative highway investments is not limited to underdeveloped countries. Highways in the United States are constructed with funds provided by the local, state, and federal governments. At each of these levels proposed construction and improvement projects are given a critical review by those responsible for the efficient use of the taxpayers' money. Before projects are approved, the taxpayers' representatives must be convinced that the anticipated benefits are commensurate with the costs.

A substantial literature has been developed on methods of estimating benefits of investments made in highway improvements. The key criterion generally recommended in this literature is the reduction in the cost of transportation which the proposed project would permit. Although additional criteria such as accident reduction and increased comfort and convenience are also considered, the key criterion remains cost reduction, widely defined to include time and other savings for both passengers and goods.

Underdeveloped countries are immediately concerned with increasing production. Cost reduction will be an adequate measure of the benefits of a highway project only insofar as it represents accurately the real increase in production which would result from the project. The authors believe that the fundamental criterion which should be used to determine investment priorities in transportation projects is the maximization of the difference between the contribution which projects make to national income and the cost of the projects.

This paper, which examines the relationship between cost reduction and production increases attributable to a highway, maintain the following:

1. Present methods used to calculate transport cost reductions are unsound conceptually because (a) they are based on a misunderstanding of the nature of the demand curve for transport, and (b) they do not recognize the importance of the presence of a complex index number problem.
2. Transport cost reductions are not an adequate measure of the increase in production which can occur, especially in underdeveloped countries.
3. A preferable method of estimating benefits in underdeveloped countries in instances where the highway improvement has a far-reaching impact on a specific region would be to estimate directly the likely increases in production which would occur.

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COST SAVINGS APPROACH

At first sight the cost reduction criterion appears excellent. When the price paid for transport reflects the product which the resources dedicated to transport could produce in alternative employments, a technological improvement which reduces the cost of transport releases some resources and permits an increase in production in other sectors. In a situation of full employment, with mobility of resources and competition within both the transport industry and the industries which use transport, it would seem that a reduction in transport cost reflects the resulting increase in total production. In Figure 1 the vertical axis measures the cost per ton-mile of transport over a given stretch of highway. The horizontal axis measures the traffic over the highway, also measured in ton-miles. Initially, the cost per ton-mile is OA and total traffic is OX_1. The total cost of transport is therefore $OABX_1$. A relatively small investment is made to improve the highway and the cost per ton-mile falls to OC. The total cost of providing OX_1 ton-miles is now only $OCDX_1$, so that there has been a cost saving on these OX_1 ton-miles of CABD. The resources which this cost saving represents are now freed to contribute to increased production in another sector of the economy.

The investment which reduced transport costs had a second effect, also shown in Figure 1. Because transport is now relatively less expensive at the margin than other production inputs, transportation will be substituted from some other productive factors and traffic over the highway increases from OX_1 ton-miles to OX_2 ton-miles. Some of the increased traffic may also be due to the increased production in other sectors of the economy permitted by the release of resources previously dedicated to transporting OX_1 ton-miles.

Assuming that a series of additional investments is made in the highway which successively reduces the cost per ton-mile to OE, then to OF, and finally to OG, each of these cost reductions affects not only the original traffic OX_1 but also the traffic generated by previous cost reductions. Thus the reduction in cost from OC to OE is applied to the traffic OX_2 rather than to OX_1 alone, and the total cost saving on this reduction is CDHE plus DJKH. The total cost savings on the reduction in cost from OA to OG are therefore ABLG plus the sum of all the smaller rectangles within BLM. Had the investments been extremely small at each stage, the total cost saving would have been the entire area ABMG.

Highway investments are seldom made in this fashion, however. More commonly, a single investment is made which affects significantly both the cost per ton-mile and the total traffic over the highway. The present cost of transport without the proposed investment is known, as is present traffic. An estimate is made of the effect of the investment on the unit cost and a traffic projection is made to take into account the traffic likely to be generated. Thus, only two points are known on the demand curve for transport: the points B and M (Fig. 1). Neither is the precise shape of the demand curve between these two points known with any certainty, so that usually the best that can be done is to assume that the increments in traffic between OX_1 and OX_5 are generated in proportion to the reductions in unit cost. Graphically, this assump-

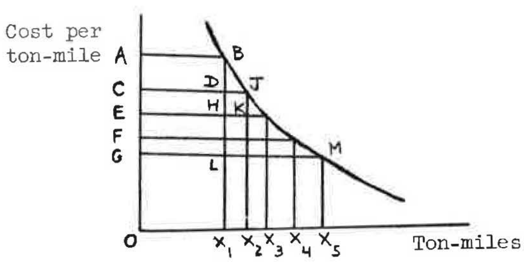


Figure 1. Transportation per ton-mile.

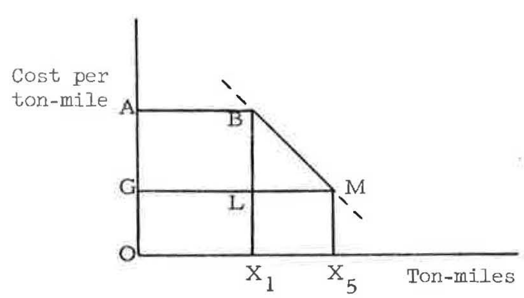


Figure 2. Effect of investment on unit cost.

tion amounts to assuming that the demand curve between points B and M is a straight line (Fig. 2).

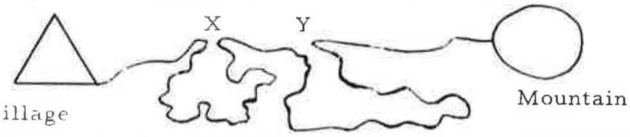
On the basis of the information in Figure 2 and the reasoning discussed, the total benefits of an investment which reduces the unit cost from OA to OG is expressed as the sum of two cost savings. On the original traffic, OX_1 ton-miles, the saving is ABLG and on the generated traffic, OX_5-OX_1 ton-miles, the saving is approximated by BLM, giving total savings or benefits of ABMG. These savings, in turn, represent resources which can now produce an equivalent value in new production elsewhere in the economy.

CRITIQUE OF COST SAVINGS METHOD

The logic of the technique presently used in estimating highway benefits appears straightforward and entirely reasonable. To evaluate its application, let us devise an imaginary arithmetical example in which an investment is made to reduce the cost of transport.

Imagine an isolated Indian village in which there are 20 workers who can devote their time to picking berries or to hunting rabbits. If a worker picks berries, which are found around the village, he can gather 12 baskets in a day. If he hunts, the same worker can capture 12 rabbits in a day. The rabbits, however, are found only on a nearby mountain, and the round-trip to and from the mountain takes three days. The total time required to obtain 12 rabbits is therefore four days, assuming that a worker can carry only 12 rabbits when he returns from the mountain.

From the following sketch it can be seen that there are two narrow points on the trail to the mountain, marked X and Y, which if they could be crossed would reduce



appreciably the time required to transport rabbits. Assume that bridges could be built across these points and that with the bridges the round-trip to and from the mountain would require only one day. Thus, with the bridges, the total time required to obtain 12 rabbits would only be two days.

With these assumptions, it is now possible to present graphically the production alternatives available to the village with and without the bridges. Without the bridges, if the village dedicates all the time of its workers to berry picking, daily production would be 240 baskets. If all the time of the workers were dedicated to obtaining rabbits, daily production would be 60 rabbits. With the bridges, the maximum possible daily production of berries does not change, as it still requires a full man-day to pick 12 baskets. The bridges, however, double the maximum number of rabbits available to the village, as now only 2 man-days are required to obtain 12 rabbits instead of 4 man-days without the bridges. Since we have assumed that there are no economies of scale either in berry picking or in obtaining rabbits, i.e., that the cost in man-days of these activities is constant whatever the amount of berries gathered or rabbits obtained, the combinations of berries and rabbits which the village can acquire are given by a straight line which connects the two maximum points. Thus, in Figure 3 line PS shows all the combinations of rabbits and berries which the village could produce without the bridges, and line PT shows the production alternatives with the bridges. An additional assumption which permits us to draw straight-

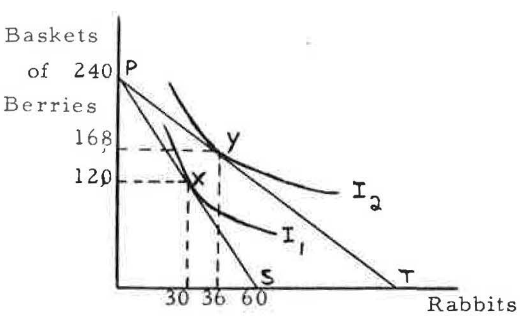


Figure 3. Village production with and without bridges.

line production possibility curves is that workers can be interchanged indiscriminately in any of the three productive processes, berry picking, rabbit hunting, and transport, with no change in productivity. In other words, the only productive input, labor, is entirely homogeneous. Finally, it is also assumed in drawing continuous curves that the labor input is finely divisible.

The actual distribution of the village's workers among the different productive processes is determined by the relative desire of the villagers for berries instead of rabbits. These relative preferences can be shown graphically through the use of indifference curves, two of which are shown in Figure 3, I_1 and I_2. The point of tangency between the production possibility curve and the highest accessible indifference curve shows how the village has decided to distribute its productive resources. Thus, without the bridges the village dedicates 10 men to picking berries, thus obtaining 120 baskets daily, and dedicates the remaining 10 men to hunting and transporting rabbits, thereby obtaining 30 rabbits. With the bridges, the production of both berries and rabbits increases, as now 14 workers gather a total of 168 baskets of berries while 6 men hunt and transport 36 rabbits. The change in total production (and consumption) of the village is summarized in Table 1.

Using this knowledge of the real increase in village production brought about by the construction of the bridges, let us see if this total benefit from an analysis of the demand curve for transport could have been predicted. Suppose that at the cost of transport without the bridges (3 man-days for each 12 rabbits), 30 rabbits are transported. Suppose also that 36 rabbits will be transported with the bridges when the cost of transport is only 1 man-day for each 12 rabbits. This information yields two points on the demand curve for transport, points B and E (Fig. 4). We do not, however, have information regarding the shape of the demand curve between these two points. Therefore, it can only be assumed that the real demand curve is best approximated by a straight line which connects B and E.

From the analysis at the beginning of this paper, it can be concluded that the benefits from the bridges are represented by the area ABEC, as this area shows the total transport cost saving brought about by the bridges. This cost saving has two components: the area ABDC represents the saving on the transport of the 30 rabbits which are produced without the bridges, and the area BED represents the saving on the generated traffic of 6 rabbits. It is clear from Figure 4 that the area ABDC is equal to 5 man-days, and that the area of BED, which is one-half of BHED, is equal to $\frac{1}{2}$ man-day. The total cost saving (or resources released) is thus $5\frac{1}{2}$ man-days.

Is this cost saving equal to the increase in village production given in Table 1? This question can only be answered by first specifying whether the observed increase in village production, 48 baskets of berries and 6 rabbits, is to be expressed in man-days using the production possibilities which existed before the bridges were built or those after they were built. To produce 48 baskets of berries and 6 rabbits before the bridges were built would have required 6 man-days: 4 man-days for the berries, $\frac{1}{2}$ man-day to hunt the rabbits, and $1\frac{1}{2}$ man-days to transport the rabbits. After the bridges were built, however, only 5 man-days are required: 4 man-days to gather the berries, $\frac{1}{2}$ man-day to hunt the rabbits, and $\frac{1}{2}$ man-day to transport the rabbits.

Thus it can be said that the increase in village income is equal to either 5 man-days or 6 man-days, depending on the point of reference. The cost saving derived from the demand curve for transport (Fig. 4), however, is not equal to either; there the cost saving was found to be $5\frac{1}{2}$ man-days. If we wish to express the increase in village income using the production possibilities after the bridges are built, we should have considered only the rectangle ABDC, which is the quantity of rabbits transported before the bridges were built

TABLE 1

VILLAGE PRODUCTION

Bridges	Berries	Rabbits
Without	120	30
With	168	36
Increase	48	6

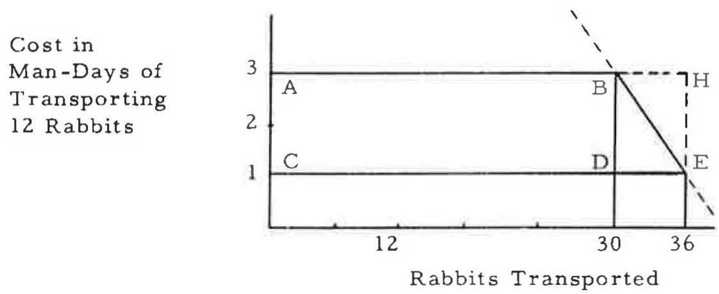


Figure 4. Rabbit production with and without bridges.

times the transport cost saving. On the other hand, if we wish to show the increase in village income in terms of resource requirements before the bridges were built, we should have multiplied the transport cost saving times the number of rabbits transported after the bridges were built, shown by the larger rectangle AHEC. The triangle BED is only some kind of fuzzy average between two clearly defined alternatives.

INDEX NUMBER PROBLEM

An index number problem familiar in economic analysis has been described. Something has been introduced in the economy which changes relative prices of different commodities and introduces ambiguity when the new situation is compared with the previous one. The way in which the problem has arisen here can be made clearer, perhaps, if we retrace some of the previous steps and introduce prices explicitly instead of measuring benefits and transport cost savings in terms of man-hours.

TABLE 2

INCREASE IN VILLAGE INCOME RELATED TO BRIDGES

Bridges	Production		Price of Rabbits in Berries	Village Income (in berries) at	
	Berries	Rabbits		Prices without Bridges	Prices with Bridges
Without	120	30	4	240	180
With	168	36	2	312	240
Increase	48	6		72	60

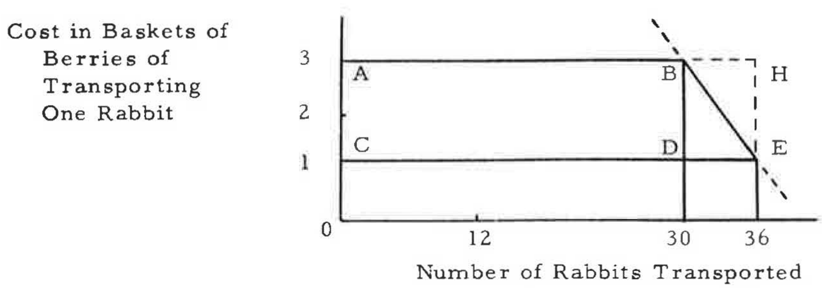


Figure 5. Number of rabbits transported vs cost of transport in terms of berries.

Referring to Figure 3, since it is assumed in this simple model that the production possibility curves are linear both with and without the bridges, so long as both products are produced the price of rabbits in terms of berries without the bridges must be 4 baskets of berries. With the bridges, the price of rabbits must be 2 baskets of berries. Regardless of the relative desire of the villagers for rabbits and berries, these prices cannot change. Thus there is no problem in pricing the increase in village production given in Table 1 using prices which exist without the bridges and prices with the bridges, as indicated in Table 2.

The data in Figure 4 can now be used to relate the number of rabbits transported to the cost of transport expressed in terms of berries (Fig. 5).

