THE ECONOMIC EVALUATION OF PUBLIC INVESTMENT IN TRANSPORTATION IN UNDERDEVELOPED COUNTRIES

by

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ABSTRACT

Public investment in transportation forms a large part of the capital budget of many developing countries. In view of the scarcity of development capital, it is essential that the available capital be used to the best advantage. This indicates the need for careful analyses of proposed public investments in transportation.

Until quite recently, transportation investment evaluation in underdeveloped countries was almost entirely within the preserve of engineers, with economists taking little active interest in the spatial aspects of economic activity. Economists have recently taken a much more active interest, and new methods of evaluation are constantly being developed and older ones improved. However, there are still some unresolved methodological problems in the evaluation of public transportation investment, and a number of deficiencies in the application of the concepts and methods which have been developed. The objective of this thesis is to describe and evaluate the methods of transportation investment analysis now in use, identify the deficiencies in the existing methods and in their applications, and to propose methods of overcoming the deficiencies.

The research which has resulted in this thesis has been in three forms. One was a review of the published literature pertaining to public investment in transportation in underdeveloped countries. The second was in the author's experience in transportation investment analysis in Canada and overseas,

for agencies such as the Government of Canada and the World Bank. This experience presented the opportunity of reviewing unpublished writings on the subject, and of reviewing the methodology used and results produced by various consultants and study groups in a wide range of transportation investment analyses in underdeveloped countries. Much of this material, particularly the consultants' reports, is held confidential by the World Bank and by the governments of the countries involved, and therefore cannot be specifically cited in references. The third source of information was in discussions with consultants working in this field, both in Canada and abroad; with representatives of the governments receiving foreign aid for transportation investments, and with the personnel of the World Bank.

Chapter I of the thesis is a general introduction to the subject. It deals with the relative importance of transportation investment in underdeveloped countries, and states the objective of the thesis. In Chapter II the objective of public transportation analysis is established, and some of the principles which are basic to all analyses of public investment are considered. In considering the principles, some problems in their applications are identified and the recommended procedures are indicated.

All acceptable analyses of public transportation investments must ultimately result in some form of comparison of the costs and benefits of the proposed investment or investments.

In Chapter III the methods of measuring costs and benefits are described, and deficiencies in the current methods and their applications are identified. In the cases of relatively minor deficiencies, the correct methods and applications are shown in Chapter III. Possible solutions to the major problems identified are proposed in Chapter IV. The major deficiencies noted in Chapter III are the common failure to relate a proposed transportation investment on an individual link of the system, to the system as a whole, and the failure to relate the transportation system to the economy of the country. These deficiencies will almost invariably result in the incorrect measurement of costs and benefits.

In Chapter IV, methods of overcoming these deficiencies are described and evaluated. The most recent published method of conducting a comprehensive analysis which takes account of these factors is the Harvard Model, which consists of two parts: a transportation model and a macro-economic model. The difficulty of applying this approach is considered, and it is concluded that, although the Harvard Model is conceptually the best approach which has thus far been developed, it cannot be applied as a practical method of evaluation at this time. An alternative approach is suggested, based on the methodology used in a recent land transportation study of Dahomey, Africa. The analysis of traffic flows is based on the transportation portion of the Harvard Model, while the economic methodology was developed primarily by the author while engaged in the Dahomey study.

The conclusions are presented in Chapter V. It is concluded that transportation investment analyses could be greatly improved, and that most of the necessary improvements are incorporated in the Harvard Model. However, the Harvard Model has not yet been applied successfully, and this will probably be the case for at least the next five to ten years. The methodology used in the Dahomey study is recommended for use as a less sophisticated, but workable alternative, which is also more appropriate to the evaluation of specific investment proposals.

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CHAPTER I

INTRODUCTION

A review of the capital budgets of underdeveloped countries indicates that transportation investment plays a very large role in plans for economic development. In the period from 1959 to 1962, it is estimated that public transportation investment accounted for 22.5 percent of total domestic investment in Mexico, 25.2 percent in Sudan, 27 percent in Pakistan, 51.5 percent in Nigeria, and 55 percent in Columbia. Even in Japan, which has achieved a relatively high degree of economic development, public transportation investment at one point in this period accounted for 34.5 percent of total public investment.[1] Over 20 percent of the development loans made by United States and international lending agencies have been for transportation investment.

There are a number of reasons for this emphasis on transportation. It is an important aspect of economic development which is amenable to government action even in the most free-enterprise economies, and in fact, it is primarily dependent on government initiative. The large investment characteristics of road, railway, port, and airport development are beyond the

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[1]Gary Fromm, ed., Transport Investment and Economic Development (Washington: The Brookings Institution, 1965), p. 226.

capacity of private enterprise even in many advanced economies. It is also an attractive investment field for governments and lending agencies, in that visible results can be obtained in a relatively short time, in the form of highway, railway, and port facilities. In this respect, it has an immediate advantage over investments in fields such as education and public health, where the time period between investment and visible results is often quite long. It also has the advantage that the effects of the investment can be measured and forecast more easily than for other investments, with education and health again providing examples. There is also what might be called the transportation mystique; the intuitive feeling that transportation is the magic key to economic development.

These reasons are relatively unimportant, however, in comparison with the real reason for the emphasis on transportation in economic development. There is little question that transportation is a necessary precondition of economic development, and further, there is strong evidence that transportation is more than just a permissive element, but often is, in fact, the key to economic development. W. Rostow has stated that "transport is the most powerful single initiator of take-offs."[2] Whether true or not, the mere belief that this is the case is ample explanation for much of the emphasis on transportation.

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[2]Quoted from George W. Wilson,"Transportation Investment and Economic Development in Underdeveloped Countries," which appeared in the Papers of the Sixth Annual Meeting, Transportation Research Forum, 1965, p. 425.

Transportation alone is obviously not enough to produce economic development. Other investments, both public and private are necessary, usually in primary sectors such as agriculture, forestry and mining, but also in secondary industry, power, communications and other sectors. The natural resource base for these sectors must be present in some degree. Most important, there must be human resources not only in terms of numbers, but also in terms of knowledge and ability, health and energy, dynamism and attitudes; in short, with the ability and the will to work for economic advancement.

These are all necessary preconditions of economic development, and all imply investment requirements. The question is, how much should be invested in each? What combination or "mix" of investment inputs will contribute most to the economic and social objectives of the population? The problem is not really a problem of economic theory, in that there are logical economic principles which, if applied, could give reasonable answers. The problem is a practical one, and is seated in the difficulty, if not the impossibility, of measuring the future productivity of possible investments in transportation, communications, power, and other intra-structure sectors, in directly productive sectors such as agriculture, forestry, mining, manufacturing and other industries, and in education, technical training, health and welfare, and similar social fields. The answer is beyond the capabilities of existing analytical techniques, and this will be the case for many years to come. However, existing techniques can and do provide valuable guidance to the decision-makers who must allocate scarce development capital, and it is vital that these techniques be developed and improved as much as possible.

Transportation evaluation is among the more highly-developed tools for the measurement and evaluation of public investment, partly because it has received a great deal of attention, and partly because it is more amenable to measurement and quantification than are most other public investments. This development has taken place over relatively few years. Economic theorists have traditionally neglected or assumed away the spatial aspects of economic activity, and practicing economists have simply not become involved in transportation evaluation to any significant degree until the post-war years. There is still a wide gap between the two levels of transportation evaluation: the academic level, where economic theory is applied to transportation, and principles are evolved which indicate how the evaluation should be done, and the practical level, where the engineer and economist decide how the evaluation can be done, often within quite limiting time and budget constraints. It is unlikely that the two levels will ever completely converge, but the gap is narrowing. There is a fortunate tendency for the "academics"--the professors and researchers--to also become practitioners, while the practitioners--engineers, and more recently economists--are making increasing efforts to put the principles developed to practical application, and in fact to make substantial contributions to the theoretical aspects of transportation evaluation. This merging of the academic and practical approaches is another factor which has aided in the development of evaluation techniques.

Despite the significant advances made in the post-war years, there are still a number of deficiencies in the methods of transportation investment evaluation currently in use, and in the specific applications of the methods. The purpose of this thesis is to review the methods of transportation investment analysis, identify the deficiencies and problem areas, and propose solutions to the problems. The proposed solutions to the minor problems encountered in the measurement of the costs and benefits of proposed transportation investments are presented in the sections dealing with the individual costs and benefits. The proposed solutions to the major conceptual and practical problems are considered separately in Chapter IV.

Although the thesis concentrates on highway transportation in underdeveloped countries, the principles and problems considered are equally applicable to other modes of transportation and to advanced economies.

CHAPTER II

THE OBJECTIVES AND PRINCIPLES OF PUBLIC TRANSPORTATION INVESTMENT ANALYSIS

A. The Objectives of Public Transportation Investment Analysis

The ultimate objective of public investment analysis is to allocate resources in such a way that each resource makes the maximum possible contribution to the attainment of the goals of the population. The goals may or may not be stated; they may be explicit or implicit. They are politically determined, and while the economist may advise and recommend in the selection of goals, he cannot in his role as an economist, determine or establish the goals. The role of the economist, then, and of economic analysis as far as public investment analysis is concerned, is to assist in the allocation of resources so that their use may be optimized in the attainment of the politically-determined objectives.

Under normal circumstances, the most common primary goal of a country is the economic well-being of the population, and the most common means of measuring progress toward the goal is in terms of National Income. Thus, the objective most commonly presented to the transportation economist, or, in the absence of specific direction assumed by him, is the allocation of resources to and within the transportation sector in such a way that the resources make the maximum contribution to National Income.[1]

The allocation of resources to the transportation sector implies a number of important decisions in economic planning. Since it is not the purpose of this thesis to delve into the complexities of general economic planning, some simplifying assumptions are made. It is assumed that the allocation of resources between public and private uses has been determined, and a public budget established, however approximate. It is assumed that a capital budget has been formulated for the public sector, and that general priorities have been established among the various sub-sectors, such as agriculture, industry, education, health, transportation, and all of the other claimants to public investment funds.

This is not to imply that transportation analysis starts at this point; indeed, it plays an important role in general economic planning and in establishment of priorities. Ideally, the allocation of funds to the public sector, and to sub-sectors such as transportation, is based on the contribution to national goals that the funds can make in the various alternative uses. The allocation of funds to public investment in transportation would ideally be based on the net returns these funds will produce when employed in transportation, compared with the returns they would produce in alternative

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[1]National Income as used here may also be taken to include concepts such as provincial, state, or regional income, appropriate to the area and level of decision in any particular case.

uses. The net return from employment in transportation is ideally determined by economic analysis of all possible transportation investments. While this ideally would be the case, it is obviously impractical to attempt to measure the returns from alternative uses of public funds through an individual analysis of every possible public investment in each sector, and in practice general priorities are established on the basis of broad, aggregated economic, political, social and military considerations involving a great deal of personal and group judgement, as well as on the basis of formal economic surveys and analyses.

The assumption that a public budget has been established, and an allocation of capital funds to the transportation sector has been made, provides a convenient starting point for the introduction of transportation investment analysis; a point where the objectives of the analysis can be stated quite precisely. Ignoring political, social and military considerations for the moment, the objective of public transportation investment analysis assumed in this thesis is to determine the allocation of public funds within the transport sector in such a way that they will produce the maximum possible contribution to National Income.

B. The Principles of Public Transportation Investment Analysis

The problem of allocation of funds within the transport sector is again one of determining the net return on funds invested in one use or project, compared with the net return from alternative projects. In all but the most elementary methods of analysis, the procedures used involve the measurement of the costs and the benefits of various alternative uses, and the application of some criterion to select the preferable project or combination of projects.

In the measurement of costs and benefits, there are a number of principles which are basic to a competent analysis. These rules represent little more than elementary common sense and economic logic, yet in practice they are frequently neglected. The application of these principles appears throughout the following chapters of this thesis which deal with cost and benefit measurement and project selection criteria, and they are outlined here so that repeated references to them will not be required in the following sections. Although the principles are dealt with here in their application to public transportation investment analysis, they apply equally to all public investment analysis, regardless of the sector, and also to most private investment analysis. The order in which the principles are listed does not imply a judgement as to their priority or relative importance.

1. Define the Level of Decision

Public investment analysis may be carried out at a number of levels, ranging from the international level down through national, regional, and sub-regional levels, to the level of single government of municipal department and an individual project. The level on which the analysis is carried out has an important effect in determining which benefits and costs should be measured and how they should be measured, and may also influence the choice of criteria for project selection and ranking. The level of decision may be based on a geographically or politically-defined area, or it may reflect the viewpoint of a single government department, depending on the terms of reference established for a specific analysis and the interests of the body commissioning the study.

Studies at an international level of decision will normally be commissioned by the governments affected by the proposed investments, as for example, the St. Lawrence Seaway, or they may be commissioned by the governments in cooperation with an international agency such as the International Bank for Reconstruction and Development. At the national level, the decision-making body is normally the government of the country involved, although international development and lending agencies may also play an important part in establishing terms of reference and appraising the economic acceptability of the proposed investment. The regional level may be represented by a province or state, by a geographic area such as a river valley with potential for development, by a municipal area, or any of a number of similar criteria.

The necessity of establishing the appropriate level of decision at the beginning of an analysis can be illustrated by the relatively simple case of the possibility of improving the Alaska Highway which extends from east-central British Columbia, near the Alberta border, through the Yukon Territory and into

Alaska. Although the highway does not extend directly into the United States south of Canada, a large proportion of the traffic using the highway is through traffic between the United States proper and Alaska. The areas most directly affected by the highway are north-western United States, the provinces of Alberta and British Columbia, the Yukon Territory, and the State of Alaska, although the other parts of Canada and the United States would be affected to some extent. The evaluation of the public investment required to improve the highway will be approached from a number of levels of decision to illustrate the differences in the form and content of the analysis which would result.

The first approach is from the international level, and it is necessary to make some rather unrealistic assumptions for the sake of the illustration. It is assumed that the decision-making body is a supra-national one whose objective is to maximize the net benefits to the whole area which would be affected by the improvement, without regard to national, state or provincial boundaries. Assuming that none of the effects of the proposed improvement would extend beyond Canada and the United States, and that the objective of the authority is to make the maximum possible contribution to the combined National Incomes of the United States and Canada, the objectives of the analysis would be to determine the contribution to National Income that various possible levels of improvement would make, select the most desirable improvement, and compare its contribution with that of possible alternative uses of the investment funds required. The analysis will not be traced in detail here, but only described to the extent that it will be affected by the level of decision.

The first aspect to be noted is that a comprehensive analysis would require that all costs and benefits must be included, regardless of their location, and there would be no differentiation between costs and benefits to Canada and the United States; between Alberta, British Columbia, the Yukon Territory and Alaska. The distribution of the benefits may be noted, but the distribution among political divisions would not affect the magnitude of the benefits or the desirability of the investment. Effects outside of the direct area of influence of the highway would be analysed. For example, if many of the benefits to Alaska and the Yukon were derived from tourist and recreational activities which would otherwise have taken place in the Maritime provinces and east-coast states, then the losses or disbenefits to the latter areas would be deducted from the benefits of the former areas. Thus, the definition of the level of decision determines <u>which</u> costs and benefits should be counted; with an international level of decision, it would be concluded that all costs and benefits should be considered.

The level of decision also affects <u>how</u> costs and benefits are to be measured. In the following chapter on the measurement of costs and benefits, a distinction will be made between economic costs and financial costs. The financial costs are generally the costs as reflected by market prices, while economic costs represent the real costs to the economy in terms of resources used, and include adjustments to market prices to correct for the effect of unemployed or under-employed resources, and to remove transfer costs. Transfer costs normally consist of tax and duty items, which are merely transfers of wealth, and do not represent the use of economic resources. In the economic evaluation of public transportation investments at an international level of decision, adjustments would be made for all unemployed resources and transfer items. Thus, in calculating the economic costs of improving the Alaska Highway, if it is assumed that part of the labour required would otherwise be unemployed in Canada or the United States, then the market prices paid for the labour would be reduced to reflect the true costs to the economy, which may be very low if there is a high level of unemployment. This may not be a significant adjustment in the case of the Alaska Highway, but in a similar case involving underdeveloped countries, it could be an important factor. Similarly, all taxes and duties levied by Canada and the United States on resources used in the highway improvement would be removed from their market prices, since they do not represent true costs to the economy. Similar adjustments would be made to the benefits of the improvements. A large part of the benefits from the improvement of the existing highway is in the form of savings in vehicle operating costs. One of the savings may be in the form of vehicle crew time, which in the long run implies fewer man-hours utilized. If these crews would be otherwise unemployed, then the financial savings must be adjusted downward to reflect this situation. Vehicle operating cost savings would also be adjusted downward to remove the taxes and duties levied on vehicles, parts, fuel, and other components of operating costs. At the international level of decision, all of these adjustments would be made regardless of where the unemployed or underdeveloped resources are located and regardless of which government or level of government levies the taxes and duties.

The level of decision is also a factor in the selection of the methodology and evaluation criteria used. At the international level of decision, the methodology must be capable of dealing with a large number of variable factors, with a high degree of interdependence among the variable factors, and large quantities of input data. The complexities of each of the various relationships may be no greater at the higher levels, but the sheer volume of input data and the interdependence among the various factors may dictate a more sophisticated methodology than would suffice for an analysis at a lower level. This point will be considered in more detail in a later chapter; it is sufficient to state here that the level of decision must be established at the beginning of the analysis in order that appropriate methodology and criteria may be selected.

The second approach to the evaluation of Alaska Highway improvements is at the national level of decision. The decision-making body is assumed to be the Government of Canada, and the objective of the government to maximize the contribution of the highway investment to the National Income of Canada. For the sake of simplicity, it is assumed that there will be no consultation between the Governments of Canada and the United States, and that only the national interests of Canada will be considered.

The first departure from the format of the analysis as it would be at the international level of decision is in the determination of what will be considered as costs and benefits, i.e. what will be measured. In the previous case, it was stated that all costs and benefits would be included, regardless of their location. At the national level, this is no longer true. The cost of improving the portion of the highway within Alaska would no longer be considered, since it is outside the sphere of influence of the decision-making body, under the assumptions adopted. Similarly, benefits in the form of accelerated economic development taking place within Alaska would not be considered, nor would savings in the operating costs of vehicles belonging to non-residents of Canada, except to the extent that the benefits could be recovered in the form of tolls, licenses or special permits. The benefits to Canada in the form of increased tourist and recreational activities would still be counted, and offset as before by any concomitant disbenefits to other parts of Canada, but disbenefits to areas in the United States would no longer be deducted. In short, any effects in the form of costs and benefits occurring outside of Canada would no longer be considered, except to the extent that the costs could be inflicted upon the residents of Canada, or the benefits could be recovered by Canada. This is far from a complete treatment of items which would no longer be included in the analysis at the lower level of decision, and is intended merely to illustrate the point that the definition of the level of decision has an important impact on what is to be measured.