Table 2 indicates that the increase in village income expressed in prices with the bridges is equal to 60 baskets of berries. This is equal to the cost saving on the rabbits transported without the bridges, the area ABDC. Similarly, the increase in village income expressed in prices without the bridges is 72 baskets of berries, which in Figure 5 is equal to the larger rectangle AHEC. In summary, on the basis of this arithmetical example, it could be concluded that the choice of the rectangle selected as a measure of the benefits of the highway improvement depends on whether the increase in income is expressed in prices without the improvement or in prices with the improvement.

Before attempting to generalize on the basis of the example already presented, let us take a final look at the triangle BED in Figure 5, traditionally considered to be the transport cost saving on generated traffic. Because present techniques commonly consider this triangle as part of the benefits of highway investments, it is worthwhile to explore further whether the triangle has any economic significance. Although few practitioners will be willing to abandon present techniques solely on the baiss of some rabbits and berries, we shall continue to use this simplified arithmetical example since it serves to clarify the basic problem.

Two new assumptions are now added to the others previously introduced. First, instead of building the two bridges simultaneously, the villagers build first one bridge and then sometime later the second bridge. Each bridge independently reduces the round-trip time to the mountain by one day. Thus without either bridge, the maximum number of rabbits that can be obtained is 60, as was previously assumed. With only one bridge in place, the maximum number of rabbits is increased to 80, as a total of three days is required to hunt and transport 12 rabbits. With both bridges in place, the maximum number of rabbits increases to 120, as also was previously assumed.

Second, we now assume that the village always produces the maximum number of rabbits possible. Although the alternative of picking berries exists, it is not used. Thus, with no bridge the village produces 60 rabbits, with one bridge 80 rabbits, and with both bridges, 120 rabbits. These two additional assumptions are shown in Figure 6.

The demand curve for transport given these new assumptions can also be presented without difficulty (Fig. 7).

The benefits from the construction of the bridges will be expressed in terms of man-days with the alternatives available when the bridges exist. With the construction

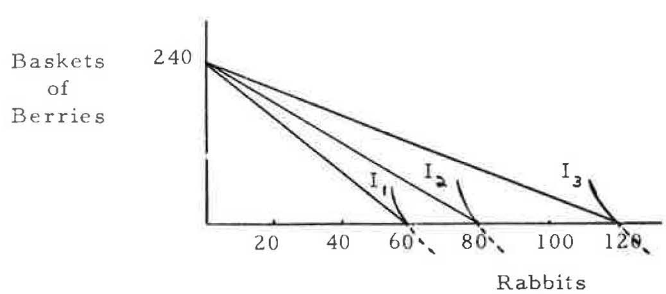


Figure 6. Number of rabbits produced vs number of bridges.

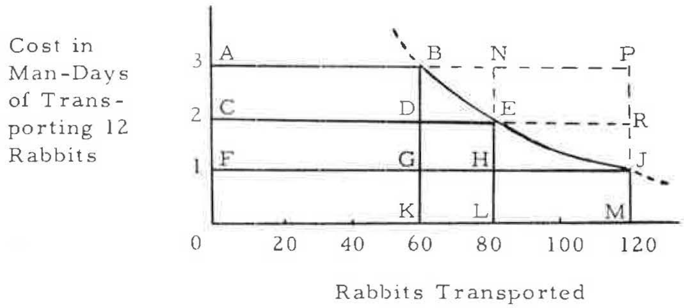


Figure 7. Demand curve for transport.

of the first bridge, the cost of transport falls from OA to OC. The benefit attributable to the bridge is shown by the area ABDC, which is equal to 5 man-days. Of these 5 man-days, the village assigns $1\frac{2}{3}$ man-days to hunting and $3\frac{1}{3}$ man-days to transporting the 20 additional rabbits at the new transport cost OC.

The construction of the second bridge lowers the cost of transport still further, from OC to OF. The benefits from the second bridge are the transport cost savings on the transport of 80 rabbits, shown by the area CEHF, which is equal to $6\frac{2}{3}$ man-days. The village assigns the released resources in accord with its preferences and the production opportunities available with the new cost of transport, OF. Thus $3\frac{1}{3}$ man-days are dedicated to hunting an additional 40 rabbits and $3\frac{1}{3}$ man-days are absorbed in the transport of the new production.

What then are the total benefits which have resulted from the construction of the two bridges measured in man-days using the production possibilities available when both bridges exist? Presumably they are the sum of the benefits from the bridges taken separately: 5 man-days from the first bridge and $6\frac{2}{3}$ man-days from the second, giving a total of $11\frac{2}{3}$ man-days. This total transport cost saving is represented by the area ABDEHF. We have explicitly excluded the triangles BDE and EHJ and have included at each step solely the transport cost saving on the transport which took place before the transport improvement.

If the situation which existed without either bridge, when 60 rabbits were produced, is compared with the situation which exists with both bridges, when 120 rabbits are produced, it is clear that the total increase in production resulting from the construction of the bridges is 60 rabbits. The man-day equivalent of these 60 rabbits when both bridges are available is only 10 man-days. Since the analysis of the transport cost savings led us to believe that the total benefits were the equivalent of $11\frac{2}{3}$ man-days, we have overestimated the benefits. Somewhere, it appears, we have counted the same benefit twice.

Figure 7 compares the original situation, when the cost of transport was OA, with the situation with both bridges, when the cost of transport is OF. From this point of view it is clear that a part of the triangle BJG, specifically the rectangle DEHG, whose area is exactly $1\frac{2}{3}$ man-days, has been included as a benefit. This area represents a benefit when the situation with one bridge is compared with the situation with two bridges, but it does not represent a benefit when the situation with no bridges is compared with that when both bridges exist, because this benefit has already been included in the area ABDC. The total cost savings resulting from the construction of the two bridges is only 10 man-days, represented by the area ABGF. Part of these savings, 5 man-days, are dedicated to transporting the additional 60 rabbits, shown by the area GJMK, and the remaining 5 man-days are now dedicated to rabbit-hunting.

Had we expressed the benefits from the two bridges in man-days based on the production possibilities which existed before either bridge was built, the benefits would be equal to 20 man-days, as only by doubling the work force could the village have doubled its production from 60 to 120 rabbits. These total benefits are represented in Figure 7 by the area APJF.

It seems clear that benefit analysis does not need to consider areas under demand curves for transport. Highway benefit analysis has been based on the theory of Marshallian partial equilibrium demand curves in instances where the theory cannot meaningfully be applied. The curve BEJ in Figure 7 is not a traditional demand curve in which one variable changes, the price of the product, whereas all other prices and income remain constant. The curve BEJ is a long-run equilibrium curve which relates the cost of transport to the demand for transport once all the variables in the economy have been adjusted to reach a new equilibrium. Specifically, the curve reflects substantial and significant changes in village income at each point. Although it is meaningful to compare two situations on the curve, such as comparing ABKO and FJMO, it is not meaningful to move along the curve and to sum up areas under it which correspond to several points, because each point corresponds to a brand new world. We can compare these two worlds, but we cannot combine them. Once we leave one point on the curve and move to another, the first point disappears.

Present techniques which include the triangle under the demand curve in estimating highway benefits represent an inappropriate and dangerous way of evading a complex index number problem. Many highway investments in underdeveloped countries affect radically the economy of the regions through which the highways pass and of the centers which the highways connect. Incomes may be increased greatly and relative price changes of different products can be large, leading to substantial shifts in the production and consumption patterns. Estimates of highway benefits based on earlier relative prices can differ widely from estimates based on prices after the investments are made. It is essential to recognize the existence of this index number problem and to confront it directly, determining the extent of the difference between the two estimates. The problem should not be hidden by using some vague average estimate which results when the triangle under the demand curve is considered as a benefit. Traditional techniques are not always applicable in underdeveloped countries; new techniques must be devised which are consistent with the nature of these economies.

A MORE GENERAL MODEL OF HIGHWAY BENEFITS

The conclusions of the previous section can be shown more clearly by using a more generalized algebraic model. The point of departure will be the two linear production possibilities curves showing the alternatives open to the village with and without the bridges used in the previous arithmetical example. The equation for the production possibilities curve without the bridges based on Figure 3 is

$$240 = A_1 + 4 B_1 \qquad (1)$$

where A_1 represents the baskets of berries which can be produced and B_1 is the number of rabbits which can be obtained. The construction of the bridges has the effect of increasing the number of obtainable rabbits without affecting the maximum number of berries. Thus the equation for the production possibilities curve with the bridges is

$$240 = A_2 + 2 B_2 \qquad (2)$$

To avoid restricting the model to the limiting assumptions and particular numbers used in the arithmetical example, it is preferable to use more generalized equations to represent the production possibilities curves with and without the bridges. Eq. 3 is the equation for the situation without the bridges and Eq. 4 corresponds to the situation with the bridges:

$$k_1 = a_1A_1 + b_1B_1 \qquad (3)$$

$$k_2 = a_2A_2 + b_2B_2 \qquad (4)$$

where k_1, a_1, and b_1 are constants.

Village income can also be expressed in algebraic form by introducing prices:

$$VI_1 = P_{A1}A_1 + P_{B1}B_1 \tag{5}$$

$$VI_2 = P_{A2}A_2 + P_{B2}B_2 \tag{6}$$

In Eq. 5 the village income without the bridges is expressed in terms of current prices, i.e., the prices existing without the bridges; in Eq. 6 the village income with the bridges is expressed in prices which exist with the bridges. To calculate the increase in village income which the construction of the bridges permits, however, it is necessary to use a fixed set of prices, either those which exist without the bridges or those with the bridges. The analysis will first be carried through using the prices which exist with the bridges, so Eq. 5 can be written using these prices:

$$VI^2{}_1 = P_{A2}A_1 + P_{B2}B_1 \tag{7}$$

Since this is a general equilibrium model based on only two products, the price of one of the products can be used as a numeraire and the village income can be expressed in terms of this product. This was done in the arithmetical example in Table 2 which gives both village income and the price of rabbits in terms of berries. Thus, Eqs. 6 and 7 are divided by P_{A2} (although they also could have been divided by P_{B2}):

$$\frac{VI_2}{P_{A2}} = A_2 + \frac{P_{B2}}{P_{A2}} B_2 \tag{8}$$

$$\frac{VI^2{}_1}{P_{A2}} = A_1 + \frac{P_{B2}}{P_{A2}} B_1 \tag{9}$$

Next, to show what village income was before and after the bridges were built, substitute the value of A_2 given by Eq. 4 into Eq. 8 and the value of A_1 given by Eq. 3 into Eq. 9:

$$\frac{VI_2}{P_{A2}} = \frac{k_2 - b_2B_2}{a_2} + \frac{P_{B2}}{P_{A2}} B_2 \tag{10}$$

$$\frac{VI^2{}_1}{P_{A2}} = \frac{k_1 - b_1B_1}{a_1} + \frac{P_{B2}}{P_{A2}} B_1 \tag{11}$$

To find the increase in village income, expressed in prices which exist with the bridges, Eq. 11 is subtracted from Eq. 10

$$\frac{VI_2}{P_{A2}} - \frac{VI^2{}_1}{P_{A2}} = \frac{k_2 - b_2B_2}{a_2} + \frac{P_{B2}}{P_{A2}} B_2 - \frac{k_1 - b_1B_1}{a_1} - \frac{P_{B2}}{P_{A2}} B_1 \tag{12}$$

The relative prices of the two products are determined by the negative reciprocal slope of the production possibilities curve at the particular point in question, or, more exactly:

$$-\frac{dA_2}{dB_2} = \frac{P_{B2}}{P_{A2}} \tag{13}$$

From Eq. 4, then,

$$\frac{P_{B2}}{P_{A2}} = \frac{b_2}{a_2} \tag{14}$$

Since a linear production possibilities curve is used in this model, the slope and, therefore, the ratio of prices remain constant at any point on the given curve.

When Eq. 14 is substituted into Eq. 12 and the terms are rearranged, we obtain:

$$\frac{VI_2}{P_{A2}} - \frac{VI^2_1}{P_{A2}} = \left(\frac{k_2}{a_2} - \frac{k_1}{a_1}\right) + B_1\left(\frac{b_1}{a_1} - \frac{b_2}{a_2}\right) \tag{15}$$

Similarly, had the entire analysis been made using prices existing without the bridges, the increase in village income would have been

$$\frac{VI^1_2}{P_{A1}} - \frac{VI_1}{P_{A1}} = \left(\frac{k_2}{a_2} - \frac{k_1}{a_1}\right) + B_2\left(\frac{b_1}{a_1} - \frac{b_2}{a_2}\right) \tag{16}$$

In the example showing the effect of the construction of bridges on the village income, $k_1 = k_2$ and $a_1 = a_2 = 1$, so that Eqs. 15 and 16 (see Fig. 4) become:

$$\frac{VI_2}{P_{A2}} - \frac{VI^2_1}{P_{A2}} = B_1 (b_1 - b_2) \tag{17}$$

$$\frac{VI^1_2}{P_{A1}} - \frac{VI_1}{P_{A1}} = B_2 (b_1 - b_2) \tag{18}$$

Since $(b_1 - b_2)$ represents the reduction of the cost of transporting rabbits and since the entire production of rabbits is transported, it was possible to determine the increase in village income solely on the basis of the total transport cost saving. But only in this simplest, and least realistic, model does it appear, from Eqs. 15 and 16, that the increase in production permitted by a highway investment can be determined solely on the basis of the transport cost saving.

A geometric demonstration may aid in the interpretation of Eqs. 15 and 16 (1). In Figures 8a and b it is assumed that without an investment in transport the production possibilities curve is represented by the line AB and that output occurs at some point N_1 representing a particular mix or composite of the two outputs OA_1 of good A and OB_1 of good B. The effect of the transport improvement is to shift the production possibilities curve to CD, and a new output level and mix is obtained at point N_2, which specifies an output of OA_2 units of A and OB_2 units of B. It is desired to calculate the increase in income which the transport improvement permits.

In Figure 8a, which corresponds to Eq. 16, the increase in income is to be measured in terms of the relative prices existing in period 1, i.e., before the transport improvement. The relative prices of the products are given by equations similar to Eqs. 13 and 14. These relative prices reflect technical coefficients of production, specifically the rate of product transformation, or the amount of one good which must be sacrificed to produce one more unit of the other good.

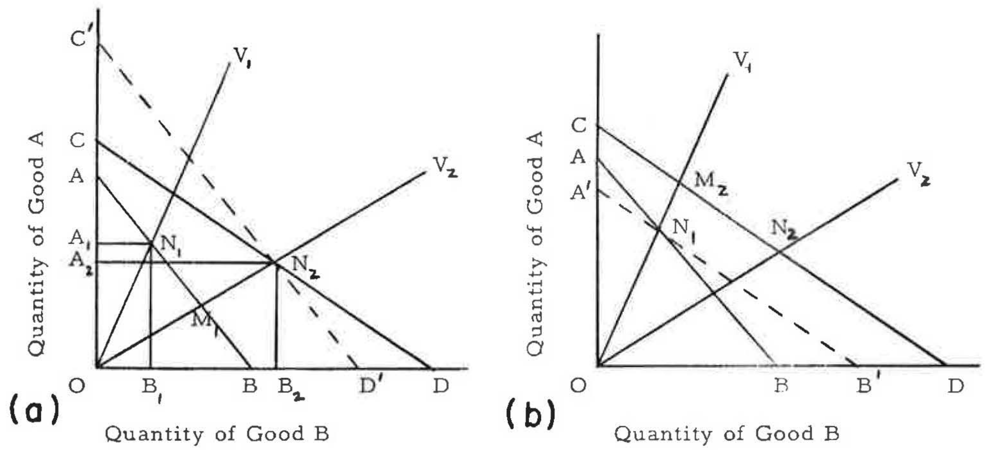


Figure 8. Production possibility curves.

Original (i.e., period 1) output valued in original prices is given by line AB, as $\frac{\Sigma p_1 q_1}{P_{A1}} = A_1 + \frac{P_{B1}}{P_{A1}} B_1$. A line C′D′ parallel to line AB is drawn through N_2, the point of production in the period 2 situation. This line represents valuation of the period 2 output in terms of period 1 relative prices, or $\frac{\Sigma p_1 q_1}{P_{A1}} = A_2 + \frac{P_{B1}}{P_{A1}} B_2$. The distance A_2C represents the valuation of period 2 output of good B at period 2 prices, while the distance A_2C' represents the valuation of that same output in period 1 prices. The difference, CC′, represents the effect of the change in the rate of product transformation brought about as a result of the transport improvement and was expressed $B_2\left(\frac{b_1}{a_1} - \frac{b_2}{a_2}\right)$ in Eq. 16.

Similarly, the distance AC represents the increase in potential output of good A (which can always be transformed into good B) shown in Eq. 16 by the term $\left(\frac{k_2}{a_2} - \frac{k_1}{a_1}\right)$.

The combined expressions may be interpreted to mean that it would have been necessary to have had additional resource capacity equal to AC′ in the old situation to have been able to have produced output mix N_2 with the original technological coefficients without the bridges.

This interpretation can also be read directly from Figure 8a: the ray OV_2 represents different volumes of output of the particular product mix in the fixed proportions between goods A and B given by point ON_2. The ratio $\frac{ON_2}{OM_1}$ is an exact measure of the increase capability of the economy to produce output in those proportions. This is, of course, precisely equal to the ratio of C′D′ to AB, or $\frac{\Sigma p_1 q_2}{\Sigma p_1 q_1}$.

The converse case is shown in Figure 8b, which corresponds to Eq. 15, where constant period 2 prices are used instead of period 1 prices. A line A′ B′ parallel to line CD is drawn through the original production point N_1. The distance AA′ corresponds to the term $B_1 \left(\frac{b_1}{a_1} - \frac{b_2}{a_2} \right)$ in Eq. 15 and the distance AC to the term $\frac{k_2}{a_2} - \frac{k_1}{a_1}$. Together they represent the increase in the capability of the economy to produce in period 2 the output mix which the economy produced in period 1. This increase in productive capability is brought about by, but is not restricted to, the improvements in transport. The general measure of the capability to produce output mix N_1 is read directly from the ray OV_1 as the ratio $\frac{OM_2}{ON_1}$, which conforms to the ratio $\frac{CD}{A'B'}$.

Thus the two estimates shown in Figure 8a and b of the benefits of a highway investment which shifts the production possibility curve from AB to CD are answers to two different questions. The question asked in Figure 8a (and Eq. 16) refers to the productive capacity which the economy would have to have had before the transport investment to have produced the output mix which was produced after the investment. Figure 8b (and Eq. 15) on the other hand, refer to the increased capacity of the economy to produce after the transport investment the output mix which was produced before the investment. The decision as to which of these questions should be used to determine investment priorities in transport must be made by the planning agency of each country. The important point is that the two questions must be kept explicit so that it is always known which question has been answered. Present techniques for evaluating highway benefits that consider areas under demand curves and that frequently are not clear about which relative prices are being used do not answer either question.

EXTERNAL EFFECTS OF HIGHWAY INVESTMENTS

Even though technicians might be successful in predicting relative price changes and future traffic over a proposed transport facility, there are more fundamental objections to using transport cost savings as an estimate of the increased production which the investment would permit. The real world does not have a single homogeneous factor of production (as the workers in the Indian village) which is always fully employed. Furthermore, the transport investment may lead to changes in the production of goods which do not use the transport facility. An important effect of the transport improvement may be to result in an overall outward shift of the production possibility curve, reflected in the expression $\frac{k_2}{a_2} - \frac{k_1}{a_1}$ in Eqs. 15 and 16. This effect may well be the most important result of penetration or development roads in rural areas.

The importance of these external effects can be illustrated by returning briefly to our Indian village. Suppose that, in addition to the alternatives of berry picking and rabbit hunting, the 20 village workers could also be used to catch fish. Suppose that before the bridges are built a worker can catch four fish in a day in a stream near the village and that the fish thus need not be transported any appreciable distance. A secondary effect of constructing the bridges, however, is to raise the water level of the stream, so that when the bridges are in place, each worker can catch 12 fish in a day.

Suppose also that in addition to the 20 workers in the village there are two old men who are too arthritic to pick berries, too old to hunt rabbits, and allergic to the cold water of the fishing stream. Without the bridges they cannot aid in transport, either, because the three-day walk is too far. If the bridges are built, however, they can make a daily trip to the mountain and each can bring back 12 rabbits caught by one of the other village workers.

TABLE 3

PRODUCTION AND VILLAGE INCOME WITH AND WITHOUT BRIDGES

Bridges	Production			Prices in Berries of		Village Income at	
	Berries	Rabbits	Fish	Rabbits	Fish	Prices Without Bridges	Prices With Bridges
Without	96	30	8	4	3	240	164
With	144	36	48	2	1	432	264
Increase	48	6	40			192	100

Before the bridges are built, the 2 old men can do nothing to help, and the village assigns 8 of its workers to picking berries, 10 workers to hunting and transporting rabbits, and 2 workers to catching fish. With the bridges, however, the 2 old men can now transport rabbits, and the village assigns them plus 4 workers to hunting and transporting rabbits, 12 workers to berry picking and 4 workers to fishing. The production and village income with and without the bridges under these new assumptions are indicated in Table 3. Both income and prices are expressed in terms of baskets of berries.

Because of the significance of the relative price changes which have occurred, the increase in village income expressed in prices without the bridges is nearly twice as large as the increase measured in prices with the bridges. More importantly, it is clear that no analysis of the demand curve for transport could have led us to expect such a substantial increase in village income measured in either set of prices. Since only rabbits are transported, the demand curve for transport is the same as under the original assumptions (Fig. 5). No juggling of the demand for the transport of rabbits shown in that figure will permit us to estimate the increase in village income. When the impact of a transport investment is far-reaching, serious errors may occur if the increase in production is estimated solely on the basis of traffic over the new facility.

This conclusion is also clear when the two-commodity model developed in Eqs. 3-16 is generalized somewhat further so as to incorporate all commodities, whether or not they are transported, while still retaining the linearity of the original model. In this case the production possibility surface without the proposed transport investment is

$$k_1 = a_1A_1 + b_1B_1 + c_1C_1 + \dots + x_1X_1 \qquad (19)$$

and the production possibility curve with the investment is

$$k_2 = a_2A_2 + b_2B_2 + c_2C_2 + \dots + x_2X_2 \qquad (20)$$

analogous to Eqs. 3 and 4. The resulting equations for the change in real income, which are again completely analogous to Eqs. 15 and 16, are given by

$$\frac{VI_2}{P_{A2}} - \frac{VI^2_1}{P_{A2}} = \left(\frac{k_2}{a_2} - \frac{k_1}{a_1}\right) + B_1\left(\frac{b_1}{a_1} - \frac{b_2}{a_2}\right) + C_1\left(\frac{c_1}{a_1} - \frac{c_2}{a_2}\right) + \dots + X_1\left(\frac{x_1}{a_1} - \frac{x_2}{a_2}\right) \qquad (21)$$

$$\frac{VI^1_2}{P_{A1}} - \frac{VI_1}{P_{A1}} = \left(\frac{k_2}{a_2} - \frac{k_1}{a_1}\right) + B_2\left(\frac{b_1}{a_1} - \frac{b_2}{a_2}\right) + C_2\left(\frac{c_1}{a_1} - \frac{c_2}{a_2}\right) + \dots + X_2\left(\frac{x_1}{a_1} - \frac{x_2}{a_2}\right) \qquad (22)$$

The changes in the productive coefficients represented by the expressions $\left(\frac{b_1}{a_1} - \frac{b_2}{a_2}\right)$, etc., reflect more than just reductions in transport costs, since many of the goods may not be transported over the particular facility. These changes reflect economies of scale and other technological factors, some positive and others negative, which result directly or indirectly from the transport improvement. An accurate estimate of the increase in real income which occurs when a transport investment is made must take into account the changes in the production of all goods, not just those using the transport facility.

NATIONAL INCOME APPROACH TO ESTIMATING HIGHWAY BENEFITS

This paper has criticized the traditional techniques used to measure the benefits of highway investments as being inappropriate in many instances for application in underdeveloped countries. Highway investments in those economies frequently have a far-reaching impact on both incomes and relative prices in the regions where the investments are made. Dramatic changes can occur when penetration and feeder roads are constructed or when previously isolated communities are brought into the national market economy. In these circumstances the transport cost savings permitted by the highway investment, even when correctly calculated so as to take into account relative price changes, are an inadequate criterion for measuring the benefits of the investment. Investment priorities which are determined on the basis of this overly narrow criterion may well lead to carrying out projects which make a relatively small contribution to increasing real income while better projects are overlooked.

A preferable criterion would go to the heart of the problem of allocating scarce capital resources and would determine which of the proposed transport projects would make the greatest contribution to real income in relation to the cost of the projects. The application of this criterion requires an analysis of possible changes in the production of all goods and services which might result from the proposed investment. It thus goes well beyond present techniques which are concerned solely with goods which would be transported over a proposed transport facility.

The national income approach to estimating highway benefits cannot be presented here in detail (a manual for the application of the national income approach is being prepared under the Transport Research Program of the Brookings Institution), but a few of the more important aspects can be indicated. In the first place, this approach focuses on the region which the proposed transport project would serve rather than on the project alone. An economic analysis is made of the region so as to determine its productive potential, based on its natural and human resources. Present and prospective markets are studied to see if there will be a demand for the goods which the region could produce. The investment plans of both the government and private sector are examined. Using the estimates prepared by the transport experts of the possible reductions in transport costs which the proposed project would permit, agricultural, forestry, mineral, and industrial experts estimate the changes in the output of each commodity, and its market value, which could be expected to result from the proposed transport investment. All of these elements interact and each affects the others, so that frequently the analysis consists of successive approximations toward a final estimate of the increase in gross production which is likely to occur.

The national income approach takes into account explicitly the fact that all increases in the region's output will not be due solely to the investments made in transport. For production to increase, investments will also be required in other sectors, such as in irrigation, to give just one example. Planners will frequently discover that they are not evaluating an isolated transport investment but rather a package of complementary investments in several different sectors. The investment decision then becomes one of selecting the best among different investment packages so as to make the greatest contribution to real income in relation to the cost of the package.

This gross estimate of the increase in production does not yet represent an actual increase in real national income. Adjustments must be made to net out purchases of each industry from other industries to avoid double counting the same outputs, and care must be taken to net out the transfers of labor and capital from other regions of the country where they would have contributed to the national income in any case. If the new investments are likely to bring about changes in the goods produced, as will occur if the agricultural sector shifts from subsistence agriculture to production of cash crops for market, the value of production under the old system must also be subtracted.

Projections must of course be made of the traffic which is likely to use the proposed transport facility, as these will determine the technological characteristics and design of the transport project. These projections are also essential to determine that not only is the proposed project economically justified but that it also is the best way to meet the region's transport requirements.

Clearly there are many problems in using the national income approach, and frequently the estimates made will be subject to a substantial margin of error. But it is essential that the transport planner use a methodology with a sound theoretical foundation. As this paper has attempted to demonstrate, in instances where a transport investment can be expected to have a significant effect on the regional or national economy, traditional techniques of estimating benefits which examine solely transport savings are without conceptual foundation and can be seriously misleading. Whatever the difficulties of using the alternative national income approach, it is clearly preferable if highway investments are to contribute to economic development.

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Economic Analysis of Highway Design in Developing Countries

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This paper deals with the selection of road transport technology for developing countries. By technology we mean a specific combination of such productive factors as labor, capital, and energy. The most efficient technology in one country such as the United States or Canada may not be the same as in another characterized by capital scarcity and the abundance of unskilled labor. In designing transportation facilities for underdeveloped countries, therefore, engineers should consider the whole range of technology available for producing transportation.

A framework for analyzing the choice of technology possible in producing a given output of transportation is formulated. By borrowing certain economic concepts such as the production function, it is possible to determine the degree to which expenditures on labor may be substituted for capital expenditures in producing a given output of road transportation. This framework is then used to determine the optimal combination of productive factors—that is, the best road design or choice of technology for a given set of conditions. In practical terms, this means finding the best trade-off among capital costs, road-user costs, and road maintenance costs under varying conditions of unemployment, interest rates, and foreign exchange rates.

A case study based on the author's research in Venezuela is presented to illustrate the data requirements for the suggested method of analysis. The example illustrates the usefulness of relatively scant cost information in making rational economic decisions. Using regression techniques, for example, estimating equations are derived which relate the cost of road construction to design standards for two types of terrain conditions. Road user cost data and maintenance cost data based on limited statistical information are also presented. In all cases, data are presented so as to permit determination of the labor, local capital, and foreign exchange components of each cost. The sensitivity of road investment decisions to change in both foreign exchange rates and labor costs is also illustrated by an example.

•THE COST of transporting goods from one point to another depends on the manner in which these goods are moved. The most efficient method in one country may not be the most efficient in another because of differences in production factors. In designing transportation facilities for underdeveloped regions, therefore, engineers should investigate the whole range of technology available for producing transportation. By technology we mean a specific combination of productive factors, such as labor, capital, energy, or any other resource which can only be obtained at a certain cost. With different technologies it may be possible to produce similar results, but at different costs.

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Thus goods may be moved over a given distance by human porters, pack mules, trucks, or railroad box cars. In each case, the technology is different, going from a very labor-intensive to a very capital-intensive method. In this instance, the changes in technology are very distinct, and it is often a simple matter to determine which technology is the most suitable. Where changes in technology are so distinct—where the medium by which the goods are carried changes—we define a change in mode.

Within a particular mode, further technological substitutions are also possible. Thus, goods may be carried in many small trucks or fewer large trucks. The mode is the same although in each case the choice of technology is different. Similarly, goods may be carried by railroads around a mountain or through it, each case involving a different combination of construction and energy costs. For each mode there will be some technology or some combination of productive inputs which is optimal in terms of its use of available resources. When intermodal comparisons are made, such as between road and rail, each mode should be compared using this optimal technology. It is important, therefore, to take a thorough look at the whole question of the substitutability of inputs, both as between modes and as between alternative technologies of a given mode. Some insight into the nature of this substitutability in transport can be gained by considering a simple model which describes the production of transportation.

TECHNOLOGICAL CHOICE IN TRANSPORTATION

Transportation involves the transfer of weight between non-coincident points. This weight has a certain bulk and follows a path between these two points which may be circuitous or direct, easy or difficult, safe or hazardous. Moreover, it may move over this path swiftly or slowly, in units which are large or small. All these factors affect the cost of moving this weight to a greater or lesser extent.