The determination of how the various cost and benefit items are to be measured is also affected by the change in level of decision. Here, it is assumed that although the improvements would be financed and carried out by the Government of Canada, some of the labour, equipment and materials used would be of United States origin. As before, the market prices of Canadian resources would be adjusted to reflect the degree of unemployment and any distortions which cause market prices to reflect other than economic values. However, no adjustments would be made to the actual prices paid for United States resources used. The fact that American labour might otherwise be unemployed, for example, does not affect the economic cost to Canada of the American labour. Adjustments would still be made to remove the effect of Canadian taxes and duties levied on materials and equipment in order to arrive at the true economic costs, but any taxes and duties levied by the United States on American materials and equipment used, prior to their export to Canada, would now be considered to be economic costs at the national level of decision. The same is true of savings in vehicle operating costs. Assuming that all of the vehicles involved were of Canadian or American origin, all taxes and duties would be deducted from the costs at an international level of decision. At the national level, only taxes and duties levied by Canadian governments would be deducted.

In the next step downward in the levels of decision, it is assumed that the decision-making authority is the Government of British Columbia, and it is assumed that at this regional level, the deciding authority is operating completely independently of the Government of Canada and other provincial governments, and that the sole objective is to evaluate the possible improvement of the highway in the light of Provincial Income. Similar considerations to those outlined above will prevail: only those costs and benefits occurring within British Columbia will be considered. Benefits accruing to British Columbia, nor would offsetting disbenefits to areas outside of British Columbia be considered. Vehicle cost savings to non-British Columbia residents, except to the extent that these could be recaptured by British Columbia, would not be included in the analysis. Resources from outside British Columbia would be valued at market prices, regardless of unemployment or under-employment.

As the lower levels of decision are reached, it may also be found that less complex and sophisticated methods of analysis can be used with satisfactory results, perhaps resulting in the transition from a computerized analysis to a manual analysis. Only after the level of decision has been determined can the probable scope and complexity of the analysis be estimated and decisions made regarding the methodology to be used.

For a number of reasons, then, only some of which have been indicated here, is it considered that the definition of the level of decision appropriate to the analysis is an important principle of public transportation investment analysis.

2. Evaluate All Alternatives

There are very few objectives which can be attained by one means only. A question which should always be considered therefore, is whether transportation investment is the only or the best solution to a particular problem, or the best path to a stated objective. An advantage which may be claimed for improved transportation is that it extends market areas and thus helps establish economies of scale, permits specialization and division of labour, and in general helps to promote an exchange economy. However, these same advantages may be equally attained by immigration and other means of increasing the population of an area, by transfer payments designed to increase consumption, by various means of increasing disposable income, or any number of alternative methods. Transportation is merely a means to an end, and it should not be assumed that transportation investment is the only solution, at the cost of excluding consideration of alternative means to attain the objective. In many cases, perhaps most, the transportation analyst is not required to consider this aspect and indeed may be precluded from considering it and rather be presented with an externally stipulated target rate of return, the "opportunity cost of capital," which will be considered in the next chapter. Whenever possible, however, the analysis should include an investigation of possible alternatives to transportation investment, even if each possibility is not to be formally evaluated.

Within transportation itself, all possible alternatives should be considered, including where appropriate, land, water and air transportation, and the various modes of land transportation. Not only should each mode of transportation and possible combinations of modes be considered, but different possible standards of the modes should be included in the analysis. It is not sufficient to show that there is a satisfactory rate of return on a proposed four-lane highway, which may be the standard selected because it is "good engineering practice" under certain conditions and traffic volumes. The goal is always optimization, and it is necessary to show that this is a better solution than a two-lane paved road, or perhaps than a two-lane gravel road now, followed by paving in five or ten years, and possible future widening. Unfortunately, it is often the case that standards which are appropriate in one country or set of circumstances are applied to other countries and in other circumstances, without consideration of the logic or reasoning behind the standards. All reasonable standards and configurations should be considered. This does not mean that every remote possibility must be formally analysed, but they should be rejected only for good and sufficient reasons clearly stated.

There is one final alternative that is often neglected: the "do nothing" alternative. A "problem" or "undesirable" situation is noted, for example, traffic congestion on a road link, and a decision is made, often politically, to remedy the situation. Various schemes are suggested, perhaps including the construction of a bypass or alternative route, or the widening of the existing route, and the best of the remedies is selected as a desirable project for investment.[2] This is not sufficient to establish the economic viability of the investment; the most economical course of action may be to allow the congestion to persist for some period of time, i.e. to do nothing. It is quite possible that the savings in congestion costs would be considerably smaller than the cost of the investment required to avoid them. This is not to suggest that the economic evaluation should be the only or even the ruling factor; political, social or military considerations may legitimately overrule the economics, but even here, the economic evaluation of the "do nothing" alternative

[2]A report dealing with proposed new crossings of Burrard Inlet in Vancouver provides an example of a similar situation. A number of alternative schemes were considered, with the objective of relieving congestion on the existing crossings, but the "do nothing" alternative was not among those analysed in the original report. The report has not been publicly released.

should be done, in order that the responsible authorities have an indication of the cost of the political, social, or military benefits to be derived.

In summary, all alternatives should be given at least preliminary consideration, including non-transport alternatives, alternative modes within transportation, various standards within the modes, and various possibilities regarding the timing or staging of the investments. Those not clearly inappropriate from inspection and reasonable judgement should be analysed in sufficient detail to permit evaluation within the required level of confidence.

3. Include All Costs and Benefits

Many errors in investment analysis are attributable to the neglect of this principle. The costs and benefits to be included in an analysis must be determined in relation to the appropriate level of decision as noted above. The measurement of costs and benefits is covered in the next chapter; here only the most common errors and omissions are considered.

Perhaps the most common fault consists of attributing benefits to a specific transportation investment without including other investment costs, both transport and non-transport, required to realize the benefits.[3] In a number of highway

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[3] Hans A. Adler, Sector and Project Planning in Transportation (Washington: World Bank Staff Occasional Papers Number Four, 1967), p. 42. This point has also been made by other World Bank personnel who are responsible for evaluating consultants' reports.

analyses, substantial benefits have been credited to the projects in the form of increased agricultural production, without mention of such costs as agricultural equipment, irrigation, land clearing, fertilizer, labour, and all of the other factors which are required in addition to the highway investment to bring forth the increased production. Not only should these associated costs be included, but also it should be shown that there is a reasonable probability that the investments will actually be made; otherwise, the benefits will be theoretical or "paper" benefits which may not be realized. Similarly, associated transportation investments are often neglected, including such things as feeder roads, loading, unloading and storage facilities, and other necessary parts of the distribution process. The capital cost of the vehicles expected to use new or improved highway facilities is normally included in the cost component of whether the country in question will have the foreign exchange required for the purchase of the vehicles implied in the traffic forecasts.

Apart from the problem of associated investments, there is little uncertainty regarding which costs are to be included once the level of decision has been defined. The benefits to be included are considerably less certain, and this aspect of investment evaluation has probably been at the root of more disagreement and error than any other. One of the most common errors is to attribute, as benefits to a project, activities which have merely transferred their locations as a result of the project.[4] For example, a benefit often attributed to highway projects consists of agricultural, industrial or commercial development which is expected to take place along the highway. For this to be a valid benefit, it is necessary to show that this development does not represent a transfer of activities which are already in progress at other locations inside the area implied by the level of decision, or which would have been conducted at other locations in the future, in the absence of the highway project. There is undoubtedly some benefit attributable to the project even if this development is only a transfer of activity which would have occurred in any case in other locations; otherwise, there would be no incentive to locate along the new highway. However, the benefits in this case are considerably smaller than the net value of the production, which would be the appropriate measure of benefit if the development would not have occurred in the absence of the highway.

A similar error arises in estimating the economic growth which will take place in the area after construction of a new highway, and attributing the growth to the highway, without deducting the growth which would have occurred in any case, whether the highway were built or not. In this instance, the cause of the error is the application of a "before and

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[4] Ibid., pp. 45, 46.

after" approach rather than the proper "with and without" approach to investment evaluation. The proper test asks what growth will occur with and without the investment, rather than comparing growth before and after the investment.

Hans Adler gives a further example of an erroneous "before and after" approach.[5] In the evaluation of a new expressway in Japan, the responsible authorities determined that the operating costs of a truck on the existing highway in 1958 were the equivalent of about fifteen cents per kilometer, excluding taxes. The costs on the new expressway, scheduled to open in 1969, were estimated at eleven cents, or a saving of four cents per truck kilometer. This saving was then applied to the estimated truck traffic for the years 1969 to 1979 to derive the benefit of the new expressway in the form of operating cost savings to truck traffic. As Adler points out, the comparison of costs on the existing highway in 1958 with those on the expressway in 1969 fails to take account of the fact that the increasing congestion on the existing highway would have increased operating costs to considerably more than the 1958 level by 1969. Furthermore, the operating costs on the existing highway would have continued to increase after 1969, while those on the new expressway could be expected to remain relatively stable until 1979, and the increase thereafter would be less pronounced than on the existing high-

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[5] *Ibid.*, pp. 45, 46.

way. Adler correctly concludes that the benefits of the new expressway were underestimated. However, he fails to mention the possibility of generated traffic in this situation. It is probable that the reduction in operating cost will result in an increase in the total volume of traffic, which means that the savings in vehicle operating costs would be somewhat smaller than Adler implies, since the original traffic will be operating under conditions of higher total volumes.[6] Here again, the "with and without" approach which would measure the total costs with the investment and the total costs without the investment, would give the correct measurement of the savings in truck operating costs for the original or "normal" traffic, assume proper account was taken of generated traffic. The application of the "with and without" approach is sufficiently important that it could by itself be considered a principle of investment analysis.

It is essential that all costs and benefits associated with the investment be included in the analysis. It is equally important that they be included only once. Errors of double counting are most common in the measurement of benefits, although they do occur occasionally in cost measurement. One possible example would be the inclusion of the cost of land purchase for highway or railway right-of-way in the construction costs, and the inclusion of a disbenefit consisting of the

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[6] There will also be an additional benefit, to the generated traffic.

attendent loss in net value of production resulting from taking the land out of agricultural or other use, in the calculation of economic benefits. Problems of this kind applying to cost calculations are rare, however.

Double counting of benefits occurs in a number of forms. One is in calculating the savings in vehicle operating costs resulting from a new or improved highway, and adding to this the increase in land values resulting from the transportation improvement. In most cases, a large part if not all of the increase in land value is the direct result of the reduced cost of access to the land, and this benefit has already been counted in the form of reduced transportation cost. It has even been suggested that non-user benefits should never be added to user benefits; that double counting will always result.[7] This is an extreme stand, as many examples could be cited of cases where the total benefits of a project are reasonably estimated to be greater than the user benefits alone,[8] but the point that double-counting may result is a valid one.

Another instance of double counting involves the estimation of benefits to generated traffic. This is traffic

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[7]R.M. Zettel, The Incidence of Highway Benefits (Highway Research Board, Special Report 56, 1959).

[8]Peter Lewis, Notes on the Economic Assessment of Road Projects (Bangkok: Royal Highway Department of Thailand, 1965), p. 7.

which would not have moved in the absence of the new or improved facility, and it usually represents the transportation of goods which would not otherwise have been produced, goods which would have been produced but not transported, goods which were previously produced and transported, but will now be transported greater distances, or more usually, a combination of these.

The measurement of benefits to generated traffic is very imprecise, as will be explained in the next chapter, but an approximation is possible. The double counting occurs when the estimated benefits to generated traffic are added to the net benefits of increased production attributable to the highway.

A third example of the double counting of benefits is the addition of increased road user tax revenue to the other benefits of a highway investment. This has appeared in a number of investment feasibility studies,[9] yet no examples of the reverse situation have been found in the studies reviewed. This would be a case such as a new road link which resulted in a significant decrease in distance travelled by vehicles between an origin and destination, which would in turn result in decreased road user tax revenue.[10] If increases in user

[9]This was done in two confidential consultants' reports reviewed by the author in Thailand, and subsequent discussion with World Bank personnel confirmed that it is not an uncommon error.

[10]Assuming generated traffic does not offset the reduced distance.

tax revenue are to be considered as economic benefits, then surely decreases should be economic losses. In fact, it is incorrect to consider either in the economic evaluation of an investment. Road user taxes represent only a transfer of wealth from the private to the public sector, and are not in themselves benefits of the investment. They are valid factors in the analysis of the financial effects of the project, but not in the analysis of the economic effects. Although this is often considered a case of double counting of benefits, it is actually more a case of counting non-existent benefits.

In summary, all costs and benefits appropriate to the level of decision should be counted, they should be counted only once, they should be directly attributable to the investment, and a reasonable basis should be established for believing that the benefits will actually be realized.

4. Consider the Timing of Costs and Benefits

There are three considerations in the timing of costs and benefits: the time period of the analysis, the time stream of costs and benefits within the period, and the discounting of costs and benefits to a common point in time. In determining the appropriate time period for an investment analysis, a number of factors must be considered. The first is the physical life of the facility. There is far from complete agreement regarding the physical lives of major transportation facilities, and even if there were rough agreement on average lives, these would vary considerably with soil and climatic conditions, methods of construction, levels of maintenance and volumes of traffic. Furthermore, the physical lives of component parts of a facility may be quite different. In the case of a highway for example, the right-of-way could be considered to exist in perpetuity, earthworks will last for perhaps fifty years, but possibly more or less under different conditions, the wearing surface may have a life of from five to twenty years, and the base course from five to thirty years.[11] Any of these very rough approximations could vary greatly depending on the conditions. Therefore, the physical life of a facility is often difficult to estimate, and in any case, it provides a guide only to what the maximum period of the analysis might be. When the life of a facility under favourable environmental conditions and with conscientious maintenance could be greater than fifty years, the risk of technological obsolescence becomes very real, as does the possibility of changing travel habits and distribution patterns, and other factors which could make the economic life of the facility shorter than its potential physical life.

In practice, the limiting factor which probably more than any other determines the time period of the analysis is the ability of the analyst to forecast future economic and demographic trends and traffic flows. The period for which a forecast can reasonably be made depends on a number of factors, including the quality and quantity of the historic data available, the consistency of past trends, the resources

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[11] Peter Lewis, op. cit., pp. 12-13.

available to carry out field work to determine the production potentials of various sectors of the economy and the plans for their development, and similar considerations which vary from country to country and project to project. Perhaps the best indication of the reliability of the economic and traffic forecasts made in transportation studies in underdeveloped countries, and of the length of time for which forecasts can be made with reasonable confidence, would be gained by a comparison of forecasts made at various times in the past with the actual situation at the present time. The literature review conducted in the preparation of this thesis failed to disclose the publication of such comparisons.[12] The review did indicate that most of the studies adopt a time horizon of fifteen to twenty-five years, with a twenty-year period being the most common.

No standard guide can be established for application to all cases, and it must therefore be left to the analyst to determine the period of time over which forecasts can be reasonably made in each case, considering the data and resources available to him. Having established this, it would then seem prudent to adopt as the period of the analysis the physical or economic life of the facility or the length of time over which forecasts may be reasonably made, whichever is the shorter. If it is considered necessary to recognize a

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[12]According to Mr. Jan de Weille of the World Bank, the Bank is now considering undertaking a study of this nature.

physical life which is longer than a reasonable forecast period, salvage values at the end of the period, properly discounted, may be deducted from the costs. This should be done with extreme caution, however. In the case of a highway for example, attributing a salvage value to anything but the right-of-way really implies a traffic forecast extending beyond the period of the analysis, since a highway is of value only in its function as a transportation facility. Also, the cost of clearing the right-of-way so that it may be returned to other uses may partly or completely offset any salvage value. In any case, the cost of capital in most developing countries is considered to be in the range of from eight to twelve percent.[13] In many cases it is probably above twelve percent. At these high rates, assumptions regarding events to take place twenty years in the future have a relatively small impact when the values are discounted to present worth.

Once the period of the analysis has been established, the time stream of costs and benefits within the period must be considered. The usual characteristics of a transportation investment include a large initial capital investment followed by annual benefits which increase each year as traffic volumes increase. This pattern implies a significant time difference in the incidence of costs and benefits, and since money now is

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[13]Hans A. Adler, op. cit., p. 40.

worth more than money later, this difference must be recognized. Assuming a three-year construction period for a facility, the costs should be allocated specifically to the year in which they will occur. Similarly, maintenance costs should be calculated for specific years if there is any reason to expect that they will vary from year to year in a predictable way. A common pattern in highway maintenance is to have relatively low but increasing annual costs in the early years, followed by a large expenditure when major resurfacing is required, followed again by a relatively low but increasing annual cost. The use of an average annual maintenance cost, as applied in some of the studies reviewed, does not take full account of these characteristics, and should be avoided if the costs are reasonably predictable.

Benefits should also be allocated to specific years. Where benefits are primarily in the form of vehicle operating cost savings, the annual benefits normally increase as traffic increases, resulting in annual benefits in the later years which are considerably larger than those in the early years. When benefits are in the form of new or increased agricultural production, there may be a considerable time lag between the completion of the project and the realization of the benefits, as land is settled, cleared, perhaps irrigated, and otherwise made ready for production. Again, the use of an average annual benefit rather than allocating benefits to specific years fails to take account of these time differences, which may be particularly important when high discount rates are used. This does not imply that separate and detailed analyses must be done for each year over the period of the analysis, but the timing of benefits should be considered in detail for perhaps the first five years, and at five-year intervals thereafter.

All costs and benefits occurring over the period of the analysis must then be brought to comparable values at a common point in time. The results of the analysis will not be affected by the point selected, although the conventional approach is to discount all values to the first year in which an expenditure on the project is made.

There are many other points or rules which could reasonably be included among the principles of public transportation investment analysis. The above principles have been selected because they are considered to be the most important, and because they are the ones most often neglected or misapplied in practice. The examples used in illustrating some of the principles have also served to indicate a number of deficiencies in the application of existing methods of investment evaluation. There are no serious conceptual problems involved in the principles; the problems are primarily in their application. Thus, although the deficiencies identified may be quite important in their effect on investment evaluations, they are relatively simple to remedy through the use of the procedures recommended above.

CHAPTER III

THE MEASUREMENT OF COSTS AND BENEFITS

A. Traffic and Economic Forecasts

All of the studies reviewed in the preparation of this thesis made forecasts of the traffic volumes expected to use the proposed facilities or improvements which were being evaluated. Most of them also made economic forecasts of some kind in the course of the analysis. That these forecasts are necessary in the economic evaluation of proposed transportation investments is obvious. However, traffic and economic forecasting are complete studies in themselves, and a detailed treatment of them is beyond the scope of this thesis. They will be considered here only to the extent necessary to support the following sections on the measurement of costs and benefits, and to identify the major deficiencies in the methods commonly used.

In the forecasting of traffic, distinctions should be made among normal, diverted and generated traffic. Normal traffic occurs only on a facility which was previously in existence, and consists of the traffic volume which would use the facility regardless of whether it were improved or not. Diverted traffic is traffic which diverts from its existing route to a new or improved facility. The origins and destinations and mode of transportation of this traffic may or may not be the same after the diversion. Generated traffic is traffic which would not have existed without the addition of or improvement to the facility and therefore varies according to the addition or improvement proposed. These distinctions are important in the analysis of single transportation links or very simple networks, but they are very difficult to distinguish in a complex network where many single improvements and combinations of improvements are possible. However, the concept that there are these different types of traffic is no less valid in a complex systems analysis, and since the benefits to the different types of traffic are measured differently, the distinction will be retained throughout this thesis.