A model describing the production of transportation should at least take into account the more important of these factors. To some extent, the model should be sensitive to differences in (a) cargo characteristics—weight, bulk, density, and perishability, (b) route characteristics—circuity and difficulty, and (c) quality of transport—speed, safety, and reliability.

In the production of road transportation, for example, the major variables include road alignment, road surface, vehicle size, and energy input. Alignment, road surface, and vehicle size usually constitute the independent variables, whereas energy input is usually a dependent variable. How these factors affect the cost of transport and to what extent they are substitutable for one another can be described in the following manner.

Consider the problem of designing a road to carry a particular axle load. The load-carrying capacity or strength of a road depends primarily on the strength of the subgrade and the thickness of the pavement structure. The relationship between these three factors can be shown by a three-dimensional surface in which the vertical axis represents pavement thickness and the horizontal axes represent design axle load and subgrade strength (Fig. 1). By cutting this surface with a series of horizontal sections, strength contours are obtained, each of which indicates the various combinations of pavement thickness and subgrade strength which will safely support that load. These strength contours can be derived from theory and their shape is independent of local conditions (Fig. 2).

Local conditions become important in determining the costs of providing the pavement structure and of preparing the subgrade material. Subgrade strength, for example, can be improved by compaction or soil stabilization methods. The cost of improving the subgrade, however, will depend on such local conditions as the nature of the soil, the availability of labor, and the cost of equipment. As the subgrade is improved, total costs might vary in the general way shown in Figure 3. Similarly, the cost of increasing pavement thickness will also depend on local conditions.

The cost relationships of Figure 3 can be combined to form a series of equal cost contours or isocost curves as in Figure 4. Each isocost curve indicates the various ways in which a stated expenditure can be divided between improving the subgrade and providing additional pavement. At one extreme, the total amount can be spent on subgrade improvements leaving nothing for pavement expenditure, whereas at the other

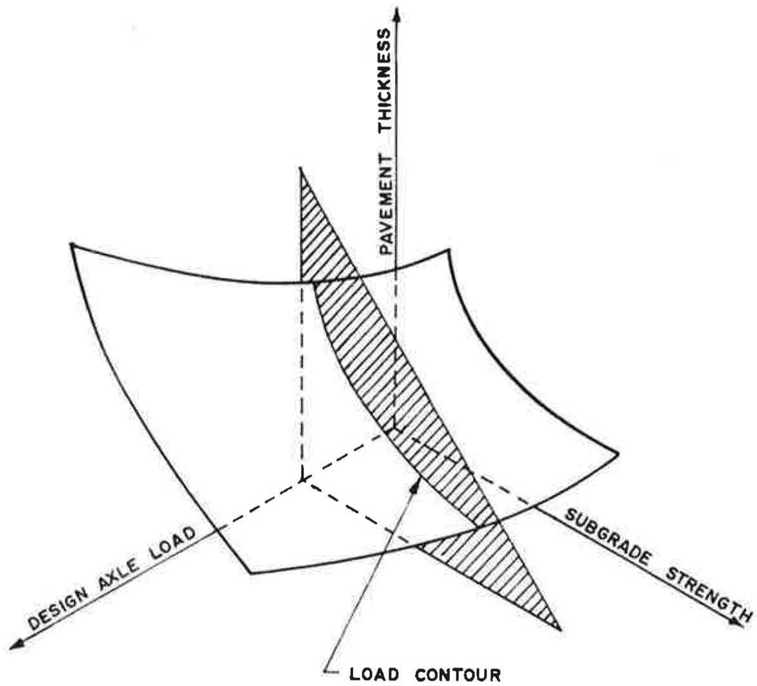

Figure 1. Relationship between axle load, subgrade strength and pavement thickness.

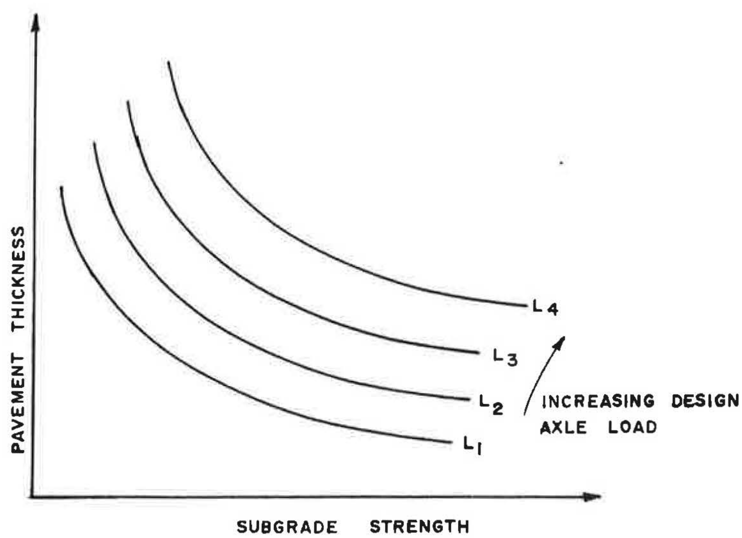

Figure 2. Road strength isoquants.

extreme, the total amount may be spent on pavement. In each, the intercepts are obtained from Figure 3 by observing what subgrade strength and pavement thickness, respectively, can be obtained for the given expenditure. In the intermediate range, the available amount of money is divided in varying proportions between the two alternative methods of increasing road strength. If the isocost map is now superimposed on the

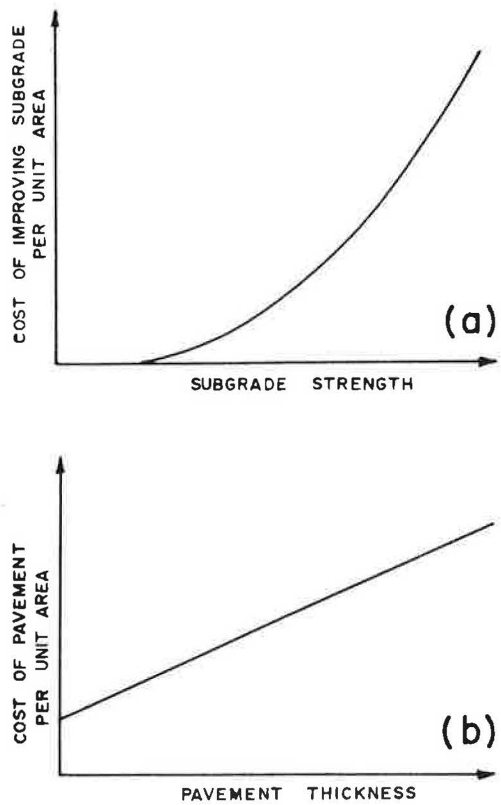

Figure 3. Subgrade strength and pavement cost function.

strength contour map (Fig. 2), the minimum cost of providing a specified road strength will be given by the isocost curve which is just tangent to the corresponding strength contour (Fig. 5). Moving in either direction from this point of tangency along the strength contour involves moving to a higher isocost curve.

In terms of the substitution relationships discussed, Figure 5 means that if a road is to be designed to carry a load, L, and if the initial design includes no pavement layer, expenditures for pavement thickness can be substituted advantageously for investments in improving the subgrade up to some point beyond which it will no longer be advantageous to continue the substitution. This point depends on the relative costs of improving the subgrade and providing additional pavement. If these relative costs change, the shape of the isocost curves will change and some new point of tangency will be indicated corresponding to a different combination of subgrade strength and pavement thickness. In other words, the proper design or choice of technology clearly depends on the relative factor costs.

Each point of tangency indicates a particular value of road strength and the minimum cost of providing this strength. The locus of all such points can be replotted (Fig. 6) to show the variation of minimum total road costs with increases in load-carrying capacity. As factor prices change, the shape of this cost curve will also change.

A similar technique can also be used to illustrate the substitution effects possible between road conditions and vehicle operating costs. For a vehicle of a given size, road conditions determine vehicle performance as well as the energy required to move the

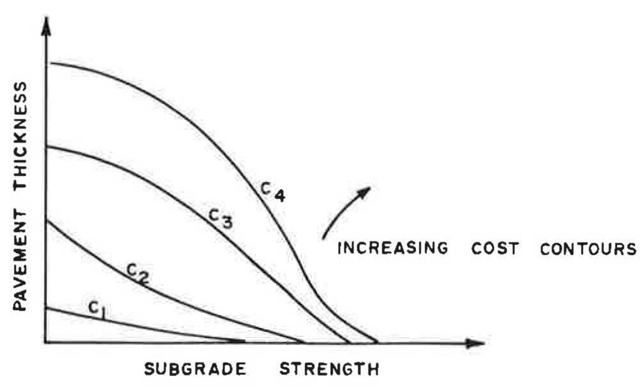

Figure 4. Road strength isocosts.

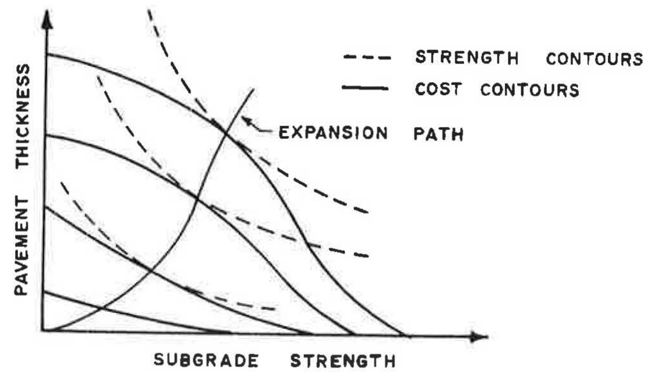

Figure 5. Road strength expansion path.

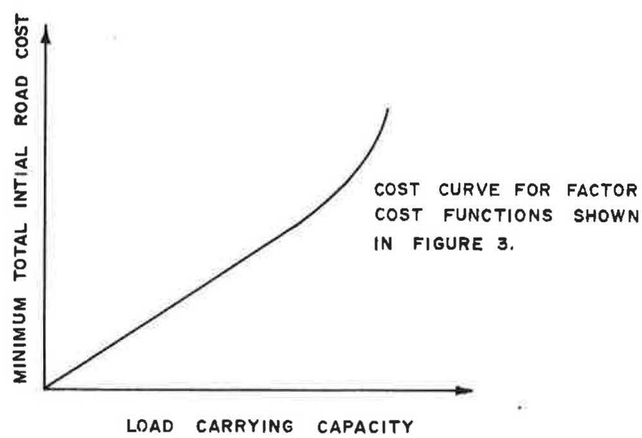

Figure 6. Minimum total road cost function.

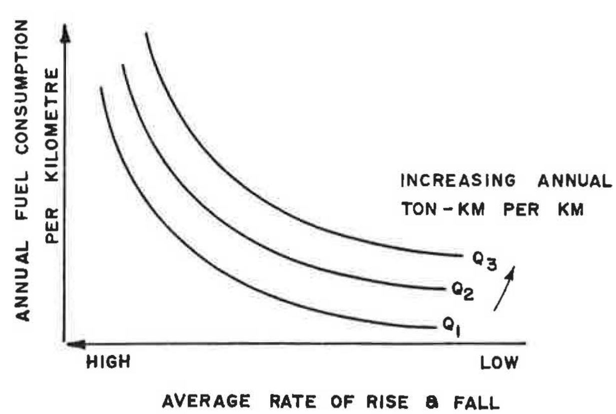

Figure 7. Transport output isoquants.

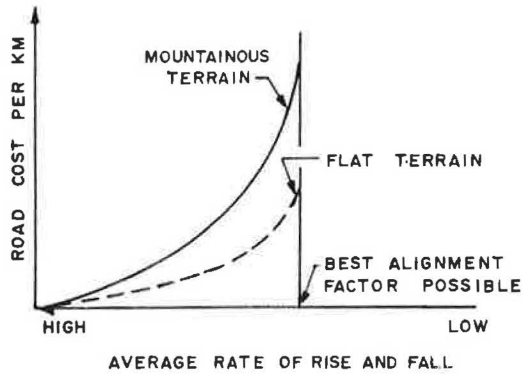

Figure 8. Aligment factor cost function.

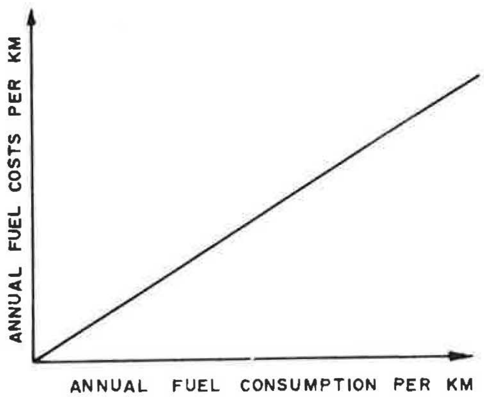

Figure 9. Operating factor cost function.

vehicle over a given distance. For purposes of illustration the major characteristic of road condition is considered to be the average rate of rise and fall; fuel consumption is taken as a measure of vehicle performance. Using these parameters, volume contours or isoquant curves can be drawn (Fig. 7), which indicate the quantity of goods that can be moved over a given distance for various combinations of fuel inputs and road conditions. If, for example, road conditions are improved by reducing the average rate of rise and fall, the quantity of fuel necessary to carry a specified tonnage will decrease correspondingly.

The cost of reducing the average rate of rise and fall of a particular road depends primarily on local topography. To a lesser extent the availability of labor and heavy earth moving equipment also influence this cost. With increasing expenditures, road conditions can be improved up to some point beyond which further expenditures will yield only slight improvements. Thus, for practical purposes, the cost curve can be considered as asymptotic to the lowest rate of rise and fall possible. As shown in Figure 8, the more rugged the terrain, the higher the cost of reaching this point. Figure 9 shows the cost curve for fuel consumption, assumed to be linear.

In Figure 4, the units of each axis represent initial or capital costs, thus allowing the costs to be combined in an isocost map. In Figures 8 and 9, however, the cost of road improvement represents an initial capital cost, whereas the cost of fuel represents a current cost related to the total quantity of transportation produced over a given time. To normalize these two axes, road improvement costs can be amortized on an annual basis (by means of the capital recovery factor), or alternatively, the present discounted value of future expenditures on fuel can be determined. In either case, the rate of interest and life of the facility must be specified.

If the costs of Figure 8 are amortized on an annual basis, an isocost map can be plotted and superimposed on the isoquant diagram (Fig. 10). Again, the tangency points indicate the degree to which operating inputs can advantageously be substituted for road improvements. At each point of tangency, both a total cost and a volume of transport output are indicated so that the expansion path through these points represents the minimum total cost curve.

In these considerations of alignment and operating factors vehicle size has been considered as given. Changing the vehicle size will change the shape of the isoquants (Fig. 7) and hence the location of points of tangency. Thus for each vehicle size a different cost curve will be obtained. When these curves are plotted

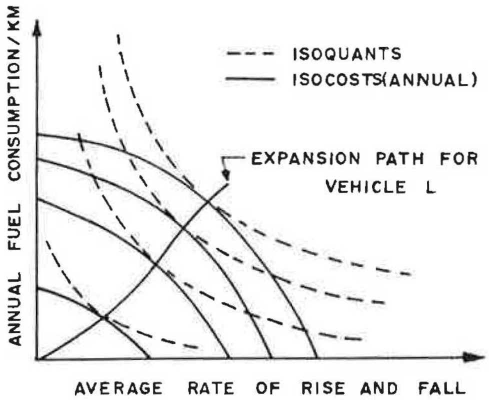

Figure 10. Transport output expansion path.

together (Fig. 11), the optimum vehicle size to be used is given as a function of transport output.

In the generalized case, however, vehicle size or load-carrying capacity of the roads can be taken into account by adding a third dimension to Figure 7. The isoquant curves would become surfaces of equal transport output and Figure 7 would represent a section through these surfaces taken perpendicular to the vehicle size axis. In other words, a particular surface would indicate the various combinations of energy input, vehicle size, and road conditions which would result in the production of the same output of transportation. This surface would be entirely independent of local conditions and would represent a relationship between physical inputs (or productive factors) and the quantity of transportation produced. The slope of the surface measured parallel to any axis would indicate the rate at which one factor could be substituted for another without changing the level of transport output. (Nothing has been said about the problem of measuring transportation output. A weight × distance measure has been used here for illustrative purposes. For a detailed treatment of output measures in transportation, see Wilson, 38.)

In a similar fashion, isocost surfaces could be found which are functions of the same physical parameters. These surfaces, however, would be entirely dependent on local conditions; they would represent particular solutions. Again, as in the two-dimensional case, points of tangency would indicate optimal points of production—optimal in the sense that output is maximized for a given cost or that cost is minimized for a given output. The expansion path through these points would specify, in addition to the best combination of road conditions and operating cost, the best vehicle size to be used.

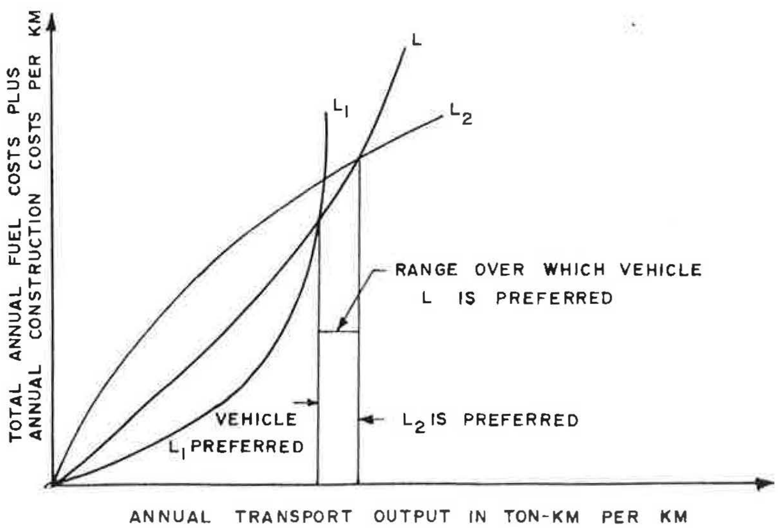

Figure 11. Minimum total transport output cost function.

NATURE OF SUBSTITUTABILITY IN TRANSPORTATION

Despite certain oversimplifications, the model described gives some indication of the nature of the substitutability possible between factor inputs in producing transportation. For a more detailed description, see Soberman (31, Chap. III). For example, in addition to the substitutability between subgrade and pavement improvements, further substitution possibilities exist. In compacting the subgrade, alternative types of equipment, such as large, heavy-duty compaction equipment requiring only a few passes over the subgrade, or lighter equipment requiring many passes, might be used. In the first case, the capital component per unit area compacted will probably be greater, whereas in the second case the labor component is likely to be more important. Thus just as load contours were drawn showing the substitutability of pavement thickness for subgrade strength, contours of subgrade strength could be obtained showing the substitutability of labor for capital.

In a similar manner, pavement thickness contours could be drawn showing the substitutability of the same inputs for one another. High labor inputs might correspond to methods of construction employing hand mixers for asphalt or concrete, whereas high capital inputs might indicate the use of large automatic paving machines.

This type of substitutability is representative of the different levels of capital intensity possible in the construction of transportation facilities. For a given final design (specified in terms of road width, pavement thickness, etc.) it deals with the alternative methods of construction which can be used to arrive at this design. The degree to which labor can be effectively substituted for capital in the construction of transportation facilities is one of the key issues to be considered in planning transportation for underdeveloped countries. Basically, however, it represents a problem in engineering construction, and as such is beyond the scope of this work. (For further discussion of the choice of construction techniques in developing countries, see 7 and 9.)

Once the decision to build a transportation facility using certain methods of construction has been made, a second type of substitutability is possible within the operating phase. This is the substitutability which is possible at fixed levels of investment between the labor, material, and capital inputs necessary to produce transportation.

Highway maintenance, for example, affects vehicle life. By maintaining a road to a high standard, the capital input per unit of transportation (in the form of vehicle depreciation) can be reduced due to increased vehicle use. Furthermore, labor-capital substitutions within the maintenance operation itself are also possible.

Probably the most important substitutions within the operating phase (certainly for any resonable degree of traffic) relate primarily to vehicle size and use. Vehicle size, for example, determines the quantity of fuel, the hours of driver time, and the proportion of total vehicle maintenance and depreciation which must be charged against each ton-mile produced. For certain types of vehicles, the quantities of each of these input factors per unit weight moved will be higher than for other vehicles, and it would be clearly inefficient to use such vehicles. It is for vehicles where more of one factor and less of others is required that the nature of the substitutability becomes interesting. In other words, if for each vehicle type coordinates could be plotted corresponding to labor and capital components per unit of transportation, our interest would be confined to the substitution relationships defined by the curve passing through all points, none of which had x and y coordinates both larger than any other point.

Finally, a third type of substitutability can be considered representing a combination of the two types previously described. This concerns the substitutability of current or variable inputs for fixed capital inputs. For each type of road, corresponding to a particular fixed investment, alternative combinations of variable inputs can be used in producing a specified output of transportation. At one extreme, light, single-unit vehicles might be used over poorly graded, unpaved roads, whereas at the other extreme, heavy, multiple-unit vehicles traveling on superhighways might be employed. The problem which is of greatest interest concerns the substitutability within all possible combinations of both the construction and operating phases.

The number of such combinations of capital and current cost combinations can, of course, be extremely large. In the final analysis the judgment and experience of the

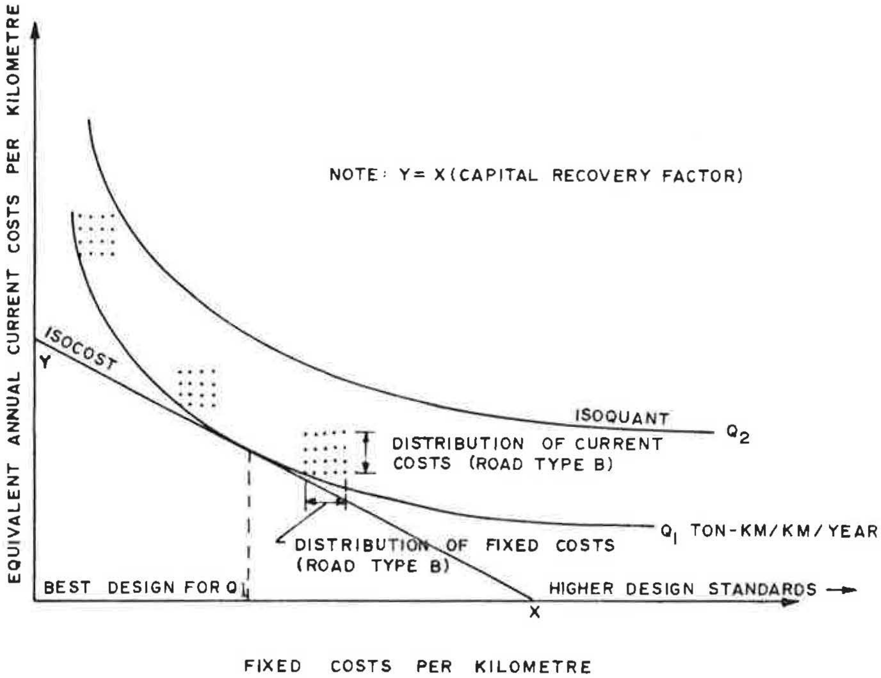

Figure 12. Substitutability between current and fixed inputs.

engineer will determine the set of alternatives which it seems feasible to consider.

For each level of fixed investment some combination of operating inputs will be optimal when the level of traffic volume to be accommodated is taken into account (Fig. 12). Several methods of construction can be used to provide a road of a given standard or design. Each method will involve different labor and capital components, leading to a distribution of fixed costs when each of these components is valued at its true cost.

In most underdeveloped countries a wide discrepancy may exist between the market prices of various factors of production and the real costs of these factors to the economy. These real costs are often referred to as shadow or accounting prices. They are fictitious prices attached to some factor inputs to give a better approximation of their relative importance to the economy. Usually they are applied to the labor, local capital, and foreign exchange components of an investment. (See 31, pp. 120-123; for methods of determining shadow prices, 35, p. 203.)

In Figure 12, this distribution of fixed costs is represented by rows of dots. Similarly, holding the traffic volume constant for each point in the distribution, a distribution of current costs is possible corresponding to various combinations of labor and working capital (local currency and foreign exchange). This distribution is shown by the columns of dots. Thus for each type of road, alternative combinations of fixed and current costs (at constant levels of traffic) are shown by a rectangular array of points on the graph. Each point in the array corresponds to a certain combination of labor and capital used in constructing the facility initially, and operating it thereafter. If these factors have been valued at their real costs, the curve passing through the lower left-hand corner of each array defines the substitutability of labor for capital for all lowest cost combinations of fixed and operating inputs. The curves of Figure 12 represent the labor-capital substitutions possible in providing road transportation. Were similar analyses to be carried out for other modes of transport, substitution relationships could be obtained showing the possible combinations of factor inputs over a much wider range of fixed and current costs.

SELECTION OF OPTIMAL TECHNOLOGY

Given the substitution possibilities described by this curve (or the family of curves for different levels of transport production), the question arises as to how to select the optimal combination of labor and capital, or current and fixed costs. In practical terms, this means selecting both the standards to be used in constructing a highway facility and the type of vehicle to be used. Here, however, the isocost curves indicate the combinations of annual current expenditures over a period of years and initial fixed investment which can be obtained for a specified sum of capital in the present. In other words, the isocost curve specifies the alternative ways of spending an available quantity of capital. On one hand, the entire sum may be invested in fixed expenditures, leaving nothing for future current expenditures. This case gives the X intercept of the isocost curve shown in Figure 12. On the other hand, the entire sum may be set aside to provide for an annual operating expenditure, denoted by the Y intercept, which is determined by the prevailing rate of interest and the assumed period of amortization. In the intermediate range a portion of the total sum is invested in capital expenditure, with the remainder set aside to meet current expenditures. As before, the optimal point of production or choice of technology is given where the isocost curves are tangent to the isoquants.

The expansion path obtained by connecting all such points of tangency indicates the minimum total cost of providing road transportation as output varies. The shape of this cost curve will vary according to the rate of interest. If several alternative modes of transport are analyzed in a manner similar to that described here for road transport, their final cost curves can be compared, thus showing over what ranges of traffic volume and for what prevailing interest rates each mode is to be preferred. In other words, once minimum total cost curves for each mode have been determined as suggested here, intermodal comparisons can be made.

DATA REQUIREMENTS—AN EXAMPLE

The diagrams previously presented are dimensionless, showing by argument alone the general shape of curves and the characteristics of the relationships involved. It would be logical to ask at this point how difficult it is to acquire the data necessary for the suggested method of analysis. The current fixed cost substitution curves (Fig. 12) suggest two basic types of data which are needed. The first relates to the variation in fixed costs as design standards are changed. In addition, some estimate of the variation in current costs for different vehicles operating on roads constructed to various design standards must also be known. How these data were acquired in the case of a newly developing region of Venezuela is discussed in the following.

Fixed Costs

To investigate the variation in fixed costs with changes in design standards, various road construction projects which had been completed in Venezuela were selected and classified according to terrain and geological factors. Within each classification attempts were then made to develop regression equations describing the relationship between construction costs and the design standards to which each road was constructed.

Because sufficient data were not available to consider the variation of each construction cost element for changes in design standards separately, all costs of construction exclusive of pavement costs were grouped together. Two terrain classifications were used: plains (llanos) which includes flat and gently rolling terrain, and mountain regions.

The major design variables taken into account were road width and design speed. The use of design speed takes implicitly into account the remaining standards which have significant effects on road construction costs (i.e., sight distances, curvature, and gradient).

Construction cost data were obtained from an analysis of approximately 2,100 km of road constructed in Venezuela before 1960. In some cases, cost data were available on a per kilometer basis, showing each of the component costs and even the division of

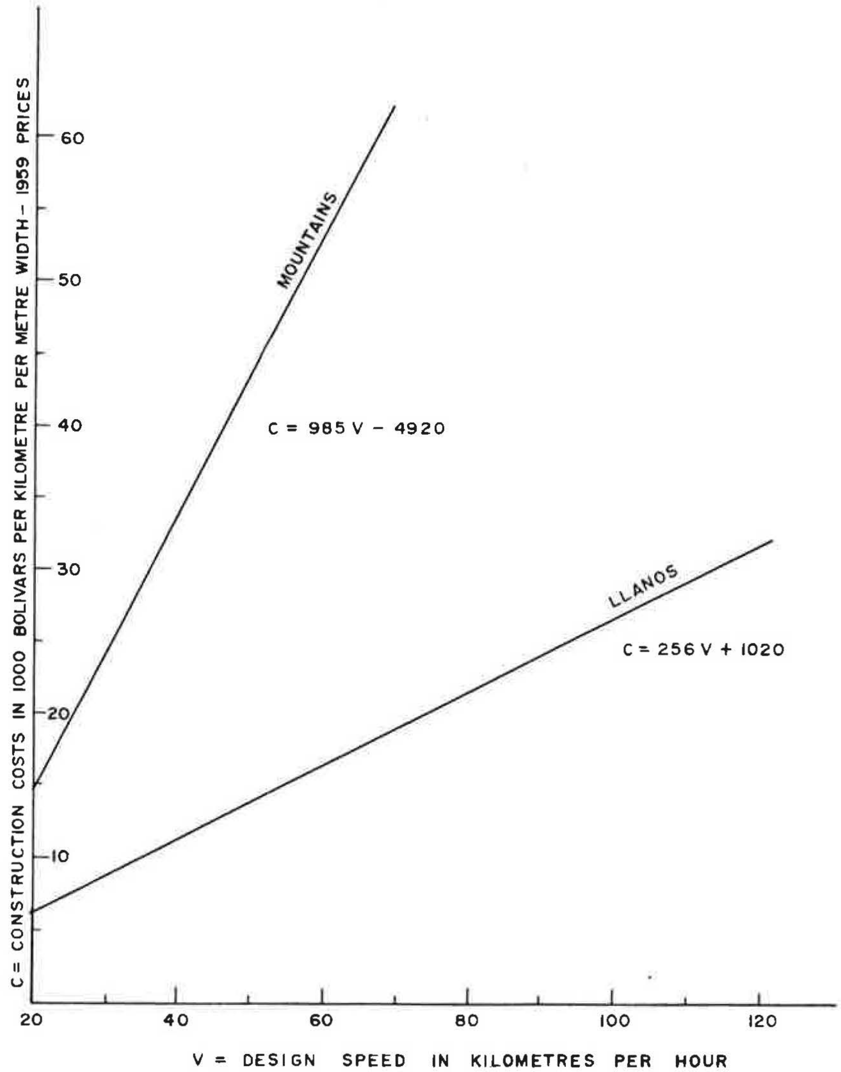

Figure 13. Effect of design speed on construction costs.

these costs between labor, imported materials, and depreciation of equipment. In other cases, cost data were expressed as lump sum figures for sections of road ranging up to 50 km in length.