Traffic forecasts are made by a number of methods, ranging from a simple extrapolation of past trends to sophisticated models which attempt to simulate the movements of individual products and of people, distribute them on the basis of a linear program, gravity model or some similar technique, and assign them to specific routes, modes of transportation, and vehicle types. In all cases, the first task is to determine the existing or base-year traffic as accurately as possible. This is normally done by origin-destination surveys and traffic counts, supplemented by records and data regarding past surveys and counts where these are available, and seldom presents any difficult problem as long as sufficient time and resources are available. The projection of future traffic is not so simple. It is here that the greatest problems arise, and the greatest deficiencies are found in practice. One of the most serious deficiencies found in the studies reviewed was the failure to relate specific investment proposals and their attendant traffic, to the economies of the areas affected. In some cases, the economic environment of the project is not considered at all. Rather, the base-year traffic is estimated, projected into the future, and the whole investment is analysed on the basis of savings to this traffic. The projections are often made on the basis of past trends in traffic, vehicle registrations, motor fuel consumption, and other general indicators of growth which apply to the country as a whole or to specific parts of the country, and which may bear little relationship to the specific link or links being studied.

This was the case in a study made in 1966 to assess the economic feasibility of improving a road between Bangkok and Sriricha in Thailand. The traffic volumes for the base year, 1965, were derived from counts made by the Royal Highway Department, supplemented by a brief test count made by the consultant. On the basis of counts made by the Royal Highway Department in 1959 and 1961, it was estimated that truck and automobile traffic was growing at a rate of seventeen percent per year, while bus traffic was growing at two percent per year. The consultant assumed that bus traffic would continue to grow at two percent over the period of the analysis, but that the growth rate of other traffic would decline to seven percent per year by 1984. This assumption was based on forecasts made by another consultant studying another highway in a different part of the country. A benefit-cost ratio was then calculated for the proposed investment, based entirely on the reduction in vehicle operating costs which were expected to result from the proposed highway improvement.

This example is not claimed to be one of the better studies of transportation investment, but neither is it the worst, and it serves to illustrate some of the deficiencies which are often encountered. No attempt was made to relate the base-year or future traffic to the movements of the commodities and people which were expected to produce the traffic. Not only was future traffic not related to the factors which were expected to produce the traffic; it was forecast using growth rates appropriate to a different part of the country, and may possibly have borne no relationship at all to future growth in the area of the Bangkok-Sriricha road. No consideration was given to the effect of the proposed road improvement on the volume of traffic. The "consumption" of transportation, like that of most goods and services, varies with the price, and an improvement of transportation facilities which has the effect of reducing the cost to the consumer will normally result in an increase in the quantity consumed. In the case of a highway, this is manifested in an increase in traffic volumes, or "generated" traffic, which will be considered further in a later part of the thesis. The fact that additional traffic would be generated by the road improvement means that the original traffic will now be operating under conditions of higher total volumes, with an attendant increase in operating cost due to the effect of traffic congestion.[1] This would to some extent offset the benefits to the original traffic.

In developing the benefit-cost ratio, the consultant considered only the benefits accruing to the original traffic. No consideration was given to the possible effect of the road improvement on the economic development of the area. This point is related to some extent to the failure to consider generated traffic, and it too will be considered more fully in a later part of the thesis. Finally, no account was taken of the interaction between this road and other roads in the area and in the country as a whole. Except in the most unusual cases, each road link is a part of a total network, and a change in an individual link can be expected to have an effect on some or all of the other links. Many of these deficiencies in the analysis can be attributed to the incomplete traffic studies and forecast and to the total lack of economic studies and forecasts. Even if they could not be thus attributed, comprehensive traffic and economic studies and forecasts are necessary to remedy the deficiencies.[2]

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[1]Above some level of traffic,each additional vehicle added to the traffic stream increases the operating cost of all vehicles in the stream. These congestion effects usually begin at quite low traffic volumes. See H.D. Mohring and M. Harwitz, Highway Benefits, an Analytical Framework (Chicago: Northwestern University Press, 1962), p. 76.

[2]In fairness to the consultants in these studies, it should be noted that in reviewing their reports, no indication of the time and budget constraints imposed on the consultants was available. To a large extent, the deficiencies may be attributable to these constraints, or to unduly restrictive terms of reference.

In a second example, the problem is in the failure to directly relate the economic studies and forecasts to the traffic studies and forecasts. In a study of a proposed road improvement in Brazil in 1967, comprehensive economic forecasts were made, considering individual industries and products. These were then aggregated to arrive at the general conclusion that the whole area could sustain an economic growth rate of eight percent per year over the period of the analysis. This growth rate was then applied to the base-year local truck traffic to produce a forecast of local truck traffic. This procedure implicitly assumes that the transportation requirements of the area will increase at precisely the same rate as the general economy of the area, which is not necessarily true. In addition, although this study mentions benefits other than those accruing to highway users, these benefits are not quantified and included in the economic analysis. The consultant states that "... the actual calculations of benefits ... are limited solely to quantifiable benefits as any attempt to include non-user benefits might unduly enhance the results and detract from the fact that user benefits alone are enough to justify completion of the project." This implies that non-user benefits are not quantifiable, which again is not necessarily true. The fact is that no economic and traffic forecasts were made which took full account of the effect of the proposed road improvement, and this being the case, not only were the non-user benefits not quantifiable, but also some of the user costs and benefits, related to generated traffic, were not quantified.

In the economic evaluation of the Thonburi-Paktho Highway in Thailand in 1966, an attempt was made to relate the proposed investment to the economy of the area in which it was to be located.[3] The production and consumption of the major agricultural and other commodities was estimated for a number of zones into which the area was divided, and population densities and concentrations were identified. These were related to the base-year traffic by regression analysis, taking into account the cost and service characteristics of the transportation facilities. The economic and demographic factors were then forecast, and used as the basis for traffic forecasts, using the relationships established in the base year. Two economic and traffic forecasts were made, one assuming no major changes in the transportation facilities, and the other assuming that the proposed new highway would be in operation at the beginning of 1970. This permitted the estimation of generated traffic, and the benefits in the form of economic development. However, although this method was an improvement over the methods used in the other studies noted, the measurement of

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[3]General Engineering Company Ltd., _Feasibility Report, Thonburi Paktho Highway, Kingdom of Thailand_ (Toronto: 1967). This report, like the others reviewed, has not been publicly released. The comments on this study are from the author's personal knowledge, gained while acting as the project director for the economic feasibility portion of the study.

total benefits was still based primarily on the savings to road users, and no account was taken of the possible effects of the new road on transportation facilities outside of the immediate area nor on economic development effects outside of the immediate area. These external effects could have been significant, since much of the traffic expected to use the new road was through traffic, with origins and destinations outside of the area considered.

The first of the above examples would not generally be considered a good economic evaluation study. However, personnel of the World Bank advise that the latter two are considered by the Bank to be among the best of the reports the Bank has received, in spite of the deficiencies outlined here. The major problem which has been identified in considering the forecasting methods used in the studies reviewed is the failure to relate the proposed investments to the economy as a whole. This results in placing undue emphasis on vehicle operating cost savings, and the neglect or complete exclusion of the other economic effects of the investment. That this is a serious and common problem is confirmed by the comments of some of the personnel of the World Bank. Vincent Hogg, a transportation economist with the Bank, states:

> While it is appreciated that consultants have to work within specific terms of reference for a specific project, far too often studies are carried out as if the project being considered were divorced from the rest of the economy. . . . A major defect in some study reports is the failure to relate the sometimes voluminous quantity of

> general economic information about the country and its transport system to the specific project under review. . . . A still further weakness of many feasibility studies is that future traffic is not estimated on the basis of clearly identified increases in real output in the service area of the project or resulting from it. Future traffic on a particular road, for example, may be derived from an uncritical trend projection of total vehicle registration in the country, or a correlation between G.N.P. or some other aggregate economic data.[4]

In his book entitled Quantification of Road User Savings, Jan de Weille states,

> On the benefit side, most analyses of the economic desirability of investments in road construction put great, if not exclusive, emphasis in practice, on the road user savings aspect.[5]

This common failure to relate specific investment proposals to the economy is perhaps the most important deficiency of the methods currently in use, and it illustrates the necessity of comprehensive traffic and economic studies and forecasts which take account of the interdependence between the specific links under evaluation and the whole transportation system, and between the transportation system and the economy. These interdependencies cannot be fully considered in a single traffic and economic forecast; a series of forecasts is required.

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[4] W.V. Hogg, Feasibility Studies, an International Lender's View (A paper prepared for presentation to the Conference on Civil Engineering Problems Overseas, sponsored by The Institution of Civil Engineers, London, 1966), pp. 38,39.

[5] Jan de Weille, Quantification of Road User Savings (Washington: World Bank Staff Occasional Papers Number Two, 1966).

The initial economic, demographic and traffic forecasts should be based on the existing transportation system in the region, and on the assumption that there will be no basic changes in the system over the period of the analysis. However, the objective of the analysis is to evaluate possible improvements or additions to the transportation system, and these improvements and additions will affect the volumes and the patterns of production, consumption and traffic in all but the most unusual circumstances. Thus, for each proposed change or group of changes in the transportation system, revised economic and demographic forecasts must be made. The changes in economic and demographic factors in turn have effects on traffic volume necessitating a new traffic forecast which in turn may suggest further changes in the transportation system. Thus, rather than a single economic and traffic forecast, a series of forecasts is required, implying an iterative procedure which continues until a state of equilibrium is reached.

The review of past transportation studies failed to disclose any instances where such a procedure had been successfully applied, and the major problems noted above solved. These problems will be considered further in the following chapter, where a possible solution will be proposed.

Before proceeding to the measurement of specific costs and benefits of public transportation investments, some further comments on traffic forecasting should be made. In a number of the studies reviewed, the different vehicle types in the traffic streams were aggregated into one or two "average" vehicle types, primarily for ease of calculation. It is preferable that a distinction be made among the various vehicle types in the traffic stream. The different vehicle types have different operating and cost characteristics, and these must be recognized in the analysis. Furthermore, the vehicle mix will normally change significantly over a twenty-year period in an underdeveloped country, with important implications for transportation costs. The use of an average vehicle with average operating and cost characteristics does not take account of these differences, nor does it take account of different vehicle mixes on different links of the highway network. It is far preferable to recognize at least four vehicle groups: automobile and light trucks, medium-weight trucks and buses, heavy trucks, and special vehicles such as tank trucks. The classifications adopted in any particular case will depend on the characteristics of the vehicle fleet, and in many cases it may even be found that bicycles and motorcycles form a significant part of the total traffic. In most cases a great deal of information on the vehicle fleet may be gained from vehicle registration records, but these should be supplemented with data from a traffic count or origin-destination survey, since the vehicle mix in the rolling fleet on any link may be quite different from the mix in the registered fleet in the country.

A final note on traffic forecasting concerns the cost concepts which are appropriate to the forecasting, distribution and assignment of traffic. Throughout this paper, the emphasis will be on the economic cost of transportation, which is the cost net of taxes and duties and using shadow prices to arrive at the real economic cost of such things as labour and foreign exchange. These economic costs may be quite different from the cost upon which the shipper will base his selection of mode, route and carrier. Therefore, in forecasting, distributing and assigning traffic, the appropriate costs are the costs as perceived by the shipper, including all taxes and duties plus any profit which may be earned by the carrier, and including such as loading and unloading, time costs, and probability of loss and damage; in short, the total cost of distribution as seen by the shipper of the goods.

In the following parts of this chapter, which are concerned with the measurement of specific costs and benefits of public transportation investments, it is assumed that the necessary traffic and economic forecasts have been made.

B. The Measurement of Costs

The example of highway transportation will be used to illustrate the cost concepts to be illustrated, primarily because highway transportation is the mode most often found appropriate to the situation in underdeveloped countries. The delineation between costs and benefits is not always clear, since benefits often consist of reductions in costs; however, for the sake of an orderly presentation, they are treated separately. Every cost which will be encountered in every situation cannot be considered in detail, as many minor variations are possible under different conditions and circumstances, but the major costs encountered in most situations are covered.

1. Construction Costs

In any analysis of highway transportation investments, highway construction costs are one of the major elements to be considered. The degree of accuracy required in cost estimates depends upon the nature of the analysis. In a comprehensive transportation analysis designed to optimize the transportation system, there is a large number of alternative possibilities to be considered. Each existing link in the road network may be considered for abandonment, to be left at its present standard, or for upgrading to a number of possible higher standards. Construction costs must therefore be estimated for each reasonable stage of improvement. In addition, cost estimates for new links which may be considered for addition to the system must be made, again for a number of possible road standards. Even assuming a relatively simple system with only one hundred links, this implies up to three hundred estimates of construction costs, and it would be most unusual to have the time or budget available to permit individual cost calculations for each link. In such a case, the most reasonable procedure is to first classify each existing link as to its present standard using perhaps six standards from a one-lane earth track to a two-lane paved highway, or possibly to a four-lane paved highway in some cases. For each standard of existing road, typical costs per mile for upgrading to the next two or three higher standards may be developed, with variations in the typical costs for a variety of soils and terrain conditions. Similarly, typical costs per mile for the construction of new roads to various standards, for a variety of soils and terrain conditions, may also be developed. The resulting construction cost tables can then be used throughout the first stages of the analysis, modified only to allow for major structures such as bridges which may be required on individual links. In later stages of the analysis, as the range of possible projects is narrowed down, more accurate cost estimates can be made for those projects still under consideration.[6]

The major elements of cost estimating, such as earthwork quantities and costs, structural requirements and similar items are normally the responsibility of the highway engineer, and will not be considered here. However, the economist has an important part to play in many aspects of cost estimating. One aspect involves the distinction between economic costs and financial costs. Economic costs represent the real cost to the

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[6]This method of estimating construction and improvement costs on a large number of highway links was used in the land transport study of Dahomey, Africa, which is still in progress at the time of writing.

economy of the resources used, and may be quite different from the prices actually paid for the resources. These are the costs which are used in the economic analysis of the transportation investment. The financial costs represent the prices actually paid for the resources. In preparing a budget for the construction of the highway and identifying sources of funds, the financial costs are the appropriate ones to use in calculating the amount of funds which will be required.

Anticipated inflation is usually omitted from the economic analysis, on the assumption that it will have a similar effect on both costs and benefits and will therefore not have a significant effect on the outcome of the analysis. A major exception to this is the case of sectoral or specific inflation where there is reason to believe that certain elements of costs or benefits will be more affected than others, which really indicates a change in relative economic values.[7] In all cases, inflation should be included in the calculation of financial costs.

(a) Engineering and design costs

These costs are mentioned simply because they are often omitted in cost calculations for economic analysis, yet they are just as much a cost of the road as is the cost of the actual construction. They are normally calculated as a percent

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[7] Hans A. Adler, Sector and Project Planning in Transportation (Washington: World Bank Staff Occasional Papers Number Four, 1967), p. 41.

of the estimated construction cost, usually about five percent. It should be noted here that the cost of economic feasibility studies are not included with the highway costs used in the economic analysis, since these are sunk costs at the time that the decision is made to proceed with the design and construction.

(b) Right-of-way costs

In estimating right-of-way costs, a distinction must be made between the economic and financial costs of acquisition. The economic costs represent the actual cost to the economy of taking land out of its present and probable future use, and are best calculated on the basis of the net value of the production which will be foregone when the land is converted to highway use. If lack of data prevents such a calculation, the most suitable substitute is the prices paid in recent private purchases of similar land, but care must be taken that these prices have not been distorted by unusual circumstances, such as knowledge or speculation that the land may be required for a highway. Any taxes included in the sale price should be removed from the estimated cost, since these represent only transferes of wealth, and are not real costs to the economy. The economic costs are then used in the economic evaluation of the transportation investment.

The financial costs represent the amounts which will actually be paid for the land by the authority building the highway, whether the land is acquired by normal purchase or by expropriation, and including legal costs and taxes if these are actually paid. In cases where title to the land is already vested in the authority, the financial cost will be zero.[8] The financial cost of the land is used in the financial analysis of the project, where sources of funds are identified and a construction budget is prepared.

(c) Cost of construction

The major task of the economist in the estimating of actual construction costs is ensuring that a distinction is maintained between economic and financial costs of construction, and between the domestic and foreign components of the costs. The distinction between financial and economic costs rests primarily on the deduction of all tax and duty items and other transfer payments from the financial costs, including costs of materials, equipment, fuel and supplies, and similar items. It should be noted that the equipment cost included should be only that portion of the total cost of the equipment which is chargeable to the specific project, i.e. the depreciation on the equipment which is attributable to the project. The distinction may also depend on the economic value of the labour employed in the construction. If much of the labour used would otherwise be unemployed or underemployed, as is often the case in underdeveloped countries, the economic cost may be significantly lower than the financial cost of the labour. This

[8] Note, however, that there will still be an economic cost, unless the land is unused and would remain so over the period of the analysis if the highway were not built.

factor should also be considered in the determination of the various combinations of inputs to be used in construction. Labour and equipment are to some extent substitutable, and the least-cost combination appropriate to North American conditions is not necessarily appropriate in an underdeveloped country, and should not be adopted merely because that is "the way it is done."

At the same time, merely because a project takes place in an underdeveloped country, it should not automatically be assumed that labour is unemployed or underemployed. Many categories of personnel-entrepreneurs, university graduates, skilled technicians, to name a few--may have a very high economic value which is not fully reflected in salary or income levels, and a "shadow price" evaluation of their economic worth which is higher than the prevailing wage rates may be appropriate.

The distinction between the domestic and foreign components of construction costs is necessary to planning the financing of the project, and in cases where international aid or lending agencies are involved, it is necessary in the determination of the proportion of the cost which will be financed by the international agency. In most cases, the agencies finance only that portion of the cost requiring foreign exchange. The foreign components of construction cost should also be adjusted to remove the effect of artificially maintained exchange rates which may distort not only the estimates of economic costs, but also the optimum combination of domestic and foreign inputs.

It is common practice to include a contingency item in construction costs, usually about fifteen to twenty percent of the total costs. This is a legitimate item for inclusion in the economic analysis as long as it represents an adjustment for probable underestimation of the costs of construction, and low estimates are in fact quite common. Care should be taken, however, to ensure that this item does not include an adjustment to allow for possible inflation between the time the estimate is made and the expected time of actual construction.[9]

Separate cost estimates should be made for each section of highway which can be identified and analysed as a single project. In examining the economic feasibility of paving a gravel-surface highway, for example, a single cost estimate covering the whole length of the highway is insufficient if traffic volumes will be different on different sections of the highway. In such a case, the whole project may show a satisfactory rate of return, when in fact the section with high traffic volumes may have an excellent rate of return, while the other section has a very low, unacceptable rate. In analysing the whole length of the highway, one section is in

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[9]Hans A. Adler, op. cit., p. 41.

effect subsidizing another. The same comment could also hold in a case where an existing highway is to be improved in more than one respect; for example, an improved surface, improved alignment, and a reduced rate of rise and fall. Here again, unless the various types of improvement are analysed independently as far as possible, the overall rate of return may include improvements which are in fact economically unacceptable.