Four types of two-lane highways (A, B, C, and D) are presently used, differing primarily with respect to design speed, pavement width, and width of shoulders. In flat terrain, road widths of 21.3, 14.6, 10.3, and 7.2 meters and design speeds of 100, 80, 60 and 50 kilometers per hour are usual for type A, B, C, and D roads, respectively. Examples of actual roads constructed corresponding to each of these road types could not always be found for both types of terrain considered. (Type A roads are generally rare in mountainous regions.) Therefore, in cases where actual data pertaining to a particular road type were lacking, it was necessary to use construction cost estimates prepared by the Ministry of Public Works.

Linear multiple-regression analysis was used to obtain construction cost equations for the two types of terrain considered.

$$C_L = 5,720\ W + 3,830\ V - 123,000 \qquad (1)$$

and

$$C_M = 57,900\ W + 5,860\ V - 490,000 \quad (2)$$

where

C_L, C_M = cost per kilometer in Bolivars for flat and mountainous terrain, respectively ($1.00 U. S. = 4.48 Bolivars);
W = design width in meters; and
V = design speed in kilometers per hour.

Least squares curve fits were also made with respect to design speed. In this case costs per kilometer were expressed per unit of road width.

$$C'_L = 256\ V + 1,020 \quad (3)$$

$$C'_M = 985\ V - 4,920 \quad (4)$$

in Bolivars per meter width. These equations are plotted in Figure 13.

TABLE 1

ESTIMATED RELATIVE IMPORTANCE OF ROAD CONSTRUCTION COST ELEMENTS FOR VARIOUS ROAD WIDTHS (FLAT TERRAIN)

Cost Element	Relative Importance (%)			
	7.2-m Width	10.3-m Width	14.6-m Width	21.3-m Width
Preparation of site	6.0	7.0	7.7	7.7
Earthwork	38.1	37.2	36.8	36.6
Culverts and drainage	11.1	16.0	19.7	21.7
Base	6.6	7.7	8.5	9.0
Bridges	35.2	30.1	26.0	24.1
Fencing	3.0	2.0	1.3	0.9
Total	100.0	100.0	100.0	100.0

TABLE 2

LABOR, LOCAL CAPITAL, AND FOREIGN EXCHANGE COMPONENTS OF ROAD COST ELEMENTS[a]

Cost Element	Detailed Breakdown (%)						Aggregate Figures (%)[c]		
	Labor[b]	Profits	Domestic Materials	Imported Materials	Fuels	Deprec. and General Expenses	Labor	Local Capital	Foreign Exchange
Preparation of site	28.2	10.4	-	22.0	7.1	32.3	28.2	33.6	38.2
Earthwork	28.2	10.7	-	25.1	5.8	29.6	28.8	31.3	39.9
Culverts and drainage	17.7	10.7	50.8	13.9	0.4	6.5	17.7	65.2	17.1
Base	29.7	10.7	12.0	20.0	3.9	23.7	29.7	38.5	31.8
Bridges	28.4	10.7	33.4	13.4	0.7	13.0	28.4	51.7	19.9
Fencing	24.3	10.7	35.0	-	-	-	24.3	75.7	-

[a]Data derived from construction projects obtained from Ministerio de Obras Publicas, Caracas; calculations based on 1959 prices.
[b]Includes 30 percent social benefits.
[c]Derived from detailed breakdown as follows: Labor = column 1; Local capital = columns 2 + 3 + 5 + 50 percent of column 6; and Foreign exchange = column 4 + 50 percent of column 6.

Estimates of the relative importance of the various construction cost elements were also made from the cost data available on a more detailed basis, and are indicated in Table 1 for flat terrain. Labor, fuel, domestic materials, imported materials, and depreciation components of these cost elements are indicated in Table 2.

The distribution of costs in Table 1 was then used to make estimates of labor, local currency, and foreign exchange components for each of the four road types considered, using the data in Table 2. Recognizing the limitations on data accuracy, the distributions as indicated in Table 3 remain remarkably constant with labor, local capital, and foreign exchange accounting for 27, 44 and 29 percent of total construction costs, respectively. These distributions can be used in conjunction with the regression equations developed previously to estimate labor and capital cost variations with changes in design standards.

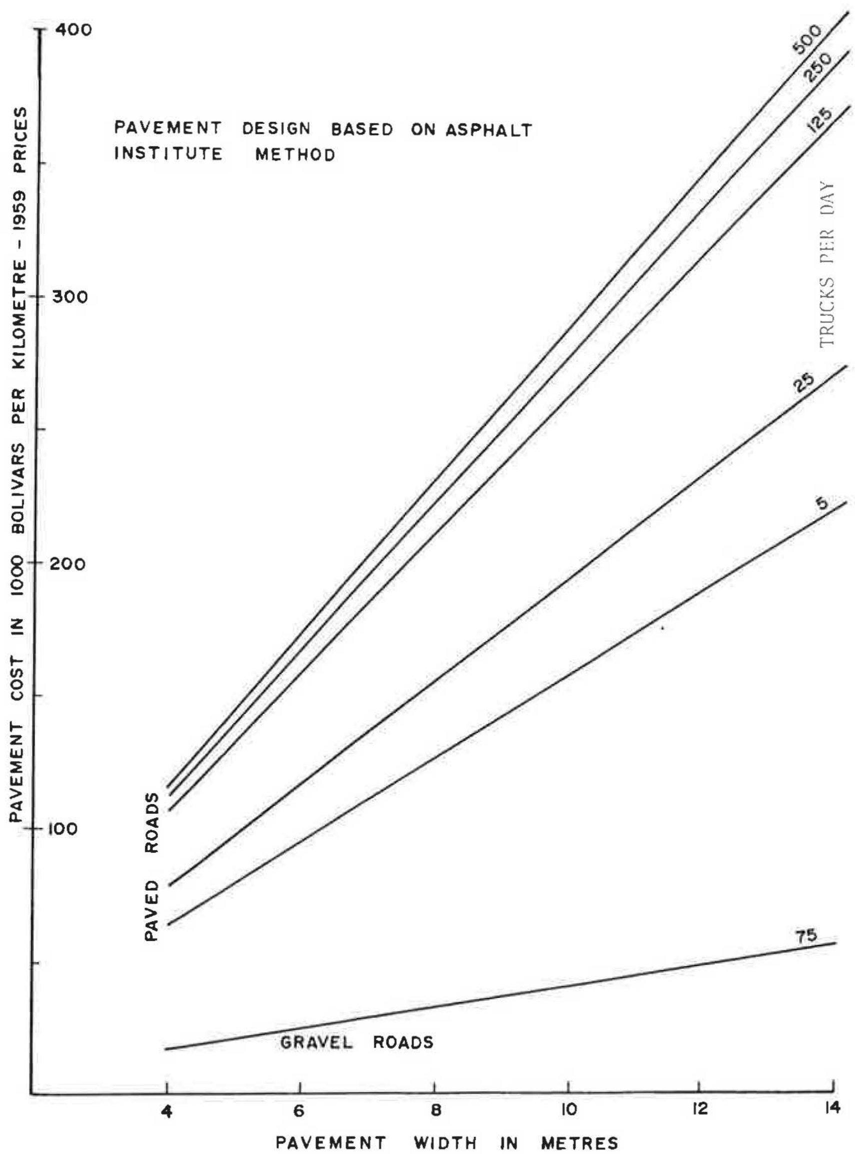

Figure 14. Effect of traffic volume and design width on pavement costs.

Estimates of pavement costs were made by designing flexible pavements for several different average daily traffic volumes and then applying local unit costs to quantities taken from these designs. The variation in pavement costs for changes in design width and traffic volume could then be determined (Fig. 14). Labor, local capital and foreign exchange components of these costs averaged 24, 58, and 18 percent, respectively.

Current Costs

Current costs include annual road maintenance and the cost of motor vehicle operation. Maintenance costs in turn include fixed and variable components. Fixed components are largely independent of traffic intensity, resulting from the deterioration of highway surfaces and structures caused primarily by climatic factors and the invasion of road margins by vegetation. In tropical climates rainfall is probably the most important climatic factor, particularly where wet and dry seasons are very distinct. During the rainy season, the cost of maintaining earth and gravel roads becomes so high that it is often cheaper to pave the road surface even where traffic volumes are very low. Variable maintenance costs, on the other hand, depend primarily on traffic intensity and the frequency of heavy trucks. In general, the relative importance of fixed costs increases from earth to gravel to paved roads, whereas variable costs decrease in importance.

Statistical information on total annual maintenance costs was available from the Venezuelan Ministry of Public Works. In addition, information on the length of various road types together with estimates of average daily traffic volumes on these roads were also available. By combining these data it was possible to develop maintenance cost estimating equations for three classes of roads.

$$M_P = 10,400 + 1\,(ADT) \tag{5}$$

$$M_G = 5,200 + 18\,(ADT) \tag{6}$$

$$M_E = 1,550 + 54\,(ADT) \tag{7}$$

where

M_P = annual cost of maintaining paved roads in Bolivars per kilometer (Bs/km);
M_G = annual cost of maintaining gravel roads in Bs/km;
M_E = annual cost of maintaining earth roads in Bs/km; and
ADT = average daily traffic.

For a more detailed explanation see Ref. 31, pp. 173-180.

No attempt has been made to take difference in road standards within the paved, gravel and earth categories used in the foregoing into account. Within each of these categories some variation in annual maintenance costs can be expected. In general, however, differences in design standards will not produce significant differences in the pattern of maintenance costs over the life of the road. For example, loads applied near the edge of a pavement produce more distress in pavements and shoulders than loads applied nearer to the centerline. Therefore, although the area to be maintained per kilometer increases as widths are increased, the relative frequency of edge loadings decreases and tends to offset increases in maintenance costs. For small increments of width (i.e., less than a lane) maintenance costs will be unaffected because the length of road for which each road gang is responsible does not change. In other words, total costs remain roughly the same and the productivity of the maintenance crew is forced to increase.

Costs of motor vehicle operation can also be divided into two groups, those which are fixed or independent of the degree to which the vehicle is used, and those which are variable or dependent on vehicle usage. In the former category are such costs as depreciation due to obsolescence, insurance, taxes and licenses, and garaging. Because the life of a vehicle is relatively short compared to the life of road facilities, these fixed costs can be considered as short-run fixed costs. The most important var-

TABLE 3

ESTIMATED LABOR, LOCAL CAPITAL, AND FOREIGN EXCHANGE COMPONENTS OF ROAD CONSTRUCTION COSTS FOR VARIOUS ROAD WIDTHS

Component	Cost (%)			
	7.2-m Width	10.3-m Width	14.6-m Width	21.3-m Width
Labor	27.3	26.8	26.5	26.3
Local capital	44.2	44.5	44.6	44.8
Foreign exchange	28.5	28.7	28.9	28.9
Total	100.0	100.0	100.0	100.0

iable costs are depreciation due to usage, fuel, maintenance, and wages paid to drivers and their helpers.

In the design of transport systems we are interested only in those elements of vehicle operation which can be affected by changes in system design. Normally, this excludes most of the elements of fixed costs. In underdeveloped regions, however, changes in system design can often affect unit fixed charges significantly by (a) increasing the useful lives of vehicles through improvements to road surfaces and alignment, and (b) improving the utilization of vehicles through overall increases in average running speeds possible. Therefore, both fixed and variable motor vehicle operating costs were considered here.

Operating cost estimates were made by supplementing available information on truck and tire prices, maintenance costs, and the price of fuel and lubricants, with United States data on fuel consumption, tire wear, and vehicle performance, obtainable from any one of a number of studies. (See, for example, the classic Oregon studies on motor vehicle operating costs by Beakey, 2; also Saal, 29.) In all cases where foreign data

TABLE 4

SUMMARY OF TRUCK OPERATING COSTS FOR OPERTION ON PAVED, GRAVEL, AND EARTH ROADS[a]

Item	Cost (Bolivars per veh-km)				
	7.8 Metric-Ton Cap.	11.4 Metric-Ton Cap.	15.9 Metric-Ton Cap.	21.0 Metric-Ton Cap.	23.5 Metric-Ton Cap.
Paved Roads[b]					
Drivers[c]	0.325	0.325	0.335	0.345	0.378
Maintenance[d]	0.055	0.063	0.085	0.104	0.107
Tires[e]	0.107	0.107	0.150	0.193	0.193
Gasoline[f]	0.051	0.063	0.075	—	—
Diesel oil[g]	—	—	—	0.021	0.023
Oil	0.010	0.016	0.022	0.025	0.025
Insurance[h]	0.036	0.042	0.050	0.069	0.075
Total	0.584	0.616	0.717	0.757	0.801
Gravel Roads[i]					
Drivers[j]	0.520	0.520	0.537	0.552	0.606
Maintenance[k] (5.6)	0.308	0.353	0.477	0.582	0.599
Tires (1.68)	0.199	0.199	0.252	0.324	0.324
Gasoline (1.15)	0.059	0.072	0.086	—	—
Diesel oil (1.15)	—	—	—	0.024	0.026
Oil (1.51)	0.015	0.024	0.033	0.038	0.038
Insurance[j]	0.058	0.067	0.080	0.110	0.120
Total	1.159	1.235	1.465	1.630	1.713
Earth Roads[i]					
Drivers[j]	0.520	0.520	0.537	0.552	0.606
Maintenance (10.0)	0.550	0.630	0.850	0.040	1.070
Tires (1.24)	0.133	0.133	0.186	0.239	0.239
Gasoline (1.11)	0.057	0.070	0.083	—	—
Diesel oil (1.11)	—	—	—	0.023	0.025
Oil (2.11)	0.021	0.034	0.046	0.053	0.053
Insurance[j]	0.058	0.067	0.080	0.110	0.120
Total	1.339	1.454	1.782	2.017	2.113

[a]All costs in 1959 Bolivars; depreciation costs not included.
[b]Annual truck utilization assumed to be 80,000 km.
[c]Base wage of Bs 2,170/month (including 45 percent benefits) increased by 3, 6, 16 percent, respectively, for 15.9, 21.0, and 23.5 ton trucks.
[d]Includes engine overhaul estimate of 7.7 Bs/HP every 60,000 km and monthly charges of Bs 150, 180, 300, 400, 350, respectively.
[e]Assumed tire life of 42,000 km and cost of Bs 450/tire.
[f]Average of empty and fully loaded fuel consumption computed for a rise and fall of 2.0 meters/100 meters, after Saal, (29), p. 39, and fuel costs of Bs 0.14/liter.
[g]Fuel consumption computed as in footnote 6 above and divided by 1.52 and 1.55 for 21.0 and 23.5 ton trucks, respectively, to allow for greater diesel efficiency. (Fuel adjustment factors taken from U.S. Congress, Final Report of the Highway Cost Allocation Study, House Doc. No. 54, Gov't. Pr. Off., p. 204, 1961. Diesel fuel costs assumed to be Bs 0.50/liter.
[h]Includes an annual charge of 3 percent of initial value of truck for collision.
[i]Truck utilization assumed to be 50,000 km/yr.
[j]Annual total remains constant while utilization is reduced from 80,000 to 50,000 km/yr.
[k]Figures in parentheses indicate adjustment factors applied to costs of operation on paved surfaces.

TABLE 5

TRUCK OPERATING COSTS ON PAVED, GRAVEL, AND EARTH ROADS SHOWING LABOR, LOCAL CAPITAL, AND FOREIGN EXCHANGE COMPONENTS AT 10 PERCENT INTEREST

Item	Cost (Bolivars per 1,000 ton-km)[a]				
	7.8 Metric-Ton Cap.[b]	11.4 Metric-Ton Cap.[c]	15.9 Metric-Ton Cap.[d]	21.0 Metric-Ton Cap.[e]	23.5 Metric-Ton Cap.[f]
Paved roads					
Labor	64.5	56.8	47.6	44.5	45.9
Local capital	39.9	38.9	40.0	37.4	36.5
Foreign exchange	21.1	24.6	25.9	32.6	36.1
Total	125.5	120.3	113.5	114.5	118.5
Gravel roads					
Labor	123.6	111.2	97.6	94.4	96.3
Local capital	74.8	71.8	71.7	71.9	70.0
Foreign exchange	42.0	47.0	49.9	60.8	65.8
Total	240.4	230.0	219.2	227.1	232.1
Earth roads					
Labor	144.7	132.4	121.6	120.1	120.9
Local capital	74.9	74.0	76.1	76.7	75.2
Foreign exchange	53.5	58.5	61.4	73.7	78.5
Total	273.1	264.9	259.1	270.5	274.6

[a]All costs in 1959 Bolivars.
[b]Two-way load factor, 70 percent.
[c]Two-way load factor, 55 percent.
[d]Two-way load factor, 50 percent.
[e]Two-way load factor, 42.5 percent.
[f]Two-way load factor, 40.0 percent.

were used, however, adjustments were made to take into account differences in unit prices, such as the price of fuel.

These cost estimates have been itemized in Table 4 for five different truck sizes. Adjustments (shown in brackets) made for operation on unpaved earth and gravel surfaces have also been included. (Adjustments are based on data from Daftary and Ganguli, 11, p. 251, and Moyer and Winfrey, 21, pp. 23, 43.) These variable costs are stated in terms of costs per vehicle-kilometer for line-haul operation. They have been recalculated on a ton-kilometer basis in Table 5. Labor, local currency, and foreign exchange components for an interest rate of 10 percent have also been estimated.

Once the variation is fixed and current costs for changes in design standards and vehicle size have been determined, these data can be applied to the framework developed earlier for choosing the optimal road transport technology. For example, estimates of total annual current costs for a particular route in Venezuela were computed for each year from 1966 to 1975. Operating costs were based on the foregoing cost data for 15.9-ton trucks and the maintenance cost equations developed previously for various road types. For each of several road types construction costs were estimated using the previously given equations. Discounting the current costs for each year and expressing them as an equivalent annual volume (39), it was then possible to describe the substitutability possible between current and fixed expenditures (Fig. 15). To make the axes comparable, fixed costs have been amortized on an annual basis at an interest rate of 10 percent. The substitution relationship is shown by curve 1, and the optimal technology is determined by the point of tangency between this isoquant and the Bs 59,000 isocost.

Figure 15 also shows the effect of using accounting prices on the selection of final design standards. For each of the three isoquants, the optimum level of fixed investment (corresponding to a particular set of design standards) is different. Lowering the real wage rate, for example, improves the position of the higher current cost alternative since current expenditures (vehicle operation and road maintenance) have higher labor components than construction expenditures.

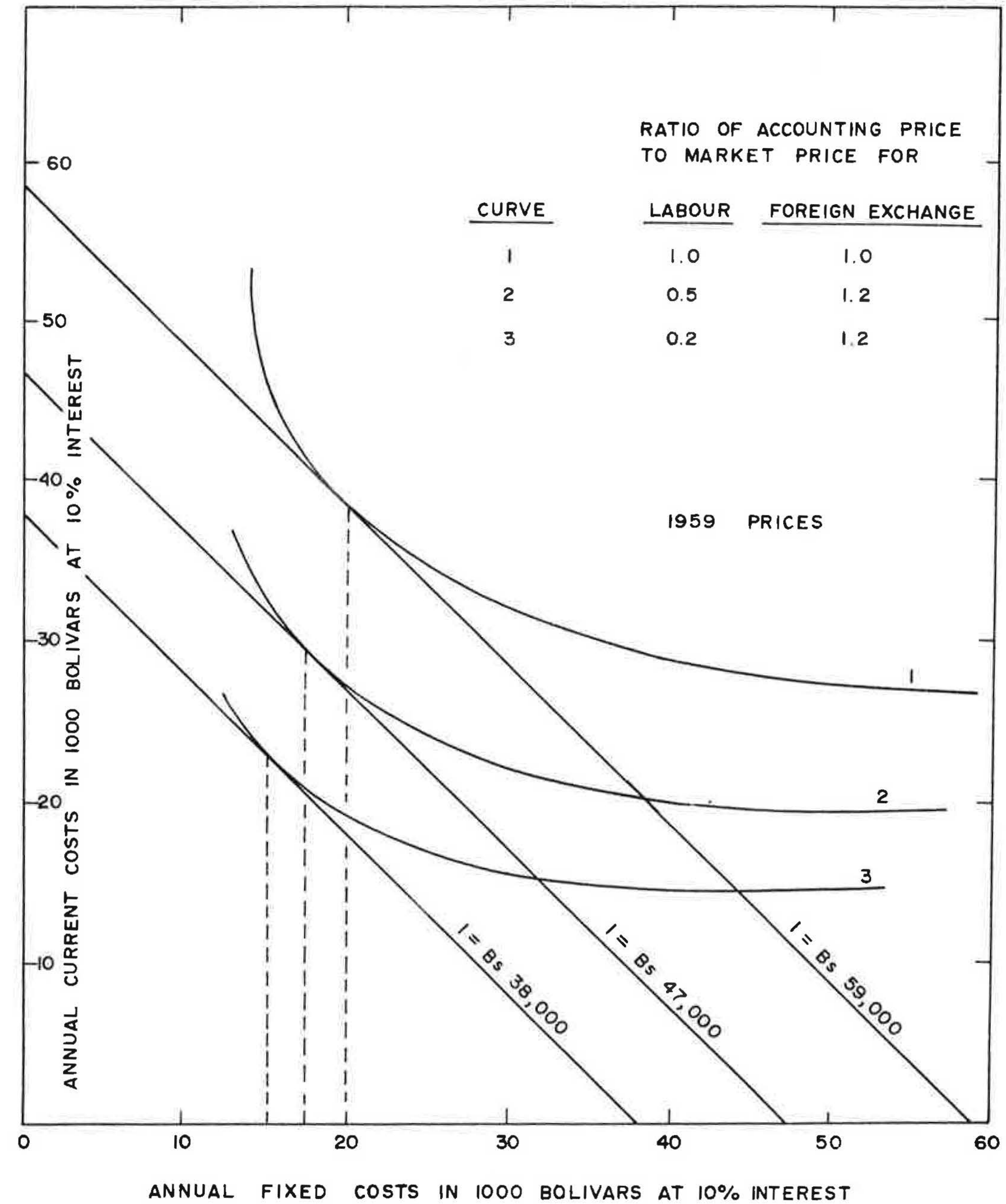

Figure 15. Selection of optimal road investment.

CONCLUSIONS

A conceptual framework for analyzing the degree of factor substitutability possible in producing transportation has shown that different transport technologies can be represented by different combinations of fixed investment and current costs. The optimal level of investment changes with changes in factor prices. Thus the level of transportation investment (as expressed by the choice of design standards) which is in keeping with best engineering practice in one country may not be justified in another characterized by different relative factor prices. Because these differences in relative factor prices are more pronounced among underdeveloped countries, the method of determining optimal investment levels suggested here is likely to be more meaningful in such countries.

The Venezuelan case study illustrates how relatively scant cost information can be used to estimate the cost relationships relevant to the method of analysis. These cost data were collected over a 3- to 4-month period. A national, familiar with local practice and working in his own country, could undoubtedly seek out the best sources of data in even less time. Moreover, a much wider range of data could readily be obtained in a shorter period of time by using some of the vehicle simulation and computer techniques available for evaluating construction and road user costs (19, 27). Recognizing that any sort of economic analysis requires some estimate of highway costs, the data requirements of this method of analysis do not appear to pose special problems.

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The Passenger Car in the U.S.S.R.

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•THIS is a brief and non-technical account of the way the Soviet regime is trying to deal with the passenger automobile. It makes an interesting story, illustrating the well-known law which says that "everything is more complicated than most people think."[1] As we know from American experience, automobiles have created some extremely complicated problems for modern society. The people of Western Europe and Japan are now running into their own versions of these problems. The U.S.S.R. is at an earlier stage, but now confronts some of the same opportunities and difficulties. How will the Russians meet them?

A key to the Soviet approach lies in the Bolshevik belief that the capitalist, free-market response to the automobile has been unscientific, even irrational. Party theoreticians argue that the U.S.S.R. can develop rational solutions that will be less wasteful, better coordinated, and more equitable than what has evolved in Western capitalist countries. Clearly Soviet success in these efforts would have important implications all over the world. Are there signs of progress to date? What follows is a sketch designed to provide perspective for informed speculation on the outcome of what can be visualized as a contest between the passenger automobile and the Soviet regime. I begin historically.

Four and a half years ago, Nikita Sergeevich Khrushchev toured the United States. You remember that he visited San Francisco and was put in the Mark Hopkins Hotel. The morning he left, Mayor Christopher escorted him to the airport by way of the great, handsome San Francisco freeway. They were bucking the incoming morning rush-hour traffic. Khrushchev apparently watched the stream of individual cars go by, with generally one passenger per car, and finally exclaimed that it was irrational. Mayor Christopher evidently conceded diplomatically that large numbers of private cars had indeed created traffic problems in our big cities. The experience seems to have made a profound impression on Khrushchev.

Shortly thereafter, when Khrushchev stopped in Vladivostok after a conference in Peking, he said, "America really does have a lot of cars." He then went on, "It is not our aim, however, to compete with the Americans in the production of large numbers of automobiles. . . . We will turn out a lot of cars, but not now. We want to establish a system for the use of automobiles that will differ from the one in capitalist countries. . . ."[2] It turned out that what Khrushchev had in mind was a kind of municipal rent-a-car service, under which each city would have a fleet of automobiles its citizens could rent for vacation or weekend trips. Since 1959, such a system has actually begun.

But this is only part of the picture. How do these miniature municipal car fleets fit into the overall structure of passenger transportation? How many automobiles are there, and what is their role? Let me take a minute or two to fill in the background for you. With this perspective, we can then return to the specific problems surrounding the use of the passenger automobile.

First, you should know that, as of January 1, 1965, the total stock of passenger automobiles in the U.S.S.R. is just over one million units. This compares with about 75 million in the United States, about 8 million each in France, the United Kingdom, and West Germany, about 6 million in Canada and about 4 million in Italy. In the

[1]Cited in Charles P. Kindleberger, Economic Development, McGraw-Hill, 1958, p. 16.

[2]Pravda, October 8, 1959, p. 1. Translated in Current Digest of the Soviet Press (cited hereafter as CDSP), Vol. XI, No. 40, p. 3.

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United States, there is now better than one car for every three people. The ratio of total automobile registrations to total population in France is about one to seven, in the United Kingdom about one to eight, and in West Germany, about one to nine. In the U. S. S. R. there is one passenger automobile for roughly every 230 people.[3] Moreover, since perhaps half of the Soviet passenger cars are operated by state agencies rather than private citizens, the number under individual control in the U. S. S. R. is something like one for each 500 persons.

In this respect, therefore, the difference between American and Soviet Society is not of the order of ten to one, but something over one hundred to one. It requires a drastic wrench of the understanding to appreciate the contrast. I can vouch for the fact that a casual Western visitor to the U. S. S. R. is unlikely to appreciate the magnitude of this disparity. In Moscow and other cities on the Intourist circuit, one rides in cars and sees lots of cars on the streets. Somehow their relative scarcity is not made vivid, though one does notice that they are outnumbered by trucks. Presumably in the vast stretches of the hinterland, and in smaller cities and towns seldom visited by Westerners, the paucity of passenger automobiles would be more apparent.

The present nationwide stock of about one million passenger automobiles is not growing rapidly. Annual production is around 175, 000 units, of which some thirty-five or forty thousand are exported, primarily to East European countries. Taking account of normal depreciation, net additions to the national stock are currently in the neighborhood of 60, 000 units a year. Compared with what is going on in Western Europe and Japan, to say nothing of North America, this is an exceedingly modest level of growth. The U. S. S. R., as the second industrial power of the world, is obviously pursuing a radically restrictive policy toward the passenger automobile.

How do people get around? Tables 1 and 2 give the picture for 1962. In urban areas, more than 40 percent of the passenger travel is by motor bus. Another 40 percent is by old-fashioned streetcar or by modern trolleybus. Suburban rail lines account for about 7 percent of the passengers carried and about 10 percent of the passenger-miles, since the average rail trip is longer than that of the strictly urban carriers. The subways in Moscow, Leningrad, and Kiev add 4 or 5 percent to the national total and are of course responsible for a substantial fraction of urban passenger traffic in these three major cities. The data in Table 1 do not cover taxi service, available in many cities, or such movement by individual automobile as takes place. Except for those who live close to their jobs, the typical Soviet urban citizen rides to work, but in a public conveyance. The carriers give service which impresses American visitors and appears to match what is available in Western Europe. The subways are showcases; bus and trolley routes are widespread; frequency of service is admirable. True, buses and cars are often very crowded, but this makes for operating efficiency.

Travel between cities is still dominated by the railroads, as is clear from the figures in Table 2. Intercity autobus traffic accounts for about 12 percent of total passenger-kilometers, supplementing rail service among nearby towns and cities. Aircraft already carry over 10 percent of the traffic, mainly on long trips. Together with the railroads, these carriers provide adequate service for the travel considered essential by the authorities. The amount of travel per capita is, however, smaller than in Western Europe, and very much smaller than in North America.

The slender stock of passenger automobiles is supported by an equally underdeveloped supporting base of paved roads, filling stations, and garages. The main streets of cities are paved, but even in Moscow the back streets can be very hard to navigate. Major interregional highways are mainly paved, though year-round maintenance in so northern a territory presents many problems. A Pravda story in the fall of 1963 indicated that the total number of filling stations for the entire country was around fifteen or sixteen hundred.[4] Servicing and repair facilities are even more scarce.

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[3]Data for two years earlier are collected in the United States Department of Commerce, Business and Defense Services Administration, Transportation Equipment Division, World Motor Vehicle Production and Registration, 1962-1963 (October 1963), pp. 4-5.