The timing of the construction costs should also be determined. With relatively high costs of capital in underdeveloped countries, it may make a significant different if the costs of construction will be spread over a three-year construction period rather than incurred all in a single year, since it will affect the present value of the total economic cost of construction. The timing of the construction cost also has important implications for the financial budgeting for the project. Therefore, not only the total cost of construction, but also the amount to be expended in each year, should be calculated.

This section has been presented as though the selection of standards and estimating of construction costs are entities in themselves. In fact, there is a wide range of combinations and substitutions possible among construction costs, maintenance costs, vehicle operating costs, and other cost and benefit factors such as the effect of different alignments on agricultural development. The final estimate of construction cost cannot be prepared until the final stages of the analysis are reached and the optimum combinations are determined; until then, any costs developed must be considered only as preliminary estimates for use in the optimization analysis.

2. Maintenance Costs

The development of highway maintenance costs is again primarily the responsibility of the engineer, with the role of the economist being to maintain the distinction between financial and economic costs, and between the domestic and foreign components of the costs. Although maintenance costs are relatively small over the life of the highway in comparison with construction costs and vehicle operating costs, the lack of funds for continuous maintenance is often a very real problem in underdeveloped countries, and inadequate maintenance can have a severe effect on vehicle operating costs; therefore the problem of maintenance is often greater than the costs alone would imply.

The distinction among the various cost classifications--economic and financial, domestic and foreign--are the same as for construction costs, and the factor of timing is similar in that the expenditure in each year should be estimated. However, the timing of maintenance costs can be very important from the point of view of economic analysis and financial budgeting. The normal pattern of maintenance for a paved road is one of relatively low but increasing annual costs in the years following construction, followed by a year or two of high costs as major resurfacing becomes necessary, then reverting to low but increasing annual costs. When discounting to present values, this actual pattern may give quite different results than would be derived from the use of an average annual maintenance cost. The implications for financial budgeting are obvious: provision must be made for the future high-cost years when resurfacing becomes necessary. In a country with extensive paved highways built at different times in the past, the problem is less acute, since resurfacing will be done continuously and there will not likely be any single year with unusually high costs, but in countries with only one or two major paved highways, resurfacing costs may require an unusually high maintenance expenditure in a specific year, and provision must be made for this probability.

An important factor in estimating maintenance costs is the relationship between maintenance costs and traffic volumes. There is very little data available on this relationship in underdeveloped countries, especially in the case of lower-class roads such as one- and two-lane tracks surfaced with local materials.[10] The maintenance costs may vary greatly under different climatic conditions,soils conditions, and the road materials and construction methods and standards used. They

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[10]This lack of data became evident in a literature search conducted in conjunction with the Dahomey Land Transport Study referred to earlier.

may also vary with vehicle axle loads and operating speeds. Some relationships were established in a recent transportation analysis in West Africa, commissioned by the United Nations Development Programme and the International Bank for Reconstruction and Development, and some of the results are shown in Table I. The maintenance costs shown in the table are economic costs, and are net of taxes and duties. In all cases, there is a constant maintenance cost which is attributable to environment conditions such as water and wind erosion, and which will be incurred regardless of the volume of traffic, and a variable cost, depending on the volume of traffic. It should be noted that these are included only as an indication of the type of relationship which may be developed, and that they are valid only for the vehicle mixes, axle loads, climatic and soils conditions, and other factors encountered in that particular study.

3. Vehicle Operating Costs

Vehicle operating costs are one of the most important factors in the evaluation of highway transportation investments. They are normally far greater in magnitude than the total costs of construction and maintenance over the period of the analysis. In many cases, savings in vehicle operating costs are the primary, if not the only, benefit attributed to a highway investment. Even in the case of a new highway built to open an area for economic development where there are in effect no "savings" in transportation costs, vehicle operating costs are an important factor in the economic evaluation. In spite of their importance, however, there has been a surprisingly small amount of empirical research on vehicle operating costs in the conditions encountered in underdeveloped countries, and much of the published information is based on ill-defined and vaguely-defined concepts and unsubstantiated assumptions.[11] The studies reviewed in the preparation of this thesis showed a wide variety of methods of calculating vehicle operating costs, with many incorrect or incomplete treatments of the subject. In de Weille's words:

> The calculation of .... road user savings ... tends to be made on an ad hoc, case-by-case basis. Both the methodology used in the calculations and the quantification of the impact of the various relevant factors at work, differ considerably from study to study and appear to depend heavily on the subjective preferences and judgements of the individual authors.[12]

Because of the large number of studies in which these costs have played a part, and because of the wide variety of methods used in attempting to quantify vehicle operating costs no attempt will be made here to describe the methods used in the past and to identify their deficiencies. Instead, the data which are considered to be the best available at this time and the methods of calculation which are considered to be the correct ones, will be presented.

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[11] Jan de Weille, _op. cit._, p. 8.

[12] _Ibid._, pp. 3-4.

TABLE I

ROAD MAINTENANCE COSTS, AND VARIATIONS WITH TRAFFIC VOLUMES

Type of Road	Maintenance Cost*
2-lane paved road	176,000 + 34 n
2-lane laterite-surfaced road	22,000 + 870 n
2-lane earth road	22,000 + 530 n
1-lane paved road	154,500 + 105 n
1-lane laterite-surfaced road	17,700 + 870 n
1-lane earth road	9,100 + 530 n

n = the number of vehicles per day

* The costs shown are in C.F.A. francs per kilometer per year. One thousand C.F.A. francs are approximately equivalent to four U.S. dollars. These are economic costs, net of taxes and duties.

Source: Dahomey Land Transport Study, Technical Memorandum No. 9, Road Maintenance Methods and Costs, 1968, pp. 9.4, 9.4.

Although the lack of empirical data relating to conditions in underdeveloped countries is a series problem, there is some evidence that the technical relationships relevant to vehicle operation do not vary greatly from country to country, so that much of the research done in the United States may reasonably be applied to other countries.[13] This is the approach adopted in what is probably the most comprehensive published treatment of the subject, Quantification of Road User Savings, by Jan de Weille of the International Bank for Reconstruction and Development.[14] De Weille uses primarily the technical coefficients developed in the United States and adapts them to cost conditions typically encountered in underdeveloped countries, and compares the results with those of actual studies made in Brazil, India, Japan and other countries.

There are many components of vehicle operating costs, and the components vary in different ways in relation to factors such as vehicle speed, road surface, road curvature, gradients and similar factors. In the following paragraphs, each major cost classification will be considered individually to indicate the most important relationships and factors which should be considered in developing vehicle operating costs to be used

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[13]Tillo E. Kuhn, Economic Analyses for Highway Improvements in Developing Countries (A paper prepared for presentation to the Ninth Pan American Highway Congress, Organization of American States, Washington: 1963), p. 7.

[14]Jan de Weille, loc. cit.

in transportation investment analyses. The relationships shown in the formulae included in the sections on the various costs are those used in a recent transportation study of Dahomey, Africa. They are based primarily on de Weille's work, but in many cases they incorporate the findings of other studies done in Africa and elsewhere, as well as those of the Dahomey study.

(a) Fuel

Fuel consumption depends on a number of factors, including:

1. Vehicle characteristics and the weight of the load;
2. Speed;
3. Road surface;
4. Road gradients; and
5. Road curvature.

The vehicle characteristics having the greatest effect are the engine type (gasoline or diesel) and the weight of the vehicle. The weight of the load is added to the curb weight of the vehicle to represent the total effect of weight on fuel consumption. The results shown in the de Weille publication do not indicate the effect of variations in vehicle load on fuel consumption, but data on this relationship are available from a study by C. Saal.[15] The relationship between total weight and fuel consumption used in the Dahomey study is based on Saal's

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[15] C. Saal, _Time and Gasoline Consumption in Motor Truck Operation_ (Highways Research Board Research Report 9-A, 1950).

report, and includes the effect of road gradient:

$$F = K4 \times \left[\frac{W + (P \times Lf)}{1000} \right]^{K5}, \text{ where}$$

F = gasoline consumption in gallons per mile,[16]

K4 and K5 = empirically-determined constants related to the rate of rise and fall of the road,

W = curb weight of the vehicle in pounds,

P = maximum payload of the vehicle in pounds, and

Lf = load factor $\left(\frac{\text{actual load}}{\text{maximum payload}}\right)$

The values of K4 and K5 for various rates of rise and fall were derived from Saal's report, modified to apply to all of the vehicle classifications used in the Dahomey study, and are shown in Table II. It is estimated that fuel consumption for diesel-powered vehicles averaged between thirty-five and forty percent below that for comparable gasoline-powered vehicles; therefore, the value of F, which is representative of gasoline consumption, must be adjusted accordingly for diesel-powered vehicles.[17]

The relationship between fuel consumption and speed shown by de Weille is in the form of a U-shaped curve, with the lowest fuel consumption per kilometer occurring at speeds of from 40 to 64 kilometers per hour, depending on the vehicle

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[16] Adjusted to litres per kilometer for use in Dahomey.

[17] R.B. Sawhill and J.C. Firey, Highways Research Board Bulletin 276, 1960, p. 54.

TABLE II

VALUES OF RATE OF RISE AND FALL COEFFICIENTS

Rate of Rise and Fall* (Meters per 100 meters)	K 1	K 2	K 4	K 5
0.0	1.16	0.0006	0.0180	0.620
1.3	1.16	0.0011	0.0178	0.660
2.3	1.16	0.0025	0.0156	0.736
3.2	1.16	0.0035	0.0154	0.775
4.0	1.16	0.0050	0.0162	0.793
5.0	1.16	0.0070	0.0144	0.881
6.4	1.16	0.0100	0.0177	0.907

* Rate of rise and fall is the total rise and fall of a section of highway in meters, divided by the length of the section in hundreds of meters.

Source: Derived from C. Saal, *Time and Gasoline Consumption in Motor Truck Operation*, Highway Research Board Report 9-A, 1950.

type. The variations of fuel consumption with speed are shown in Table III. The free speed of the vehicle on a level tangent paved road, assuming no other vehicles affecting the speed, is related to the gross weight and power of the vehicle and the rate of rise and fall of the road:

$$MPM = K1 + K2 \left[\frac{W + (P \times Lf)}{HP} \right], \text{ where}$$

MPM = travel time in minutes per mile,

K1 and K2 = empirically-determined constants related to the rate of rise and fall,

W, P and Lf are as defined previously, and

HP = vehicle horsepower (S.A.E.).

The values of K1 and K2 are shown in Table II.

This formula relates speed to vehicle, load, and rate of rise and fall, but does not take account of traffic effects or the road surface. The speed of a vehicle is influenced by the amount of other traffic using the road. Since large vehicles have a greater effect on other traffic than smaller ones, all vehicles except automobiles are multiplied by a factor to express total traffic in terms of equivalent automobiles,[18] and the speed adjusted for the effect of traffic volumes is determined as follows:

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[18]The factors vary depending on the characteristics of the vehicle fleet in a country or on a particular road. Commonly-used values are 1 light truck = 2 automobiles, and 1 heavy truck = 3 automobiles.

TABLE III

FUEL CONSUMPTION AND SPEED

(Index Numbers: fuel consumption at 64 km. p.h. = 100)

Speed (km.p.h.)	Average Car	Trucks I	II	III	IV
24	116	107	113	176	143
32	104	97	104	138	116
40	98	93	99	116	103
48	95	93	98	104	98
56	97	95	98	101	97
64	100	100	100	100	100
72	105	108	104	103	108
80	111	120	109	109	120
88	120	136	117	126	139
97	131	160	128	154	155
105	146	195	133	---	---
113	165	258	---	---	---

Average car: average of the weight, power and other relevant features of a Volkswagen and a Chevrolet.

Truck I: pickup or panel with payload of approximately 1 ton.

Truck II: single unit, with payload of approximately 3.5 tons.

Truck III: tractor and semi-trailer, payload approximately 15 tons, average gross weight about 18 tons, gasoline-powered.

Truck IV: tractor and semi-trailer, payload approximately 18 tons, average gross weight about 22.5 tons, gasoline or diesel.

Source: Jan de Weille, <u>Quantification of Road User Savings</u> (World Bank Staff Occasional Papers No. 2, 1966).

$$S = V \times (1 - .315 \frac{EQVOL}{C}), \text{ where}$$

S = speed in miles per hour, adjusted for the effect of traffic volumes,

V = free speed, derived from MPM developed in the previous formula,

EQVOL = total daily 1-way vehicle volume expressed in equivalent automobiles, and

C = an empirically-determined value representing the capacity of the road.

The value of C is based on the maximum daily volume, in equivalent automobiles which can maintain an average speed of twenty-five miles per hour in the peak hour.[19]

The type of road surface affects a number of facets of vehicle operation, including speed. The relationships between surface types and operating characteristics are listed in Table IV.

The effects on fuel consumption of vehicle characteristics, load, speed and rate of rise and fall are included in the above sections. The road surface type also has an effect on fuel consumption. The relationships between surface types and fuel consumption for a range of vehicles representative of the Dahomey vehicle fleet are shown in Table IV.

The effect of road curvature on fuel consumption is derived directly from de Weille's publication and is shown in Table V.

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[19]This relationship was developed by M.R. Seekings, and is shown in Dahomey Land Transport Study Technical Memorandum No. 8, Highway Operating Costs, 1968 (unpublished).

TABLE IV

ROAD SURFACE FACTORS FOR VEHICLE OPERATING COSTS

	Road Surface Type				
	1	2	3	4	5
Fuel					
Vehicle Class 1	3.40	1.70	1.52	1.23	1.00
2	2.90	1.45	1.35	1.16	1.00
3	3.40	1.70	1.52	1.23	1.00
4	2.64	1.32	1.24	1.11	1.00
5	2.84	1.42	1.31	1.14	1.00
Oil	3.00	1.50	1.35	1.15	1.00
Tires	2.65	1.30	0.85	0.24	-0.05
Maintenance	5.20	2.60	2.10	1.40	1.00
Depreciation	3.20	1.60	1.37	1.10	1.00
Speed	0.47	0.63	0.84	0.90	1.00

Vehicle classes are representative of vehicles in Dahomey:

	Curb Weight (kg)	Horse-power (SAE)	Pay-load (kg)
Vehicle Class 1	10500	210	16700
2	4450	120	4900
3	12000	240	14500
4	1450	75	1100
5	850	53	460

Class 1 represents vehicles used on a specific route where all through shipping is controlled by the state railway.

Class 2 is the prevalent general cargo truck used in Dahomey, and is most closely represented by a Berliet L.62

Class 3 represents tank trucks.

TABLE IV (Continued)

Class 4 represents the average public passenger vehicle commonly used in Dahomey.

Class 5 represents private automobiles.

The road surface types are:

1. 1-lane track, local material
2. 1-lane laterite-surfaced road
3. 2-lane laterite-surfaced road
4. 1-lane paved road
5. 2-lane paved road.

Sources: derived from J. de Weille, _Quantification of Road User Savings_, 1966, and M.R. Seekings, _Dahomey Land Transport Study Technical Memorandum No. 8, Highway Operating Costs_, 1968.

TABLE V

FUEL CONSUMPTION AND CURVATURE OF THE ROAD

(in percent increase from consumption on a tangent paved road)

Passenger Car

Speed	Degree of curvature								
(km.p.h.)	2	4	6	8	10	15	20	25	30
24									--
32								--	3
40						--	4	8	13
48					--	4	9	20	38
56			--	2	3	10	22	44	--
64		--	2	3	6	18	42	--	
72	--	2	3	6	10	32	--		
80	--	3	5	10	17	--			
88	--	4	8	15	26	--			
97	2	6	12	22	37	--			
105	3	8	17	30	--				
113	4	10	22	--					

Truck I

Speed	Degree of curvature									
(km.p.h.)	1	2	4	6	8	10	15	20	25	30
24										--
32								--	--	--
40							--	3	7	12
48					--	--	4	9	19	36
56				--	2	3	9	22	44	--
64			--	--	3	6	20	45	--	
72		--	2	4	7	12	40	--		
80		--	3	7	12	17	--			
88	--	2	5	11	21	36	--			
97	--	3	8	16	32	52	--			
105	2	4	11	26	47	--				
113	2	5	15	38	--					

TABLE V (Continued)

Truck II

Speed (km.p.h.)	Degree of Curvature									
	1	2	4	6	8	10	15	20	25	30
24										--
32								--	--	2
40							--	2	7	10
48						--	3	7	--	--
56					--	2	7	18	--	
64				--	3	5	16	--		
72			--	3	6	10	--			
80		--	2	5	10	17	--			
88		--	4	9	16	27	--			
97	--	2	6	13	--	--				
105	--	3	8	18	--					

Truck III

Speed (km.p.h.)	Degree of Curvature									
	1	2	4	6	8	10	15	20	25	30
24		--	2	3	4	4	4	3	3	3
32		--	2	3	3	3	3	3	5	7
40			--	2	2	2	3	8	21	29
48			--	2	2	3	9	22	46	86
56		--	2	3	4	7	22	--	--	--
64		--	3	5	10	17	51	--		
72	--	2	5	10	19	33	--			
80	--	3	8	18	36	63	--			
88	2	5	13	30	--	--				
97	3	7	--	--						

Truck IV

Speed (km.p.h.)	Degree of Curvature									
	1	2	4	6	8	10	15	20	25	30
24		--	2	4	5	5	4	4	3	3
32		--	2	3	3	3	3	3	5	8
40			--	2	2	2	4	8	24	34
48			--	2	2	3	12	25	53	100
56		--	2	3	4	7	15	--	--	--
64		--	3	5	9	16	50	--		
72	--	2	4	9	17	29	--			
80	--	3	7	15	29	49	--			
88	2	4	11	24	--	--				
97	3	6	17	--						

TABLE V (Continued)

Vehicle types are the same as those shown in Table III.

Degree of curvature is the total number of degrees of curves for any curved section of highway, divided by the length of section in hundreds of feet.

Source: Jan de Weille, _Quantification of Road User Savings_ (World Bank Staff Occasional Papers Number Two, 1966).

From the above relationships it is possible to develop fuel consumption for a range of vehicle types and climatic conditions. It is then a relatively simple matter to apply the cost of gasoline and diesel in the country to the consumption figures to derive fuel cost, maintaining the distinction between the financial and economic cost of fuel.

(b) Oil

The cost of oil is a relatively minor item in total vehicle operating costs, but it is included for the sake of completeness. Oil consumption varies primarily with speed and surface type. Oil consumption and the relationships between consumption and speed for various types of vehicles are shown in Table VI, while the effect of the road surface type is included with the other road surface factors in Table IV.

(c) Tires

Tire wear varies with the road surface, vehicle speed, total vehicle weight, road curvature and temperature. There is not sufficient data available to the author to establish the effect of the latter three factors, although they are probably important determinants of tire wear. The relationship between tire wear, speed and road surface is as follows:[20]

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[20]Derived from J. de Weille, Quantification of Road User Savings, and shown in the above form in Dahomey Land Transport Study Technical Memorandum No. 8, Highway Operating Costs, p.4.5.