[4] CDSP, Vol. XV, No. 36, p. 24.

TABLE 1

URBAN PASSENGER TRANSPORTATION, U.S.S.R., BY CARRIER, 1962, IN MILLIONS OF PASSENGERS CARRIED

Carrier	Millions of Passengers Carried	Percentage Share of Total
Autobus	12,634	46.8
Tramway (streetcar)	7,937	29.4
Trolleybus	3,353	12.4
Railroad (commutation)	1,791	6.6
Subway	1,301	4.8
Five-carrier total	27,016	100.0

Source: Tsentralnoe Statisticheskoe Upravlenie, Narodnoe khoziaistvo SSSR v 1962 godu (Moscow, 1963), pp. 385,415,421.

TABLE 2

INTERCITY PASSENGER TRANSPORTATION, U.S.S.R., BY CARRIER, 1962, IN BILLIONS OF PASSENGER-KILOMETERS

Carrier	Billions of Passenger-Kilometers	Percentage Share of Total
Railroad (non-commutation)	145.2	74.6
Autobus (intercity)	23.2	11.9
Civil aircraft	20.3	10.4
River	4.6	2.4
Sea	1.3	0.7
Five-carrier total	194.6	100.0

Source: Tsentralnoe Statisticheskoe Upravlenie, Narodnoe khoziaistvo SSSR v 1962 godu (Moscow, 1963), pp. 381,385,416.

The rare possessor of a private automobile therefore faces many frustrations. Garages work under plans which make them reluctant to take on minor servicing jobs, since major overhauls and replacements contribute more effectively to plan fulfillment. Complaints indicate that spare parts are frequently not available. Filling stations sometimes do not have supplies of gasoline, or observe limited hours of business. All of this reflects the low priority assigned by the authorities to the private passenger automobile in the Soviet economy. For example, four years ago in Frunze, a regional capital of 250,000 people, there were fourteen hundred individual cars and fifteen hundred motorcycles, but only a single filling station. Car owners obtained gasoline illegally from truck drivers or through other devious channels.[5] A few years earlier, in a novel celebrating postwar progress, part of the story involved a happy vacation trip on the newly-paved highway from Moscow south all the way to the Crimea. Dramatic tension was provided intermittently as the vacationers faced a recurring crisis. It was not whether the next motel would have an empty room, with or without swimming pool, but whether the filling station said to be in the next city would have any gas! Gas is gratefully purchased in the U.S.S.R., even without trading stamps.

The current situation, then, may be summed up as follows: the 230 million people of the U.S.S.R. live in a largely industrial society that makes use of only about one million passenger cars, of which less than half are in individual ownership. Most passenger transportation is by public conveyance. There are perhaps seventy-five thousand taxis. Roughly half of the noncommercial passenger cars are owned by government organizations and assigned to leading officials. The remainder have been acquired, at very high prices, by patient citizens with ample cash, willing to keep their names on waiting lists and undergo the paperwork required to demonstrate eligibility, obtain a driver's license, etc. It is interesting to observe the pressures that come into play under these conditions.

For example, there was what we may call the "Krasnoyarsk incident." In this provincial district of Siberia, some enterprising municipal authorities decided in the spring of 1960 to develop rent-a-car services in the major cities of their territory. They did not simply purchase new automobiles. Instead, they sought to round up the passenger cars currently owned by various factories, offices, trusts, and other government institutions. "It was decided, on the basis of a territory executive committee decree, to set up centralized common-carrier units in place of the small separate garages of individual offices, factories and trusts. The intention was to assemble all the cars from the latter and to operate them from two new garages, one holding 150, the other 130 cars. The saving would be substantial. The Moskvich or Volga car that once stood idle in front of a director's office would be able to serve both

[5]Ibid, Vol. XII, No. 16, pp. 24-25.

its former individual owner and also several additional persons entitled to the use of a car in the performance of their duties."[6] How do you suppose the officials of these organizations reacted? They showed both imagination and initiative. As soon as the order was issued, requests came in to exempt cars as "special vehicles." "On the streets of Krasnoyarsk, Abakan, Norilsk, and other cities, dozens of passenger cars have started to appear with the most diverse emblems and signs, from the blue cross of the veterinary service to a neatly painted line reading 'Culinary Products Delivery.' There were 'mobile emergency repair cars,' 'operational-emergency-technical cars,' and still other special purpose cars." After three months, 107 cars had been turned in, but 166 had obtained exemptions.

What does the "Krasnoyarsk incident" show? Clearly government officials find that the cars assigned to them are convenient and useful for official and personal trips. They are reluctant to turn them in to a municipal pool. The centralized fleet would perhaps make more continuous use of each car, cutting costs, spreading overhead, and eliminating waste and duplication. But the officials who have tasted the delights of a personal car are reluctant to give their cars up.

Another important phenomenon arises under Soviet conditions, reflecting the chronic shortages of various consumer goods and services that have plagued the Soviet economy for many years. The cars that are personally owned by individual Soviet citizens are sometimes used to produce what the regime calls "unearned income." We have it on the authority of the Minister of Internal Affairs of the principal Soviet Republic that, where the state fails to provide adequate supplies of consumer goods and services, private citizens tend to move in to fill the vacuum.[7] An enterprising individual can use his car, for example, to bring fresh fruit or vegetables to cities where, at uncontrolled prices in collective farm markets, they command a substantial premium over their cost in producing areas. By the canons of Adam Smith, this function of relieving shortages and reducing price discrepancies is an honorable contribution to the general welfare. In the U. S. S. R., however, such activities are considered anti-social, and those who engage in them are termed "parasites," getting "unearned income" from their capitalist activities. Privately-owned automobiles figure prominently in the lurid accounts of the evil doings of such "speculators" when they are brought to trial under the campaign that has now been going on for four years.

Even more modest means of transportation can offend the authorities. In May 1962, Izvestia reported the case of a forty-seven year old schoolteacher, in a country district near the Caspian Sea, who gave up school teaching in favor of growing vegetables and fruit. Over seven years he built himself a brick house and planted a large vegetable garden, thirty-two fruit trees, two hundred and thirty-six grape plants, and sixteen hundred tomato plants. He bought a motor and installed a watering system. He built a hothouse. He bought a motorboat to carry the vegetables to a nearby city and beyond. His neighbors "expressed indignation and asked that the machinations of the swindler be looked into. Finally, criminal action was instituted against the inveterate money-chaser. The court decided to exile Stepanov from the province and to confiscate the house, the hothouse, and the motorboat."[8] In Soviet eyes, the profit-seeking motivation behind such private enterprise is a survival of the past, a selfish, anti-social drive to be cleansed from the soul of the new Soviet man. Where this motivation is present, the private passenger automobile must be seen, from an official point of view, as a dangerous instrument in the hands of parasites.

So far I have tried to sketch briefly the current situation in the U. S. S. R., both as regards the physical presence of passenger automobiles and as regards the attempts of the authorities to control their use. Let me now turn to prospects for the future, through weighing the forces at work.

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[6] Sovetskaia Rossiia, April 3, 1960. Translated in CDSP, Vol. XII, No. 14, pp. 24-25.
[7] V. I. Tikunov in Izvestia, April 13, 1962, p. 3. Translated in CDSP, Vol. XIV, No. 15, p. 23.
[8] Izvestia, May 26, 1963, p. 4. Translated in CDSP, Vol. XIV, No. 21, p.23.

First, we may assume, I think, that a mute underground revolutionary thrust is latent in the desires of the Soviet people. It has even been given oblique expression by a courageous academician who, in criticizing the modest target for 1965 automobile output that was proposed for the seven-year plan in early 1959, suggested that personal mobility was an important component of a high standard of living. It would not be surprising if the Soviet man in the street showed the same weakness for having his own car that has proved so powerful in North America and Western Europe. The automobile enables an individual in a mass society to get away, on his own, from the organized life around him. It permits footloose weekend jaunts with girl friend or family. It facilitates vacation visits to relatives or to scenic wonders. It is a time-saving convenience and it demonstrates one's status. Left to themselves, consumers will put automobile outlays ahead of health, education, and culture, to the distress of academics and planners. Western experience demonstrates conclusively the enormous strength of the urge to acquire a car, if this urge is given free rein.

But remember the views expressed by Khrushchev. In his eyes, that great incoming stream of bloated monsters, carrying commuters, one by one, into downtown chaos. was clearly irrational. Moreover it exemplified the "unorganized" quality of Western society that he has frequently criticized. The Soviet regime hopes to develop a different answer. The automobile would, as we have seen, be available mainly through municipal rent-a-car services, supplying them to the public for vacation and weekend trips. Daily commutation would continue to be by public carrier: bus, subway, trolley, or train. Moreover this government vision of a rational technical solution is backed by an equally important political and psychological vision of what is now called "full communism." Under full communism, as Marx wrote in 1875, "Society will inscribe upon its banners: 'from each according to his ability, to each according to his needs.'" Soviet theorists have recently developed the view that these needs should be interpreted as "the rational needs of a cultured man." Comic books and chewing gum are not cultured, and will therefore not be part of full communism. Senseless proliferation, duplication, ostentation, and selfish display are not rational, so they too will be absent, even when that great day of abundance arrives.

These matters have been carefully considered by Soviet theorists in connection with the new Party program adopted in 1961. It is recognized, for example, that summer cottages, private automobiles, and private truck gardens are still necessary among the incentives that motivate Soviet citizens. Responsible theoreticians caution against premature suppression of these rewards for hard work.

But the future is seen in rosier terms. There will be state parks, state summer resorts, and state-provided vacation facilities that will remove any need for private dachas. Abundant supplies of food will eliminate any need for personal gardens. And similarly, municipal rent-a-car services will meet any personal needs for passenger automobiles. Thus, as one enthusiastic doctor of philosophy argued in September 1960, "when the public forms of satisfying needs, both in terms of quantity and especially of quality of service, reveal their advantages, people will begin voluntarily to give up their dachas. . . . When all the necessary material and spiritual prerequisites are created, there will no longer be an economic necessity for a number of items of personal property (personal dachas, automobiles, personal savings, etc.). The spiritual prerequisites include a comprehensively developed social awareness: a developed sense of collectivism and the disappearance of all traces of a private-property psychology and survivals of egoism and individualism."[9] That is one vision of the Soviet future.

Meanwhile, survivals of capitalism are still evident. When the Vice-Director of the Academy of Sciences Institute for Complex Transportation Problems twitted me in 1957 about New York City traffic jams, I replied diplomatically (I thought) that Moscow's broad avenues would perhaps permit them to avoid such congestion. "Oh no," he said, cheerfully. "We will soon have traffic jams too!" It almost seems as though national

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[9] Ts. Stepanyan in Oktyabr, 1960, No. 9, pp. 3-12. Translated in CDSP, Vol. XII, No. 42, pp. 19-20.

stature requires traffic jams in one's capital city. This elderly, distinguished academician accompanied me from his building after our interview in order to show me, proudly, his own personal car parked in the street outside. Here was a major analyst of rational transportation showing appreciation of both the international and the individual status conferred by the automobile. Doesn't this suggest the strength of the forces against which the regime is contending?

Since 1957 the growth of truck traffic in Moscow, together with larger numbers of taxis and individual passenger automobiles, has required a number of traffic-relieving projects. A limited-access belt highway around Moscow is now nearing completion. Underpasses and other center-city projects remind a Western visitor of painfully familiar Western attempts to relieve traffic congestion. The Soviet capital appears to be coming slowly under the same pressures that have plagued American, European, and Japanese cities in recent times, but so far there are no signs of fresh Soviet solutions. Instead of competing with the West in finding engineering or city-planning answers to urban traffic problems, Soviet authorities appear to be placing major weight on the drive to suppress the desire for individually-owned passenger automobiles.

In summing up, it may be useful to identify six functions performed by the passenger automobile, and to reflect on ways in which each is likely to be fulfilled in the Soviet setting. First, a car is a time-saver in getting to and from work. The regime can minimize this consideration by providing frequent bus service to within, say, two blocks of every apartment and work place in urban Russia, along with efficient transfer points. Secondly, door-to-door movement by car eliminates the discomforts of winter cold and snow, summer heat and dust, and the rains and mud that mark the intervening seasons. The present generation of Russians is perhaps tougher in accepting these inconveniences than we have become. In any case, these two considerations can perhaps be dealt with through ample routes and service, covered shelters at stops, and a good deal more paving of roads.

The role of Soviet passenger automobiles in relieving food and consumer-goods shortages, as the so-called "parasites" conduct their so-called "private enterprise" operations, could be eliminated if the regime channeled enough resources into consumer-goods production and distribution to meet current demands. The great gains of the past decade in this respect still leave a large gap to be filled, deepened by recent difficulties in agriculture. Shortages mean, therefore, that for at least another decade the regime will see individual cars as potential instruments for flagrantly anti-social behavior; this peculiarly Soviet aspect of the problem will figure heavily in official policies toward automobile use.

Three further functions of the individual passenger automobile, less tangible than the three I have mentioned, also deserve our speculative contemplation. The car as a status symbol is well known in the West; can the new Soviet man be disabused of this motivation? The status aspect of car ownership is the least defensible against official strictures, and perhaps the least worthy of support. We can be sure of the regime's continued efforts to keep this a minor motive, though personal cars will remain a valued prerequisite for officials.

Passenger cars in the West have also provided unchaperoned privacy for boys and girls, or men and women; this function may well have special importance for Soviet urban citizens who still face extremely crowded living conditions. Soviet young people frequently have to defer marriage until they can find a room to share, and married couples generally limit their families because of the housing shortage. More cars would surely mean more lovers' lanes. Under these conditions, my guess is that both the authorities and the general public will give higher priority to building apartments than to supplying cars, at least for another decade.

Finally there is the role of the individual passenger automobile in providing unregulated mobility to its owner. Here the regime faces a profound dilemma. Cars are tremendously efficient in providing low-cost mobility for the infinitely diverse tasks of a modern society. Even if other carriers handle commutation and long-distance traffic, the passenger automobile is needed for a host of other assignments. Hence there is sure to be genuine pressure from all sides in the U. S. S. R. for more and more cars. Clearly, however, it is difficult to confine individuals to officially sanctioned uses of the automobile. As the stock of automobiles grows, even if cars are mainly corralled in municipal rent-a-car fleets, some Soviet officials are likely to be increasingly distressed at the enhanced power of the indvidual citizen to pursue his own independent purposes. They may be innocuous rather than sinister. The point is that they are unorganized. Thus one can foresee a silent contest between ideologues visualizing a rational future and citizens thirsting for personal cars.

Our sympathies lie, of course, with the individual. And yet my own hope is that the Russian people and their government will find a way to harness the uncontrolled proliferation of automobiles and highways that has created such difficult problems for wealthy Western nations. These problems are only beginning in the U. S. S. R. Suppression of the automobile, as suggested by party ideologues, is unlikely to be a feasible solution. Khrushchev's successors will probably have occasion to paraphrase Evan's law and observe, ruefully, that "dealing with the passenger automobile is more complicated than Nikita Sergeevich thought!" If the Russians find workable compromises between an automobile-dominated and a state-dominated society, the lessons will be useful all over the world. I'm not sanguine, but I wish them luck.

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THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 700 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

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