TABLE VI

ENGINE OIL CONSUMPTION AND SPEED

(liters of oil per 1,000 kilometers
on level tangent paved roads)

	Passenger cars			Trucks			
Speed (km.p.h.)	European car	Average car	American car	I	II	III	IV
24	0.6	1.4	2.0	1.8	2.6	3.8	7.9
32	0.6	1.2	1.7	1.6	2.4	3.4	7.0
40	0.6	1.1	1.6	1.5	2.2	3.2	6.4
48	0.6	1.1	1.6	1.5	2.1	3.0	6.0
56	0.6	1.1	1.5	1.4	1.9	2.8	5.6
64	0.6	1.1	1.5	1.4	1.8	2.6	5.1
72	0.6	1.1	1.5	1.3	1.6	2.4	4.4
80	0.5	1.0	1.5	1.2	1.5	2.3	3.9
88	0.5	0.9	1.4	1.1	1.6	2.5	4.1
97	0.6	1.0	1.4	1.1	1.8	2.8	4.5
105	0.7	1.2	1.6	1.1	2.1	--	--
113	0.9	1.7	1.9	1.3	--		

Vehicle types are the same as those shown in Table III, with the addition of the European and American cars.

Source: Jan de Weille, Quantification of Road User Savings (World Bank Staff Occasional Papers Number Two, 1966).

$$T = L \times (Sp + RSFT \times 100), \text{ where}$$

T = number of tires used per mile;

L = the increase in the percentage of one tire used per mile for a 1 mph. increase in speed;

Sp = speed adjusted for road and traffic conditions, and

RSFT = the road surface factor for tires, as shown in Table IV.

The values of L are shown below for the vehicle types used in the Dahomey Land Transport Study.

	Vehicle Class				
	1	2	3	4	5
L =	.00067	.00033	.00067	.00021	.00025

The resulting value of T, multiplied by the cost per tire in any given area, gives the total tire cost for any vehicle class for a given speed and road surface type.

(d) Vehicle maintenance

Maintenance cost is normally divided into two components, parts and labour. Some substitution between the two is possible, but there is very little data available on the range of possible substitution and the advantages of various combinations of parts and labour. For this reason, the combinations assumed in de Weille's study, based on a wide range of American conditions, are accepted here. De Weille's assumptions regarding the interdependence and substitutability between maintenance and depreciation, and the relatively small impact of this on the total operating costs, is also accepted for lack of data to indicate the relationship more precisely.

Maintenance costs were found to vary with speed and road surface. The maintenance cost per kilometer in the following formula is Cp + Cl, i.e. cost of parts plus cost of labour. The cost of parts, $Cp = \frac{P_k \times RSFM \times C_v}{1000}$, where

Cp = cost of parts per kilometer, in dollars (or other monetary units) on level tangent paved roads;

P_k = cost of parts per 1000 km., expressed as a percent of the value of the vehicle;

RSFM = the road surface factor for maintenance, and

C_v = the capital cost of the vehicle.

Values for Pk for various vehicle types are shown in Table VII, and values for RSFM are shown in Table IV.

The cost of labour, $Cl = \frac{Lh}{1000} \times RSFM \times W$, where

Cl = cost of labour per kilometer, in dollars (or other monetary units) on level tangent paved roads;

Lh = hours of labour per 1000 kilometers;

RSFM = the road surface factor for maintenance, and

W = wage rate per hour for maintenance labour.

Values for Lh are shown in Table VII, and those for RSFM in Table IV.

TABLE VII

VEHICLE MAINTENANCE: COST OF PARTS AND HOURS OF LABOUR

(cost of parts as a percent of the value of the vehicle per 1000 kilometers, and hours of labour per 1000 kilometers)

Speed (km.p.h.)	Passenger car	Trucks I	II	III	IV
		I. Cost of Parts			
24	0.07	0.09	0.20	0.08	0.05
32	0.08	0.10	0.21	0.09	0.06
40	0.08	0.10	0.22	0.09	0.06
48	0.09	0.11	0.24	0.10	0.06
56	0.09	0.11	0.25	0.11	0.07
64	0.10	0.12	0.27	0.12	0.07
72	0.10	0.12	0.30	0.12	0.07
80	0.11	0.13	0.32	0.14	0.08
88	0.11	0.14	0.35	0.15	0.09
97	0.12	0.15	0.37	0.16	0.10
105	0.12	0.16	0.40	--	--
113	0.14	0.17	--		
		II. Hours of Labor			
24	0.45	0.56	1.55	2.48	2.32
32	0.48	0.58	1.62	2.59	2.42
40	0.50	0.62	1.72	2.75	2.57
48	0.53	0.65	1.85	2.96	2.75
56	0.56	0.68	2.00	3.20	2.98
64	0.59	0.72	2.17	3.47	3.22
72	0.63	0.76	2.35	3.76	3.49
80	0.66	0.80	2.54	4.07	3.77
88	0.70	0.85	2.74	4.39	4.06
97	0.73	0.89	2.94	4.70	4.35
105	0.78	0.95	3.14	--	--
113	0.83	1.02	--		

Source: Jan de Weille, Quantification of Road User Savings (World Bank Staff Occasional Papers Number Two, 1966).

(e) Depreciation and interest

Depreciation. The effects of various operating factors on vehicle depreciation are rather obscure, and for this reason some studies omit consideration of vehicle depreciation entirely on the assumption that changes in highway standards will not have a significant effect on depreciation. Depreciation is an important element in total operating costs, however, and there is little question that changes in operating speeds, vehicle utilization and road surfaces will have some effect on vehicle depreciation. There is some empirical evidence on the effect of road surface types on depreciation; for the effect of speed, de Weille has used reasonable assumptions rather than actual evidence or study.

The lifetime depreciation of a vehicle should cover its purchase price, less tires, which are included elsewhere. Assuming no scrap value, average depreciation per kilometer is determined by the value of the vehicle, divided by its lifetime mileage. Lifetime mileage is a function of years of service and annual mileage, but these factors are interrelated: a higher annual mileage shortens the lifetime of the vehicle, but less than proportionately. De Weille assumes that speed affects depreciation in the following way:

(i) a higher road speed is speed reflected in higher annual mileage, implying a constant rate of utilization in hours per year. This seems reasonable in underdeveloped countries, where commercial vehicles normally account for the bulk of the total vehicle operating costs.[21]

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[21]This assumption may not be valid in a case where a road improvement results in a small time saving for each of a number of vehicles.

(ii) a curvilinear relationship exists between annual mileage and total years of service, such that at high annual mileages, the lifetime of the vehicle is two-thirds of the average number of years of service.

Thus, higher speeds result in correspondingly higher annual mileages and a less than proportionate increase in total lifetime mileage. De Weille tested the results for sensitivity to these assumptions, and found that the effects of changing the assumptions were relatively minor. De Weille's results were adapted for use in the Dahomey study, and the following formula was developed:

$$D = \frac{C_V}{1000} \times \left[\frac{3 \times RSFD}{Mv \times \frac{1 + 2 \times S1}{Sa}}\right], \text{ where}$$

D = cost of depreciation per kilometer;

Cv = capital cost of the vehicle (less tires);

RSFD = road surface factor for depreciation;

Mv = average lifetime mileage for the vehicle class;

Sl = average speed on the specific highway link; and

Sa = average year-round operating speed for the vehicle type.

Speeds and mileages may be in terms of kilometers or miles. The road surface factors for depreciation are shown in Table IV. Values of Mv and Sa applicable to the vehicles and conditions found in Dahomey are shown below.

	Vehicle Class 1	2	3	4	5
Mv(in km.)	500,000	400,000	500,000	250,000	150,000
Sa(in kmh)	50	50	50	55	60

Interest. Interest is not normally a large part of the total vehicle costs, although the relatively long vehicle lives in some underdeveloped countries (up to 14 years) and the high interest rates often encountered can make this an important factor. Again following de Weille, it is assumed that the average age of the vehicles is half of their total life, and the average value is half of the new value. Following the assumption that lifetime mileage varies with speed, the following relationship is developed:

$$I = \frac{Cv}{1000} \times \left(\frac{i \times Sa}{200 \times Sl \times Mva}\right), \quad \text{where}$$

I = cost of interest per kilometer;

Cv = capital cost of the vehicle;

i = rate of interest;

Sa = average year-round operating speed;

Sl = average speed on the specific highway link; and

Mva = average annual mileage.

The values of Mva found in Dahomey were:

	Vehicle Class				
	1	2	3	4	5
Mva(km.)	75000	60000	75000	50000	30000

In the calculation of economic costs, Cv is the capital cost of the vehicles less taxes and duties, and i represents the opportunity cost of capital. In calculating financial or "perceived" costs, Cv is the actual price paid by the purchaser and i is the rate of interest actually paid in the financing of the vehicle.

(f) Occupants' time

The cost of occupants' time per vehicle kilometer varies with the number of occupants, the speed of the vehicle, and the value per hour of the occupants' time. The average number of occupants per vehicle is normally determined by a vehicle survey, and the speed is determined from the calculations performed above in determining fuel consumption. The value per hour of occupants' time is much more difficult to determine, and there is no generally-agreed criteria for use in all cases. In the case of drivers and crews of commercial vehicles, the hourly wage rate is most commonly used. This may or may not be reasonable, depending on the skills of the personnel involved, and their relative scarcity in the country. In Thailand, for example, it was found that the truck drivers were also skilled mechanics, able to perform major repairs in the event of vehicle breakdowns.[22] In such a case, it is possible that

[22]General Engineering Company Ltd., op. cit., p. 8-13.

wage rates do not fully recognize the scarcity of such skilled personnel. The rest of the truck crews, however, were normally common labourers, and their value in an economy with a fairly high degree of unemployment or underemployment was probably overstated by the prevailing wage rates. Therefore, although wage rates may provide a reasonable value of time for persons travelling while engaged in their occupations, it should be modified according to circumstances. The value of time for other than vehicle crew will be considered in the next chapter dealing with benefits.

(g) Other costs

The vehicle operating costs noted above are the major ones normally considered in highway investment analysis. The cost of insurance should be added to these, except in those cases where a separate analysis of the cost of accidents is made. Unless a specific accident study is made, it is difficult to predict the effect of road changes on the incidence and cost per kilometer, based on annual insurance premiums and average annual vehicle mileage, is considered acceptable.

The costs shown do not include items such as licensing, overhead and profit. To the extent that vehicle licensing represents a service rather than a tax, it should be included with economic costs. The cost of overhead in underdeveloped countries is often insignificant, especially in cases where the majority of the vehicles are owner-driven, with the owner having only a single vehicle. In cases of multi-vehicle ownership, there are presumably some economies which justify the overhead involved, in which case the overhead is a valid item for inclusion in the economic costs. A normal margin of profit is also a legitimate economic cost for inclusion in the analysis.

C. The Measurement of Benefits

Vincent Hogg, speaking of the experience of the World Bank with feasibility study reports submitted by consultants, states that "... the main difficulty arises from conceptual and measurement problems relating to the benefits anticipated from the projects under investigation."[23] In an earlier part of this chapter, it was noted that one of the most serious deficiencies of transportation investment studies has been the failure to relate the proposed investments to the economies of the areas affected, and that one of the results of this deficiency is the tendency to calculate the benefits of the investments primarily or exclusively on the basis of vehicle operating cost savings. This tendency is not surprising in view of the time and budget limitations often imposed on consultants and the difficulty of measuring non-user benefits. The difficulty of their measurement is emphasized by Gary Fromm.

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[23] V.W. Hogg, *op. cit.*, p. 31.

> Because the benefits of transport facilities are frequently more indirect than direct, they are extremely difficult to quantify. The transport sector. . . is dynamic in altering relative price relationships between production factors (by reducing distribution costs through the provision of ports, highways, pipelines, etc.), thereby facilitating the exploitation of unutilized, or underutilized resources. Improved transport may also help to increase the spread of the market economy, entrepreneurship, and private savings and investment in productive activity.
>
> Determining the extent of this dynamic stimulation of production is difficult, however, if not impossible. It is even more hazardous to place a value on these external developmental effects than to ascribe them to particular projects or sectors . . . In most cases, especially when the stimulation of development by transport appears tenuous and the effects are problematical, these benefits should be classed with other non-quantifiable economic factors--to be identified and measured to the degree feasible and included in the cost-benefit project evaluation as an addendum.[24]

As an aid in the analysis of this problem, public capital investments in transportation facilities can be classified into two major types: those designed to improve an existing transportation system or some of the individual links in the system, and those designed to extend the system and expose new areas of land, or other resources to economic development. In most studies of the first type of investment, the savings in vehicle operating costs form the greater part, if not all, of the benefits measured. When attempts to measure other benefits are made, they are most often based on an estimate of generated

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[24]Gary Fromm (ed.), Transport Investment and Economic Development (Washington: The Brookings Institution, 1965), pp. 91-93.

traffic and the assumed benefits represented by this traffic. In the case of penetration roads designed to open new areas for production, almost all of the traffic on the facility will be generated traffic, and vehicle operating cost savings will be non-existent. In this case, the analyst is forced to take a different approach to the measurement of the benefits of the proposed investment. The distinction between the two types of investment is not difficult to make in practice, although many transportation investments contain some of the elements, in greater or lesser degree, of both classifications. Each type of investment will be considered individually in the following pages.

1. <u>Improvement of an Existing Road or System of Roads</u>

When existing facilities are improved, all of the benefits stem initially from the resulting reduction in vehicle operating costs. As indicated earlier, many studies consist of only the measurement of these cost savings, and their magnitude in relation to the capital costs and incremental maintenance costs required. The measurement of these benefits will be considered first.

Although operating cost savings are normally the easiest of all benefits to quantify, and present few conceptual problems, some of the studies reviewed failed to measure them completely or correctly. The benefits in the form of operating cost savings accrue initially to normal and diverted traffic.

Normal traffic is the traffic both present and future which will use a particular road link over the period of the analysis whether the link is improved or whether it remains in its existing condition. Normal traffic is thus encountered only on links which are in existence at the beginning of the analysis period. If the link is a proposed new link, then there will be no normal traffic; all of the traffic will be either diverted or generated.

The annual operating cost savings for normal traffic consist of the total annual operating costs of the traffic on the link in its present condition for each year of the analysis, less the same costs as they would be with the proposed improvements to the link. Thus, the calculation of the operating cost savings for normal traffic requires that operating cost coefficients such as those shown previously be applied to the traffic volumes, vehicle types, and highway characteristics for the link in its present condition, and for the link in one or more stages of improvement, for each year of the analysis period.[25]

Diverted traffic is traffic which would have used a different route or mode of transportation in the absence of the proposed investment which may consist of the improvement

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[25]Although this considers only the benefit to normal traffic, the vehicle operating costs used should be the costs appropriate to the total traffic volume on the link, including diverted and generated traffic.

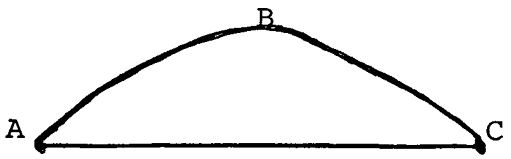
of an existing link, or the construction of a new link designed to reduce congestion, distance, curvature or rate of rise and fall, by by-passing the existing link. The operating cost saving to diverted highway traffic is calculated in the same way as that for normal traffic: total annual operating cost on the original link or route, less the same cost on the improved or new link or route. Again, the traffic volumes used in calculating operating costs should be the total volumes appropriate to each route in each year. When the traffic is diverted from another mode of transportation, the costs on the original mode must be compared with the costs on the new or improved road link to determine the benefits. In the case of traffic diverted from railway to highway, only the marginal cost of transportation by railway for the diverted traffic should be considered. The differences in quality of service between the different modes should also be taken into account, considering total distribution costs as far as possible; otherwise, the costs of the two modes will not be fairly comparable.

In the case of traffic diverted from one highway to another, the savings in operating costs to the diverted traffic can be calculated by the above procedure. However, there is usually an additional saving to traffic remaining on the original highway, since it is now operating under conditions of reduced traffic volumes.[26] This benefit is often

[26]Maintenance costs on the original highway may also be reduced because of the reduction in traffic volume.

neglected in the studies of transportation investments.[27]

A simple example will serve to illustrate the measurement of benefits in the form of operating cost savings to normal and diverted traffic. Assume a paved road



A B C with a gravel-surfaced short-cut, A C. The eastbound traffic flows are with origin destination pairs of A C, A B and B C, and west-bound, C A, C B and B A. It is proposed to pave the short-cut A C, which is at present carrying only half of the through traffic between A and C. The remainder of the through traffic is now travelling via A B C. After paving it is expected that all through traffic will travel via A C. The analysis period is assumed to be twenty years, with traffic growing at five percent per year.

The benefits in the form of vehicle operating cost savings will be as follows:

(a) Normal traffic: this is traffic now using the route A C, having operating costs in each year of the analysis appropriate to a gravel surface, and to the current and expected future annual traffic volumes, taking account of normal traffic growth. After the link A C is paved, the operating costs

[27] H.D. Nobring and M. Harwitz, op.cit., p. 4.

costs of this traffic will tend to decline because of the improved surface, but will tend to rise because of the increased volume of traffic which will use the link after the improvement (normal plus diverted plus generated traffic). Assuming a net decline in annual operating costs, the saving in year 1 will be the total operating cost of the normal traffic on the unimproved road, minus the total operating cost of the same traffic as it would be on the improved road, operating in the heavier traffic. The saving in year 20 will be calculated on the same basis, but with traffic volumes both with and without the improvement increased at five percent per year, leading to higher unit operating costs.

(b) Diverted traffic: the portion of the through traffic between A and C which is now using A B C will divert to A C if the improvement is made. Assuming roads A B C and A C will be of similar standards after the improvement, the operating cost saving to the diverted traffic will consist of the saving in distance on the shorter route A C, plus (or minus) the difference in unit operating costs corresponding to the difference in traffic volumes. Again, traffic volumes will increase each year, both with and without the improvement.

The diversion of traffic from A B C to A C will also benefit the traffic remaining on A B C since it will be operating in lower total traffic volumes.

In measuring the benefits in the form of vehicle operating cost savings, care must be taken to conform to the "with and without" methodology mentioned earlier in this thesis, and the "before and after" approach should be consciously avoided. The simplest approach to a situation such as the one used in the example is to adopt a "total cost" approach to the measurement of the operating cost savings for normal and diverted traffic. This approach consists of forecasting the traffic over the period of the analysis, assuming no change in the road system, and calculating the total annual vehicle operating cost, taking account of the increased unit operating costs resulting from increasing traffic volumes. This total annual cost, including all vehicle kilometers operated on all of the links shown in the diagram, is then compared with the total annual cost of the comparable traffic, with the highway improvement in effect. This means that a second traffic forecast must be made for the period of the analysis, taking account of the changes in the proportion of the traffic on each route which will result from the improvement in route A C, and also taking account of the generated traffic which will result from the highway improvement. The total cost in this case will reflect the shorter distance travelled by the diverted traffic, and the fact that the traffic remaining on A B C will be operating under conditions of lower total volume than would be the case without the improvement. The generated traffic is included in the second forecast in order that the operating costs of the normal and diverted traffic will be those appropriate to the total traffic volumes in which they operate. When comparing the costs with and without the improvement, the operating cost of the generated traffic must be deducted from total operating costs with the improvement, in order that only the costs of the normal and diverted traffic will be compared in each case.[28]

In many cases of investments designed to improve an existing system, the benefits are primarily in the form of operating cost savings, and although these may be some mechanical problems in the measurement of the savings, there are seldom any conceptual problems. However, in any case where transportation costs are reduced, there will also be some generation of new traffic,[29] and the determination of the benefits represented by this traffic is not quite so simple as the determination of operating cost savings for existing and future normal and diverted traffic. By definition, generated traffic is traffic which would not have existed without the road improvement; therefore there is no cost saving involved, and the benefit must be measured in some other way.

Generated traffic may represent one or more of three situations which result from the road improvement.[30]

(1) transportation of goods which would not have been produced without the road improvement;

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[28]This method was used in the evaluation of the Thonburi-Paktho Highway in Thailand referred to earlier in this chapter.

[29]Except in the unusual case of a perfectly inelastic demand for transportation.

[30]This refers to commodity traffic. Person traffic may also be generated.

(2) transportation of goods which would have been produced, but not transported without the road improvement, and/or

(3) the additional transportation of goods which would have been produced and transported in any case, but are transported over greater distances as a result of the road improvement.

Hans Adler suggests that the real measurement of the economic benefits in the first case is the net value of the new production, i.e. the value of the production, less the economic cost of the production. In the second and third cases, Adler states that the benefit could reasonably be calculated on the basis of the price in the original market where the goods were sold and the price in the new market, deducting from the price differential the extra transportation costs involved.[31] Also, in order to consider these as benefits attributable to the transportation investment, it must be shown that:

(a) the activities would not have taken place except for the transportation investment;

(b) the resources used in the activities would otherwise be unemployed, or would have been employed less productively in their alternative uses, and

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[31] Adler, *op. cit.*, pp. 55-56.

(c) the activities do not displace other activities which would otherwise have taken place.[32]

However, this procedure does not consider the possibility that the increased production may result in a reduction of the average cost of production, and that the increased distribution of goods may result in a decrease in the average cost of operating distribution facilities other than the road itself. Also, it does not consider the possibility that the market price of the total output of each commodity may change as a result of the increased supply.

The determination of the real economic benefits would require comprehensive studies of the production, distribution and marketing processes and their cost and price characteristics, however, and the cost of such studies may not be considered warranted in cases where generated traffic, and the benefits represented by this traffic, are expected to be a relatively minor by-product of the investment. The problem, of course, is that the analyst cannot be sure that these effects will be minor without conducting the studies.

The method commonly used to estimate the benefits represented by generated traffic is to credit the generated traffic with one-half of the unit operating cost savings resulting from the highway improvement.[33]

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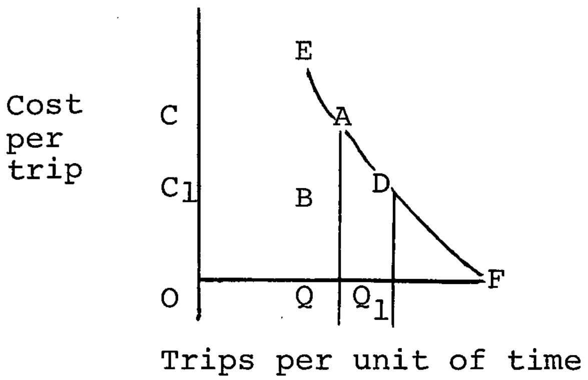
[32] Ibid., p. 54.

[33] Robert T. Brown and C. G. Harral, Estimating Highway Benefits in Underdeveloped Countries (Washington: The Brookings Institution, n.d.), pp. 3,7.

In the following diagram, it is assumed that a highway improvement has reduced vehicle operating costs from C to C_1 and that as a result, the volume of traffic has increased from Q to Q_1 per unit of time.



The area C A B C_1 represents the benefit to the normal traffic O Q, resulting from the cost reduction from C to C_1. The area A D B is held to represent the benefit to the generated traffic Q Q_1. Mohring and Harwitz provide a complete explanation of this method of measurement, and argue, with some qualifications, that it provides an accurate measurement of the benefits represented by the generated traffic.[34] David Winch also states that the net benefit to generated traffic is represented by the

[34] H.D. Mohring and M. Harwitz, op. cit, Chap. I. The The authors refer to the area A D B as the benefit, which is not quite the same as the common approximation of crediting the generated traffic with one-half of the cost savings, except in cases where the portion of the demand represented by curve A D is linear.

area A D B.[35] On the other hand, Brown and Harral claim that this method does not provide a measurement of all of the benefits represented by generated traffic; that ". . .transport cost reductions are not an adequate measure of the increase in production which can occur, especially in underdeveloped countries. . . ."[36] and that ". . .traditional techniques of estimating benefits which examine solely transport savings are without conceptual foundation and can be seriously misleading."[37]

The resolution of this difference of opinion will not be attempted in this thesis, because whether or not the area A D B in the diagram is a true measure of the benefit is not the basic problem. The above methodology requires that the volume of generated traffic be estimated before the methodology can be applied. The volume of generated traffic cannot be reasonably estimated without knowledge of the characteristics of the transportation demand curve for each component of the generated traffic expected to use the improved link or links. In order to determine the characteristics of the curve, data regarding the economic characteristics of the production,

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[35]David M. Winch, The Economics of Highway Planning (Toronto: University of Toronto Press, 1963), pp. 93-94.

[36]Robert T. Brown and C.G. Harral, op. cit., p. 3.

[37]Ibid., p. 35.

consumption and distribution of the commodities involved must be developed, so that the reaction to a change in the cost of transportation can be estimated. Thus, since a comprehensive economic study is required in order to estimate the volume of generated traffic and thus allow the above method to be used, and since the data obtained in such a study could be used to measure the benefits directly, it hardly seems reasonable to then disregard the data and instead attempt to measure the benefits indirectly through the volume of generated traffic, especially when the validity of the results has been seriously questioned.

David Winch suggests that generated traffic is best estimated "... in the light of experience with other comparable facilities," and suggests the use of a "gravity-model" formula of the form

$$T = (K.P1.P2)/D^n, \text{ where}$$

T = traffic flow per unit of time between the two areas;

P1, P2 = populations of the two areas;

D = distance between the two areas. This can be measured in terms of travel cost, since a time reduction is as important as a reduction in mileage;

K = a constant, dependent on incomes, etc.; and

n = a positive exponent found empirically to vary between 0.6 and 3.36.[38]

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[38] David M. Winch, *op. cit.*, p. 95. Winch also suggests the use of a similar approach to forecasting traffic growth, again based primarily on population, income and distance (or cost).

A number of objections to this method could be stated. Obviously, distance alone as the impedence factor is insufficient. A paved, well-aligned highway may well provide lower transportation costs than a one-lane earth road, even though the distance via the latter were shorter, and the longer highway would then be expected to result in greater traffic generation. Thus, as Winch allows, the impedence factor should reflect travel cost. This is also insufficient, however. Even though travel cost were reduced by a highway improvement, there would be little generation of traffic unless the savings were passed on by the highway operators, at least to some extent. The incremental volumes of production, consumption and transportation are affected by the changes in costs as perceived by shippers and others, which may be quite different from the changes in actual transportation costs. The main objection, however, is that the factor used in the measurement of mass is population alone, modified by a constant "dependent on incomes, etc." Unless the "etc." takes into account the productive capacities of the areas, the elasticities of supply and demand of the various products transported, and a number of similar factors, then most of factors which determine the reaction to a change in transportation costs will not be considered.[39]

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[39]The generation of person travel may possible be reasonably estimated by the use of such a model, however. Similar models are used extensively in studies of urban traffic, where person trips normally form a large proportion of total trips.

In summary, the measurement of the benefits represented by generated traffic, on the basis of the area A D B in the diagram, is not a satisfactory method. In practice, however, situations arise where vehicle operating cost savings are reasonably expected to be the major benefit of a road improvement, and time and budget constraints do not permit a comprehensive analysis of other benefits. In such a case, a measurement on this basis is probably preferable to no measurement at all. However, it should be recognized that this provides only a very rough approximation of the real benefits, and that it is a poor substitute for a comprehensive economic study and the direct measurement of other benefits. This problem is considered to represent a major deficiency of existing methods and applications, once again resulting from the failure to relate proposed transportation investments to the economy, and will be considered further in Chapter IV.

2. Construction of New Roads to Develop New Areas

The "pure" example of this situation would be a case where there was absolutely no economic activity in an area, and all of the traffic on the proposed road would be generated traffic. A more common case would be one where there was some commodity transportation, by human porterage or by animal, for trade purposes, but to all intents and purposes the only economic activity of the area consists of subsistence agriculture. In either of these cases, an attempt to measure the benefits of the road investment by considering only traffic volumes and changes in operating costs would be unsatisfactory. The most acceptable measurement of benefit in such a case is the net value of the new production which is attributable to the highway investment, plus the net increase in value added to goods previously produced but not transported.[40] Although agriculture is the most common activity in such a case in underdeveloped countries, and is therefore used as an example, the general measurement procedure can be equally applied to forestry, mining, or most other types of economic activity. The net value is normally considered to be the price paid in the market where the goods are exchanged, less the incremental economic cost of producing the goods and delivering them to the market. This again requires a comprehensive study of the production processes, the resources required and their economic values, and the factors which determine the price in the markets for the production; in short, a comprehensive economic study of the area affected, similar to that required for the measurement of the benefits represented by generated traffic in the case of the improvement of an existing road.

In concept, the measurement of the benefit in the two cases is the same, with the difference being largely one of degree. In the case of improving an existing road, the analyst

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[40]Hans Adler, op. cit., pp. 55-56.

must attempt to measure the results of a change in transportation costs in an area which was previously economically accessible, and the changes, while they may be significant, would not normally be expected to be revolutionary. In the case of a new road, penetrating an area which was previously economically inaccessible, it is still a question of reducing transportation costs, but the changes resulting in this case may be very far-reaching ones, perhaps resulting in the beginning of the transition from a subsistence economy to an exchange economy, and in radical changes in the types of agricultural crops traditionally produced.

In opening up new areas to production, or in the transition from subsistence to market production, investments in irrigation, land clearing, equipment and other facilities, as well as in the transportation facility, are often required. When significant non-transport investment is required to realize the new production, the problem arises of allocating the benefits among the transport investment and the other investments. The preferable approach in such a situation is not to make an allocation at all, but rather to consider all of the investments as part of the same project and compare total benefits with total costs. In some cases, however, grouping all of the investments into a single project is unsatisfactory, and an allocation of benefits to the various investments must be made. This could be the case, for example, if the different investments were being undertaken and financed by different international agencies, and each agency required that a return be calculated on its particular investment. It is difficult to make such an allocation except arbitrarily, or on the basis of subjective judgment, but there are alternative methods which may be tested. One is to allocate benefits to the transportation investment in the same ratio as the transport investment has to the other investments.[41] Another is to assume that the non-transport investments will earn a return equal to the opportunity cost of capital, and to deduct a corresponding amount from the total benefits forecast for each year of the analysis. Neither of these methods really distinguishes among the benefits attributable to the different investments, however, and an allocation should be avoided if possible.

The creation of economic access to a previously undeveloped area can only create the opportunity for economic development; it cannot ensure that the development will, in fact, take place. The response to the opportunity depends on a number of factors, not all of which are economic factors. "The response may be zero, negative, or positive in terms of developmental impact and is broadly bound up with aspects of culture, social relationships, individual psychology, and levels of well-being."[42] Wilson quotes the example of the

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[41] Ibid., p. 55.

[42] George W. Wilson, et al., The Impact of Highway Investment on Development (Washington: The Brookings Institution, 1966), p. 192.

Kota Belud district of North Borneo where two races, the Dusuns and the Bajaus, occupy adjacent areas. The Dusun area is hilly, and is served by only one road, while the Bajau area is easier country and is served by a small network of roads. In spite of these differences,

> nearly 100 percent of the rubber planted in the Kota Belud district is in the Dusun area, and the road is well used. The Bajaus, however, have continued to cultivate padi fields and to rear buffaloes, the return from these being lower than that from rubber and the work only occupies about four months of the year, the roads barely being used. In fact, it is doubtful if road access in the Bajau area has led to any increased local development at all.[43]

Similar situations have been noted in Malaysia, where the groups involved were Chinese and Malays.[44] The differences in response to the economic opportunities in these cases are attributed to the attitudes of the different ethnic groups. Obviously, a consideration of economic factors alone cannot provide reliable indications of the economic benefits of transportation improvements, which suggests the necessity of including other social sciences in the evaluation of transportation investments. The importance of other factors relative

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[43] Ibid., p. 140. Quoted from R.S.P. Bonney, The Place of Transport, Particularly Road Transport in the Economic and Social Development in North Borneo (United Nations, Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas, 1962).

[44] Ibid., p. 141; also W. Hughes, The Contribution of Highway Transportation to Economic and Social Development (Address to the Automotive Transport Association Annual Convention, 1964).

to that of economic factors will differ from case to case, but it has been suggested that the economic factors may not be the primary ones. ". . . in those countries where growth seems most essential for human welfare, problems outside the conventional limits of economics are surely paramount."[45]

There is no simple solution to this problem, and none will be attempted here, except to recommend that non-economic determinants of economic development be subjected to studies equally comprehensive as those applied to economic determinants.

D. Summary: The Measurement of Costs and Benefits

This chapter has provided a far from exhaustive treatment of the costs and benefits of transportation investments, and their measurement. However, it has served the purpose of identifying many of the problems encountered in the measurement. Solutions have been suggested for many of the minor problems identified; particularly those problems which arise in the applications of the methodology, rather than in its conceptual foundations. However, some major problems in the existing methods, and some major deficiencies in their applications, have also been identified, and no solutions have been offered.

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[45] B.F. Hoselitz, et al., Theories of Economic Growth (New York: The Free Press of Glencoe, 1960), p. 242.

Most of the major deficiencies in current methods can be ascribed to the failure to make a comprehensive economic study of the area appropriate to the level of decision, and to consider the relationships between the economy and the transportation system. The demand for transportation is primarily a derived demand, thus traffic flows must be forecast on the basis of forecasts of the economic activities which are expected to produce the traffic. This must be done with a considerable degree of disaggregation--at the level of industries, and for relatively small areas--because of the fact that aggregated indications of economic growth for a country or for a large area may bear little relationship to the situation in a specific, small area or on a single link of the transportation system.

Changes in the transportation system, or to a link in the system, will in turn have an effect on the economy. Thus, changes in transportation service characteristics and costs which will result from proposed investments must be related back to the economy, and their impact evaluated in terms of their effect on production, consumption, distribution patterns, and thus on traffic volumes. The changes in quantities and patterns of production, consumption and distribution imply costs and benefits other than those directly related to transportation. An analysis of these factors based solely on vehicle operating cost savings and the assumed benefits to generated traffic is a more indirect and less satisfactory method of measuring these other costs and benefits than are other methods which will be proposed.

The other major deficiency identified is the failure to evaluate single transportation investments in the context of the whole transportation system. A change in a single link of the system will almost always affect traffic volumes on some or all of the other links. These effects are seldom considered in the application of current methods of transportation investment analysis.

This tendency to analyse specific transportation projects as though they were divorced from the rest of the economy and from the rest of the transportation system must almost invariably result in inaccuracies in the measurement of costs and benefits. A considerable degree of inaccuracy is unavoidable in forecasting the future effects of proposed transportation investments, particularly in view of the difficulty of predicting human reactions to a change in circumstances, the frequent lack of reliable data, and the uncertainty which will always accompany forecasts ranging up to twenty years or more in the future. However, the inaccuracy should not be compounded by the use of methods which are conceptually incorrect or incomplete.

These major problems will be considered further in Chapter IV, and possible solutions will be proposed.

CHAPTER IV

SYSTEMS ANALYSIS AND NATIONAL INCOME METHODS

A. Systems Analysis

The methodology selected for the evaluation of proposed public investments in transportation should not only take account of the relationships between the transportation system and the economy, and between individual links and the whole system, but it should also be able to accommodate the procedures recommended previously to remedy the minor deficiencies identified. It must therefore be capable of handling a large number of interdependent variable factors. Even in a relatively simple analysis, there may be more than one hundred existing and possible new highway links, with each existing link having a number of possible levels of improvement, and each proposed new link having a number of possible construction standards, each with a different capital cost. For each possible standard of each link, there may be two or more possible levels of maintenance, each with a different maintenance cost. For each highway standard and maintenance level, there is a different level of vehicle operating costs, for each vehicle type. In addition, vehicle operating costs also vary with the volume of traffic, the load factor, power, road gradient and speed, which themselves are to some extent interdependent. The different components of vehicle operating

operating costs vary differently with changes in these determinants.

Each possible change on each link has different implications in terms of savings to normal traffic, and in terms of the volumes of diverted and generated traffic; thus, also in terms of its effects on other links. It also has different implications in terms of the quantities and values of changes in production and consumption and other indirect effects, which in turn act back on the transportation system.

Thus, in any but the simplest of cases, a systems analysis is required, and the volume of computation dictates the use of an electronic computer. The term 'systems analysis' as used here simply implies a method of analysis which takes account of the fact that in the system, no one part--be it a road link, a vehicle, a unit of production or consumption, or any other part of the system--is entirely independent of the other parts, and a change in one part of the system will affect the operation of some or all of the other parts. In this context, both of the methods of investment analysis to be considered in this chapter are systems analyses.

B. National Income Methods

It was stated in Chapter II that the objective of public transportation investment analysis assumed in this thesis is to determine the allocation of public funds within the transport sector in such a way that they will produce the maximum possible contribution to national income. Therefore, the ideal method of investment evaluation is one which will evaluate proposed investments in terms of their effects on national income. In practice, the term 'national income methods' of evaluation has come to have two meanings. In one, it implies a simulation of the economy and the actual measurement of national income, with the justification for transportation investments being evaluated in terms of their total effects on the measured national income. In the other, it is taken to mean an approach to investment evaluation which attempts to measure the full impact of transportation investments on the whole economy, but without simulating the whole economy, and actually measuring national income. Hans Adler advocates this approach.

> . . . the national income approach is useful in focusing on costs and benefits from the point of view of the economy as a whole and not merely of the parties directly involved.
> In this way it helps in selecting the benefits to be included and those to be omitted. . . . It is helpful in identifying economic costs and benefits, but not in measuring them.[1]

The first of the two methods to be considered here is commonly referred to as the Harvard Model. It comes within

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[1]Hans A. Adler, Sector and Project Planning in Transportation (Washington: World Bank Staff Occasional Papers Number Four, 1967), p. 37.

the first meaning of national income methods in that it attempts to simulate the economy, measure national income, and evaluate transportation investments in terms of the changes they produce in the measured national income. The second method, which was developed specifically for a land transportation study of Dahomey, Africa, will be referred to here as the "Dahomey method." It comes within the second meaning in that it does not attempt to measure national income, but it does attempt to measure the effect of transportation investments on national income to the greatest practicable extent.

1. The Harvard Model[2]

The Harvard Model was developed by the Harvard Transportation and Economic Development Program, with assistance from the Brookings Institution. It actually consists of two distinct models: a macro-economic model, which measures national income and furnishes regional production and consumption data to the second model, the transport model, which in turn provides transportation flows and costs for the economic model. These models are run for each year of the analysis

[2]There is very little published data regarding the Harvard Model. Except where otherwise noted, all of the material on the Model has been derived from the following publication. Paul O. Roberts, *Transport Planning: Models for Developing Countries* (Ann Arbor, Mich.: University Microfilms Inc., 1967). This is a reproduction of a Ph.D. dissertation submitted to Northwestern University in 1966.

period, with the outputs of each year being used as inputs for the succeeding year. A detailed description of the Harvard Model is beyond the scope of this thesis; therefore, only the major features which are relevant to its use in investment evaluation will be considered. In the following sections, an analysis at the national level of decision is assumed. Although all modes of transportation may be included in the model, the description is based on highway transportation in keeping with the rest of this thesis.

(a) The Transport Model

The purpose of the transport model is to simulate commodity and vehicle flows on a transportation network, and to calculate vehicle operating costs resulting from the flows. In using the model, the country is first divided into a number of geographical regions, with an extra region to represent the external world. The transportation system is represented as a series of links and nodes joining the regions, with the links representing transportation facilities such as roads and railways, and the nodes representing cities and points of transportation interchanges. The basic inputs to the transport model consist of link characteristics, vehicle characteristics and operating costs, and regional supply and demand data by commodity or commodity group.

The link characteristics in the case of a road link include the following:

length of the link,

surface type,

design speed,

rise and fall,

width,

number of lanes.

The vehicle fleet in the country is divided into three classes of trucks--bulk vehicles, general vehicles, and special vehicles such as tank trucks--plus buses and private automobiles. For a representative or 'average' vehicle in each class, the following data is recorded:

weight	vehicle capital cost
payload	cost per tire
horsepower	crew wages per hour
number of tires	fuel cost per gallon
lifetime mileage	oil cost per quart
number in crew	maintenance cost

Formulae similar to those shown in Chapter III are also included to permit the calculation of vehicle operating costs under various road, traffic and vehicle load conditions.

The regional supply and demand data are derived from the economic model, which will be described in a later part of this chapter. For each commodity, a commodity preference factor is developed to indicate the relative importance to the commodity of transport cost, waiting time, travel time, reliability in terms of the variability of travel time, and the probability of loss. Link performance factors are also developed to indicate the performance of each link in terms of transport cost, waiting time, and the other factors noted above. These two sets of factors--commodity preference factors and link performance factors--are then combined to indicate the utility to the shipper (or conversely, the total cost) of shipping a commodity over a link. If all of the qualitative factors noted above are expressed in terms of cost to the shipper, for example, the 'R-factor' will be expressed in terms of total cost as perceived by the shipper.[3]

Given the above input data, the flow of each commodity between the supply region and the demand regions is simulated by either a linear program or a gravity model, and is assigned to transportation modes and links, such that the sum of the R-factor is minimized. Each commodity flow is assigned to a particular vehicle class, depending on the characteristics of the commodity. The resulting flows, by commodity and vehicle classification, are accumulated on the links to show the total commodity and vehicle volumes on each link. The empty back-hauls resulting from directional imbalances in commodity

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[3] The 'R-factor' is the expression used in the model to denote the combined effects of the commodity preference factor and the link performance factor.

flows are considered in converting commodity flows to vehicle flows.[4]

The analyst has the choice of a linear program or a gravity model in distributing each commodity between production and consumption areas. In the use of a linear program, each production area will supply only a limited number of consumption areas, and no cross-hauling can take place. The use of a gravity model results in every production area supplying at least some of the commodity to every consumption area, and cross-hauling can occur. The method which will best simulate the actual flow of any commodity depends largely on the nature of the commodity. In the case of a homogeneous product with similar physical and cost characteristics regardless of the location of the supply area, the linear program will normally provide the best simulation of the actual flow, while the gravity model normally provides the best simulation in the case of non-homogeneous products, or product groups.

In cases where there are significant seasonal variations in commodity flows, seasonal disaggregation tables for the commodities can be prepared, showing the proportion of the total annual flow of each commodity which occurs in each of the defined seasons. The transport model can then be run separately for each season in the year.

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[4]Rather than expressing directional imbalances in terms of empty back-hauls, they may be expressed in terms of reduced average load factors for each vehicle classification.

In summary, given the above transportation and economic inputs for a given year, the transport model is simply a tool for simulating commodity and vehicle flows over the transportation system for that year, and for calculating the associated transportation costs.

(b) The Macro-Economic Model

The macro-economic model has two purposes: the development of regional supply, demand and cost data for use in the transport model, and the calculation of national income, both for each year of the analysis period. It represents an attempt to simulate a whole economy, taking account of the interrelationships among general economic variables such as prices, incomes, consumption, savings, investments and profits, and emphasizing to some extent the role of transportation in the economy.

The core of the model is a national input-output table which is used to determine the inputs required to produce a unit of output of each commodity, and which incorporates, by means of its technical coefficients, the inter-industry transactions which are generated by any given set of demands for final products. In addition to the input-output table, the model incorporates a series of equations which express the interrelationships among the various variable factors which determine national income. For each year and for each region, a final bill of goods is determined on the basis of private consumption, investment in plant, investment in inventory and government expenditures; exports are added to obtain national demand. Some of the variables, such as government expenditure, exports and part of the investment, are specified exogenously for each year. Consumption is based on wages and dividends from the previous year. The output of each industry is obtained from the input-output computation for the whole country, and allocated to regions on the basis of regional outputs in the previous year, regional profitability and regional capacity.

Regional output is in turn the basis for computing regional wages, depreciation of plant, revenue, cost of materials and taxes. From these, profits, retained earnings, dividends and average revenue are computed for each commodity, using prices from the previous year in the revenue calculations. Regional demands are developed by computing intermediate goods demand on the basis of the technological coefficients incorporated in the input-output table and adding this to regional final demands. A new price for each commodity is then calculated, using average supply costs, marginal supply costs, average transport costs and specific sales taxes. The new prices are then used in the operation of the model in the subsequent year. The final output which is relevant to the transport model is the regional supply, demand, and production cost for each industry included in the input-output table.

The development of these data is one of the purposes of the macro-economic model.

The other purpose of the model is to calculate national income.[5] Total national demand is taken as the sum of all regional consumer demands for final goods and services, plus investment demands to replace plant and equipment or to increase capacity, plus government and export demand, which in total are virtually equivalent to gross national product. National income is then derived through appropriate adjustments in inventories and savings. Regional demands for final goods and services are derived from the input-output table. Investment demand is derived from an exogenous term which includes foreign grants and loans as well as more complicated factors such as changes in capital flight and hoarding practices, plus an internally-derived term based on savings and profit levels. Government demand and exports are specified exogenously, as stated earlier.

The input data requirements of the model are obviously quite demanding. Since knowledge of these requirements is essential to the assessment of the applicability of the model to a given situation, a partial list of some of the data re-

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[5]The description of this feature of the model is derived from Brian V. Martin and Charles B. Warden, "Transportation Planning in Developing Countries," Traffic Quarterly, vol. 19 (January 1965), pp. 59-75.

quired is given below.[6] The inputs are broken down into those required for the initial year, and those required for each subsequent year.

Initial Year

Regional production cost by commodity

Prices of domestic goods and of imports

Regional incomes

Average propensity to consume

Average propensity to import

Initial inventories by commodity

Initial outputs, by industry and commodity

Investment gestation periods, by industry

Past profits and expected earnings, by industry

Initial investments, by industry

Input-output table coefficients (i.e. technological coefficients, by industry)

Initial capacity, by industry

Rate of capital depreciation, by industry

Incremental rates of depreciation on over-capacity production

Marginal efficiency of capital

Proportions of profits distributed

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[6] Information regarding the data requirements of the model was provided by Enelco Limited, a Toronto-based firm of computer specialists who took part in an application of the Harvard Model in a transportation study in Somalia in 1966.

Subsequent Years

Export prices by commodity

Changes in sales taxes

Changes in import prices

Government expenditures

Exports

Wage rates, normal and overtime

This is not a complete listing of input data requirements, but it is considered sufficient to indicate the nature and extent of the requirements.

(c) Evaluation of the Harvard Model

The Harvard Model provides a conceptual framework for many phases of general economic planning and for many facets of transportation analysis and planning, as well as for the evaluation of transportation investments. It is judged here only in its role as a method of transportation investment analysis.

In its application as a tool of transportation investment evaluation, individual investment proposals or combinations of proposals can be formulated, tested in the model, and their results determined in terms of their effect on national income, for a single year or over the whole analysis period. Thus, investments can be evaluated directly in terms of the objective assumed in this thesis. The model permits a level of decision to be specifically defined, limited only by data availability and computer capacity. It is a framework within which all reasonably quantifiable costs and benefits can be included, and to a significant extent it forces their inclusion through its requirement for internal consistency. It takes account of the timing of costs and benefits in that differences in national income with and without proposed transportation investments are calculated year by year. It simulates traffic on the basis of the production, consumption, and other economic factors which produce the traffic, and on the basis of total transportation costs as perceived by the shipper. It distinguishes among the various types of vehicles with their different physical and cost characteristics. It takes full account of the differences among normal, diverted and generated traffic, although it does not specifically identify each type in the total flows on the various links.

From the description of the model, it is apparent that the transportation system is fully related to the economy, and that in the year-by-year operation of the model, changes in the transportation system are reflected in changes in the economy, which in turn act back on the transportation system. All of the links in the transportation system are considered simultaneously, taking full account of the interdependencies among the links. Thus, the Harvard Model provides a conceptual framework which overcomes the major problems identified in this thesis, and which incorporates features which remedy the minor deficiencies identified. Its scope also extends far beyond the economic evaluation of proposed transportation investments.

However, the application of the model is not without problems. The input data requirements, especially for the macro-economic model, require a major effort in the development and collection of data, which is both costly and time-consuming. In many cases some of the data simply will not be available, requiring that approximate values be estimated in order that the analysis may proceed. "It appears, in general, that one must be prepared to use one's intuition freely, where necessary."[7] This being the case, there is some question as to whether the sophistication of the model, and the computational effort and cost involved, are warranted, in view of the probable inaccuracies in the input data. Even if the input data could be developed for the base year, it is almost impossible to ensure that the manipulation of the data actually results in a reasonable simulation of the transport system and the economy over time. In order to determine this with a reasonable degree of confidence, the model would have to be tested and the results compared with the actual situation over at least two, and preferably more years in the past, which means that the input data would have to be developed for past years as well as for

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[7] Paul O. Roberts, op. cit., p. 131.

the current or base year. Such data availability would be most unusual which makes the calibration of the model extremely difficult if not impossible.

The model is strictly a simulation procedure; it is not a search procedure. It does not attempt to identify an optimum transportation system or an optimum configuration for any link or links in the system. It will only simulate the results of changes in the transportation system which are introduced exogenously, and the quality of the results is greatly dependent on the judgment of the analyst in selecting investment proposals for testing. If it is desired to test the effect of a single change on a single link, the whole model must be operated for each year of the analysis period, with and without the change, and assuming other factors remain constant. The model is expensive to operate, making it very costly to thus evaluate each individual change which may be proposed. In addition, to take account of the interdependencies among the different links, each investment proposed would theoretically have to be tested in conjunction with all possible combinations of all other investment proposals, which would be prohibitive in terms of cost. Instead, 'packages' of proposed investments are tested, which leads to the possibility that an economically viable package may contain individual projects which are not economically justified. Thus, in effect, the model cannot evaluate all alternatives, except at prohibitive cost. Also, whether rightly or wrongly, most transportation studies undertaken by consultants in underdeveloped countries are restricted to analyses of single links or combinations of relatively few links, and apply only to relatively small areas of the countries involved. In these cases, it is questionable whether the use of such a comprehensive and sophisticated method of analysis is warranted or even possible within the time and budget limitations normally imposed.

Finally, the Harvard Model as a whole has never been successfully applied. Paul Roberts states that, at the time of the writing of his dissertation in 1966, practical applications in Somalia, Pakistan and Colombia had begun.[8] The application in Somalia was largely unsuccessful, and it appears that the applications in Pakistan and Colombia also failed to produce the desired results.[9] The principal problems were encountered in obtaining data for input to the macro-economic model, and in the operation of this model. Valuable experience was gained in these applications, and useful knowledge regarding the transport systems and the economies of the

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[8] Ibid., p. 260.

[9] Discussions with personnel of Enelco Ltd. who took part in the application in Somalia, indicated that the application was not successful. Discussion with Paul Roberts in late 1967 and with personnel in the World Bank in 1967 and 1968, indicated that serious problems were still being encountered, particularly with the macro-economic model. The transport model is operating reasonably satisfactorily.

countries was developed, but it seems clear that the Harvard Model, and particularly the macro-economic model, is still largely in an experimental stage of development.

Thus, in the opinion of the author, based on the above considerations, the Harvard Model has not yet reached a stage of development where it can be used with confidence as the analytical basis of recommendations for the allocation of scarce development capital to and within the transport sector.

2. The Dahomey Method

(a) Introduction

This method of analysis was developed specifically for use in the Dahomey Land Transport Study, undertaken by a group of consultants for the Government of Dahomey and the United Nations Development Programme in 1967.[10] The World Bank are acting as executive agents for the government and the U.N.D.P. The study is not yet completed, therefore the description of the methodology will be in conceptual terms, rather than in terms of a description of the project itself, although the project will be used to illustrate some of the points.

The primary objective of the study was the formulation of a public capital investment and maintenance program for land transportation in the country. Specific recommendations

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[10] No published material has been generated by this study at the time of writing, although a number of internal memoranda have been produced. The description of the methodology is based on the author's experience while engaged in the study.

were to be made for the three-year period from 1968 to 1970 inclusive, and indications of general priorities were to be provided for the subsequent five years. The analysis period selected was twenty years.

Since the primary objective was to search for and evaluate possible capital and maintenance projects and identify the economically justified ones, the desired methodology was one based on a searching procedure rather than on a simulation procedure. The Harvard Model was considered for use in the study, but because it is primarily a simulation procedure, and because of the other problems noted in the evaluation of the Harvard Model, its use as a complete unit was rejected. Budget and time constraints were important considerations in this decision. However, the transportation model portion of the Harvard Model was used in the transportation simulation and forecasting part of the study, with only minor modifications.[11]

Instead of the macro-economic portion of the Harvard Model, a "link optimization program" was developed. This is not a substitute for the macro-economic model; it is an entirely different procedure with a different purpose. Rather than simulating the economy and providing inputs to the trans-

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[11]Paul O. Roberts, op.cit., p. 41. Roberts points out that the transportation model does not require the use of the macro-economic model in order to be operative, since it requires only regional supply and demand for each industry.

portation model, its purpose is to evaluate a large number of possible capital and maintenance projects and select those which are economically justified.

Unlike the transportation model which operates on the basis of perceived costs, i.e. costs as seen by the shipper, the link optimization program operates entirely on the basis of economic costs and benefits, net of taxes and duties and using shadow prices where appropriate. Given the traffic volumes on a link by vehicle type which are developed in the transportation model, the optimization program calculates the annual vehicle operating costs appropriate to the commodity types, traffic volumes and link characteristics, using factors as explained earlier to take account of commodity preferences and link performance. It also calculates the annual road maintenance cost on the link, appropriate to the volume of traffic, the construction standard, and the level of maintenance. This calculation is based on a series of maintenance formulae similar to those shown in Chapter III. There is also provision in the program for capital costs and for "other costs and benefits," which will be explained later. The effect of seasonal variations in supply, demand and transportation are accounted for in two ways in the program. First, seasonal peaks in traffic are recognized through the increased operating costs associated with the higher volumes of traffic. Also, a "seasonal delay factor" is calculated for each link, based on the proportion of the time the link is impassable due to climatic conditions in the rainy season or seasons. This is incorporated into the link performance factor.

The program discounts the annual values for vehicle operating costs, maintenance costs, capital costs, other costs and benefits, and total costs, to their present values as of the base year, at a series of discount rates. It can accommodate nine different discount rates, among which will always be included the rate representing the estimated opportunity cost of capital in the country. The program makes the above calculations for each reasonable construction class and for each maintenance level simultaneously, and prints out the results for each year of the analysis period, and also in the form of total present values for each cost classification and for total cost. "Other costs and benefits," which will normally be in the form of a net benefit, are treated as negative costs in the program. The operation and application of the link optimization program will be further clarified in a later part of the chapter.

(b) Field surveys

In the application of the Dahomey Method of transportation investment evaluation, the country or area being analysed is first divided into zones on the basis of population, geographic features, economic activities, political boundaries and other factors. Dahomey, with an area of about 113,000 square kilometers and a 1967 population of approximately 2,480,000, was divided into eighty-five zones with each zone represented by an "economic node." The transportation network is divided into nodes and links, with the nodes representing cities and towns, crossroads and other intersections, and points along roads where the road construction standard changes, and the links representing the road sections between the nodes. The nodes in the transport system include all of the economic nodes, plus others which are required for the road system alone. External links, nodes and zones are established at points of road connections with neighbouring countries and at seaports, to accommodate flows of imported and exported commodities.[12] In the Dahomey study, there are approximately 145 links representing about 4,500 kilometers of highway, and 115 transportation nodes. For ease of calculation, the highway links are grouped into a number of classifications or construction standards. The construction standards used in Dahomey included one-lane tracks, one-lane earth roads, two-lane earth roads, one-lane laterite-surfaced roads, two-lane laterite-surfaced roads, one-lane paved roads and two-lane paved roads.

A number of field surveys are required to develop input data for the analysis. An inventory of the existing

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[12]Depending on the transportation system, there may also be rail or water links, and transfer links, which represent transfer costs at points where commodities are transferred from one mode to another. In keeping with the rest of the thesis, only road transportation is included in this description, and the emphasis is on commodity rather than passenger transportation.

road system is required, showing the construction standard and maintenance level of each link, the rate of rise and fall, and other factors which affect the performance of the link in relation to the commodity preference factors mentioned earlier. Maintenance levels are classified as adequate, minimum or zero. The capital costs required to up-grade each link to the next higher standard, and to each additional higher standard considered reasonable, must be estimated; also, the maintenance cost for each link for each construction standard and maintenance level.

A base-year traffic survey must be conducted to determine origins, destinations, and routes by commodity and by vehicle type, and should be supplemented by any available data from past traffic counts and surveys. Ideally, the origin-destination survey should be of sufficient length to indicate seasonal variations in commodity and vehicle flows. A rate survey is undertaken in conjunction with the origin-destination survey to determine the rates charged by transporters, and a shipper survey is also conducted to determine the commodity preference factors for each commodity.

A survey of past and base-year population, production, consumption, imports and exports must be conducted in each of the zones, and sufficient data collected to permit these factors to be forecast over the analysis period. Again, data regarding seasonal variations in production and consumption should be gathered. The population study will be used as a factor in estimating consumption by zone, and in the simulation and forecasting of passenger travel, and it should be supplemented by data on income.

The study of production, consumption, imports and exports is used to develop supply and demand inputs for the transportation model, and is also required as the basis for estimating the effect of changes in the transportation system on production and consumption. The study may be in the usual form of an input-output table, but it may be abbreviated to consider only the zonal surpluses and deficiencies requiring transportation. When much of the economic activity in a country consists of subsistence agriculture and there is little transportation of the inputs and outputs, a considerable saving may be realized by coding only net surpluses and deficiencies by commodity and by zone, rather than coding total production and consumption, for input into the transportation model. The costs and cost characteristics of production, prices, supply and demand elasticities, and the non-economic factors which determine the reaction to reduced transport costs for inputs and outputs must be estimated by commodity and by zone, in order that the effect of changes of different magnitudes in transportation costs can be estimated. The effects will be those noted in the previous chapter dealing with generated traffic, and will include increased production and consumption, transportation of goods which were previously produced but not transported, increased transportation of goods which were previously produced and transported, and possible economies of scale resulting from increased levels of production.

In each case, the non-transportation costs of the increased production and the effect on average costs of production, changes in market prices, and the non-transportation capital costs required must be estimated in order that the value of the net benefit may be calculated. In the calculation of the net value of these "other costs and benefits," it is assumed that non-transportation investments will earn a return equal to the assumed opportunity cost of capital. The ultimate effects of transportation changes on production and consumption can only be estimated on the basis of a relatively detailed study of the production, distribution and marketing of each commodity, and it is desirable that these estimates be made by specialists in agriculture, mining, forestry and other relevant sectors, taking as full account as possible of the non-economic factors which influence reactions to cost and price changes.

The existing transportation model program is able to accommodate a maximum of forty commodities or commodity classifications. This limitation was found to be somewhat restrictive, even in the relatively simple Dahomey economy, but the capacity could be increased.

The final result of this part of the study will be a base-year table of supply and demand by commodity, zone and season, and sufficient data to permit the forecasting of supply and demand as it will be over the analysis period if there are no major changes in the transportation system, and as it will be for a range of possible changes in the transportation system and in transportation costs. It will also provide data for the calculation of the net value of "other costs and benefits" resulting from transportation improvements.

(c) Operation

The supply and demand data by commodity, zone and season for the base-year are inserted into the transportation model, and the base-year traffic is simulated for each season, using linear programming or gravity models as considered appropriate to the various commodities. The simulated traffic is then compared with the actual base-year traffic by commodity, vehicle type, route and season, and adjustments are made until a satisfactory simulation of the actual flows is achieved. If data are available, this calibration procedure should also be carried out for one or more years in the past, in order to provide a better indication of the nature of the adjustments which should be made. In the Dahomey study the calibration was based on one year only, and since runs of the transportation model were required to achieve an acceptable simulation of the actual commodity and vehicle flows. In the simulation of base-year traffic, the existing rate structure is approximated as closely as possible in order that traffic will be simulated on the basis of costs as perceived by the shipper, including the costs associated with waiting time, travel time, and other measures of commodity preference and link performance.

The output of the transport model shows among other things, the flows on each link in each season by commodity and vehicle type, and an origin-destination matrix which indicates the total perceived transportation cost for each commodity from each origin to each destination, by season.

Production and consumption by commodity and zone are then forecast for each season of each year over the analysis period, on the assumption that no major changes will be made in the road system. These forecasts are used as input to the transportation model which then simulates future traffic. The economic forecasts and traffic simulations may be made individually for each year of the analysis period, or they may be made for selected years, for example every third or fourth year, and the values for the intervening years developed by an interpolation program. In either case, the result is in the form of traffic flows by vehicle type on each link for each season and year of the analysis period. The traffic flows are then used as input to the link optimization program.

Although the optimization program is designed to calculate all of the costs for each construction standard and maintenance level on each link simultaneously, in this first run it is constrained to consider only the existing construction standard and maintenance level on each link. A sample of the output of this run, for one of the links of the road system in Dahomey, is shown in Figure 1.[13] This output indicates that the existing standard of the link between nodes 10 and 115 is construction class 4, or a one-lane laterite-surfaced road, and the existing maintenance level is level 2, or minimum maintenance. The output shows the operating cost, maintenance cost and total cost in each year from 1967 to 1990, and their present values as of the beginning of 1967 at a range of discount rates, assuming that the same standard and maintenance level will be continued over the whole period. This gives the total economic cost of transportation over the analysis period for the null or "do nothing" alternative. Similar tables are produced for every other link, and the cost portions of the tables are combined and printed out for the network as a whole.

Using the same traffic forecasts, the link optimization program is run again, still constrained to the existing construction standard on each link, but now free to consider all

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[13]The monetary values in this sample output are in million C.F.A. Francs, but naturally any currency unit may be used. The annual values are the sums of the values for each season of each year, which are calculated separately and combined before this output is printed. The traffic volumes shown are average daily volumes of total vehicles, and do not enter into the calculations.

FIGURE 1

SAMPLE OUTPUT - LINK OPTIMIZATION PROGRAM

Optimization of Link Between 10 (Pobe) and 115 (Ikpin) Mode 23 - Present Conditions - Construction Class 4

Link Characteristics: Distance (km): 12.30; Design Speed (kph): 80.00; Rise/Fall (ft): 290.00; Region: South; Delay Season: 1; Delay Factor: 1.08.

Interpolations: Vol. pres. system: 2; vol. impr. system: 2; Cst. pres. system: 2; Cst. Impr. system: 2.

	Operating Cost			Maintenance Cost		Capital
Year	M/L 1	M/L 2	M/L 3	M/L 1	M/L 2	Cost
67	0.	30.458	0.	0.	1.544	0.
68	0.	32.580	0.	0.	1.607	0.
69	0.	34.851	0.	0.	1.673	0.
70	0.	37.279	0.	0.	1.741	0.
71	0.	39.877	0.	0.	1.813	0.
72	0.	42.656	0.	0.	1.888	0.
73	0.	45.629	0.	0.	1.967	0.
74	0.	48.808	0.	0.	2.049	0.
75	0.	52.210	0.	0.	2.135	0.
76	0.	56.697	0.	0.	2.254	0.
77	0.	61.621	0.	0.	2.380	0.
78	0.	67.029	0.	0.	2.513	0.
79	0.	72.972	0.	0.	2.654	0.
80	0.	79.510	0.	0.	2.804	0.
81	0.	86.706	0.	0.	2.962	0.
82	0.	94.635	0.	0.	3.131	0.
83	0.	103.376	0.	0.	3.309	0.
84	0.	113.020	0.	0.	3.498	0.
85	0.	123.668	0.	0.	3.698	0.
86	0.	135.433	0.	0.	3.911	0.
87	0.	148.440	0.	0.	4.136	0.
88	0.	162.832	0.	0.	4.375	0.
89	0.	178.765	0.	0.	4.628	0.
90	0.	196.416	0.	0.	4.896	0.

PRESENT VALUES

DISC Rate						
5.0	0.	973.70	0.	0.	34.49	0.
8.0	0.	667.29	0.	0.	24.65	0.
10.0	0.	532.77	0.	0.	20.22	0.
12.0	0.	434.01	0.	0.	16.90	0.
15.0	0.	330.38	0.	0.	13.32	0.
20.0	0.	227.05	0.	0.	9.60	0.
30.0	0.	133.01	0.	0.	5.99	0.
40.0	0.	92.65	0.	0.	4.31	0.
50.0	0.	70.96	0.	0.	3.37	0.

FIGURE 1 (Continued)

Other Costs and Benefits	Total Cost M/L 1	M/L 2	M/L 3	Daily Volume
0.	0.	32.001	0.	239
0.	0.	34.187	0.	250
0.	0.	36.523	0.	261
0.	0.	39.021	0.	273
0.	0.	41.690	0.	286
0.	0.	44.545	0.	299
0.	0.	47.596	0.	312
0.	0.	50.858	0.	327
0.	0.	54.345	0.	341
0.	0.	58.951	0.	362
0.	0.	64.001	0.	384
0.	0.	69.541	0.	407
0.	0.	75.626	0.	431
0.	0.	82.313	0.	457
0.	0.	89.669	0.	485
0.	0.	97.765	0.	514
0.	0.	106.685	0.	544
0.	0.	116.518	0.	577
0.	0.	127.366	0.	612
0.	0.	139.343	0.	649
0.	0.	152.576	0.	687
0.	0.	167.207	0.	729
0.	0.	183.393	0.	773
0.	0.	201.312	0.	819

Present Values

Disc Rate			
0.	0.	1008.19	0.
0.	0.	691.95	0.
0.	0.	552.99	0.
0.	0.	450.91	0.
0.	0.	343.70	0.
0.	0.	236.65	0.
0.	0.	139.00	0.
0.	0.	96.97	0.
0.	0.	74.33	0.

three possible levels of maintenance. The output is similar to that of the previous run, except that maintenance levels 1 and 3 are now included. Since level 3 represents zero maintenance, no maintenance costs are shown for this level, but the effect of this maintenance level is reflected in vehicle operating costs. All changes are assumed to go into effect at the beginning of 1971; therefore the operating costs up to this time are those appropriate to the existing maintenance level.

On each link, one maintenance level will produce a lower present value of total costs than either of the other two levels. Assuming the opportunity cost of capital in the country is ten percent per year, then the maintenance level producing the lowest present value of total costs at a discount rate of ten percent is selected as the initial "optimum" maintenance level.

On each link where the "optimum" level is different from the existing level, there will be a change in vehicle operating costs when the maintenance level is changed. This, in turn, implies changes in traffic volumes on these and other links, and possible changes in supply and demand. Therefore, the file of road link characteristics in the transportation model is revised to show the new maintenance levels, and the transportation model is run again, still using the original supply and demand inputs.

As noted earlier, the transportation model output shows not only the flows on each link, but also an origin-destination matrix by commodity, and the perceived costs of transporting each commodity from each origin to each destination. The new perceived costs are compared with those from the original run of the transport model, and the reductions in perceived costs resulting from the maintenance improvements can be calculated for each commodity, from each origin to each destination. On the basis of the reductions in perceived costs, and from data developed in the initial production and consumption surveys, new estimates of production and consumption are made, and the net values of the "other costs and benefits" are calculated. A commodity may use a number of links in its travel from an origin to a destination. The net value of other costs and benefits is distributed to the various links on the basis of the saving in perceived costs which occurs on each link used.

The revised estimates of production and consumption are then used in a further run of the transportation model, and the resulting traffic volumes are used as input for another run of the optimization program. The net value of other costs and benefits associated with each link is introduced into the optimization program exogenously, for each year of the analysis period. The optimization program again tests each link at each maintenance level, and the "optimum" levels at a discount rate of ten percent are again selected. The levels selected are those which provide the lowest present value of total costs on each link, with the net value of other costs and benefits being treated as negative costs.[14]

The link characteristics file in the transportation model is again revised in accordance with the new maintenance levels on the links, and the procedure is repeated, until further iterations produce no appreciable change in the maintenance levels selected. The final maintenance levels thus selected are considered to be the optimum ones, assuming that construction standards will remain unchanged over the analysis period. The difference between the total costs with existing conditions and the total costs with optimized maintenance represents the benefits which could be derived through improved maintenance alone, while the difference between the original and the new maintenance costs represent the incremental maintenance cost incurred to produce the benefits.

It should be noted that the maintenance levels could be optimized concurrently with the optimization of construction standards, which would simplify the analysis and reduce the

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[14]It is possible that the maintenance level selected on a link will be lower than the existing level which means that vehicle operating costs and thus perceived costs, will increase, and "other costs and benefits" will represent a net disbenefit and production consumption could decline. However, because maintenance costs are relatively small, and because low maintenance levels have a significant effect on vehicle operating costs, this is very unlikely. It did not occur in the Dahomey study.

cost. The results would be the same in terms of the final selection of capital and maintenance projects. However, the benefits of improved maintenance could not then be distinguished from the benefits attributable to capital improvements and the terms of reference of the Dahomey study required that internal rates of return on the individual capital investments be calculated.[15] For this reason, it was necessary to follow the above procedure.

The next step in the procedure is to identify possible capital investment projects and evaluate their economic justification. These may take the form of new links to be added to the system, or the up-grading of existing links to higher construction standards. Two types of new link possibilities can be identified: those which are designed to penetrate new areas, and which join the existing system at only one end of the new link, and those which are alternatives to existing links or combinations of links, and which are joined at both ends to the existing system. The first type of new link possibility is identified during the economic survey when the productive potential of each zone is estimated by the agricultural, forestry, and other specialists. The second type, which may also have the effect of penetrating new areas, is

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[15]Rates of return on individual projects within a system are somewhat unrealistic because of the interdependencies among the links. They can be approximated, however, as will be explained later in the chapter.

identified by a combination of the above considerations and engineering judgment, considering possible short-cuts and other improvements which could be made by adding new links to the existing system. The new links are added to the link file of the transportation model at construction standards which are considered by judgment to be appropriate to the probable volumes of traffic which they will carry. Construction costs are estimated for the new links for the standards at which they are added to the network, and for all reasonable higher and lower standards.

The transportation model thus revised is then run with the existing links at their original standards and optimum maintenance, and with the new links at the inserted standards and adequate maintenance. The supply and demand inputs used are those which resulted from the final maintenance optimization. The resulting traffic flows are put into the link optimization program which is now operated without constraints, i.e. it can evaluate every reasonable construction standard and all three maintenance levels on every existing and new link. A sample of the output of this run, for one link, is shown in Figure 2. Alternative 0 represents the link at its existing construction class while Alternatives 1 to 3 represent consecutively higher classes with the associated capital costs for upgrading from the existing standard.

On each existing link there will be one construction standard and maintenance level which produces a lower present

FIGURE 2

SAMPLE OUTPUT - LINK OPTIMIZATION PROGRAM

ALL ALTERNATIVES

(a) Optimization of Link Between 10 (Pobe) and 115 (Ikpin) Mode 23 - Alternative No. 0 - Construction Class 4

Link Characteristics: Distance (km): 12.30; Design Speed (kph): 80.00; Rise/Fall (ft): 290.00; Region: South; Delay Season: 1; Delay Factor: 1.08.

Interpolations: Vol. pres. system: 2; Vol. Impr. system: 2; Cst. pres. system: 2; Cst. Impr. system: 2.

	Operating Cost			Maintenance Cost		
Year	M/L 1	M/L 2	M/L 3	M/L 1	M/L 2	Capital Cost
67	30.458	30.458	30.458	1.544	1.544	0.
68	32.580	32.580	32.580	1.607	1.607	0.
69	34.851	34.851	34.851	1.673	1.673	0.
70	37.279	37.279	37.279	1.741	1.741	0.
71	33.108	41.397	53.239	3.381	1.868	0.
72	35.462	44.322	57.010	3.526	1.946	0.
73	37.984	47.454	61.049	3.678	2.028	0.
74	40.685	50.807	65.374	3.837	2.114	0.
75	43.579	54.397	70.005	4.003	2.204	0.
76	47.345	59.099	76.056	4.230	2.326	0.
77	51.480	64.260	82.698	4.471	2.456	0.
78	56.023	69.931	89.996	4.726	2.594	0.
79	61.018	76.167	98.021	4.997	2.740	0.
80	66.515	83.028	106.851	5.283	2.895	0.
81	72.569	90.585	116.576	5.587	3.059	0.
82	79.241	98.913	127.294	5.909	3.234	0.
83	86.599	108.098	139.114	6.251	3.418	0.
84	94.721	118.236	152.162	6.613	3.614	0.
85	103.692	129.435	166.573	6.997	3.821	0.
86	113.608	141.812	182.501	7.403	4.041	0.
87	124.575	155.502	200.119	7.835	4.274	0.
88	136.713	170.653	219.618	8.292	4.520	0.
89	150.156	187.433	241.213	8.776	4.782	0.
90	165.053	206.029	265.144	9.289	5.060	0.
Present values						
Disc Rate						
5.0	834.39	1012.05	1268.12	59.85	35.42	0.
8.0	576.38	691.98	858.56	41.63	25.28	0.
10.0	462.91	551.56	679.27	33.48	20.71	0.
12.0	379.48	448.54	548.02	27.41	17.28	0.
15.0	291.71	340.54	410.86	20.94	13.60	0.
20.0	203.78	233.04	275.16	14.33	9.77	0.
30.0	122.80	135.55	153.87	8.15	6.07	0.

FIGURE 2 (a)(Continued

Other costs and Benefits	Total Cost M/L 1	M/L 2	M/L 3	Daily Volume
0.	32.001	32.001	32.001	239
0.	34.187	34.187	34.187	250
0.	36.523	36.523	36.523	261
0.	39.021	39.021	39.021	273
0.	36.489	43.264	53.239	295
0.	38.988	46.268	57.010	309
0.	41.662	49.482	61.049	323
0.	44.522	52.921	65.374	338
0.	47.582	56.601	70.005	353
0.	51.575	61.425	76.056	374
0.	55.951	66.717	82.698	397
0.	60.749	72.525	89.996	421
0.	66.015	78.907	98.021	446
0.	71.799	85.923	106.851	473
0.	78.156	93.644	116.576	501
0.	85.150	102.146	127.294	531
0.	92.850	111.516	139.114	563
0.	101.334	121.850	152.162	597
0.	110.689	133.255	166.573	633
0.	121.011	145.852	182.501	671
0.	132.409	159.775	200.119	711
0.	145.005	175.173	219.618	754
0.	158.932	192.215	241.213	799
0.	174.342	211.088	265.144	847

Present Values

Disc Rate			
0.	894.24	1047.47	1273.93
0.	618.01	717.25	863.97
0.	496.39	572.26	684.45
0.	406.89	465.82	552.98
0.	312.65	354.14	415.51
0.	218.11	242.82	279.37
0.	130.96	141.62	157.38

FIGURE 2 (continued)

(b) Optimization of Link Between 10 (Pobe) and 115 (Ikpin)
Mode 23 - Alternative No. 1 - Construction Class 5

Year	Operating Cost M/L 1	Operating Cost M/L 2	Operating Cost M/L 3	Maintenance Cost M/L 1	Maintenance Cost M/L 2	Capital Cost
67	30.458	30.458	30.458	1.544	1.544	0.
68	32.580	32.580	32.580	1.607	1.607	0.
69	34.851	34.851	34.851	1.673	1.673	0.
70	37.279	37.279	37.279	1.741	1.741	13.900
71	19.329	24.381	31.225	3.434	1.881	0.
72	20.272	25.571	32.749	3.579	1.960	0.
73	21.260	26.819	34.347	3.731	2.042	0.
74	22.296	28.129	36.023	3.890	2.127	0.
75	23.383	29.502	37.781	4.056	2.217	0.
76	24.837	31.336	40.131	4.283	2.340	0.
77	26.385	33.289	42.631	4.524	2.470	0.
78	28.033	35.367	45.293	4.779	2.608	0.
79	29.787	37.581	48.128	5.049	2.754	0.
80	31.656	39.938	51.147	5.336	2.909	0.
81	33.646	42.450	54.364	5.640	3.073	0.
82	35.768	45.127	57.792	5.962	3.247	0.
83	38.029	47.980	61.446	6.304	3.432	0.
84	40.441	51.022	65.342	6.666	3.627	0.
85	43.013	54.267	69.498	7.050	3.834	0.
86	45.758	57.730	73.932	7.456	4.054	0.
87	48.687	61.426	78.666	7.887	4.287	0.
88	51.815	65.372	83.720	8.344	4.534	0.
89	55.156	69.588	89.118	8.829	4.796	0.
90	58.726	74.092	94.887	9.342	5.073	0.
Present Values						
Disc Rate						
5.0	444.54	529.62	644.77	60.39	35.56	11.44
8.0	328.05	384.78	461.56	42.01	25.37	10.22
10.0	275.19	319.38	379.20	33.79	20.78	9.49
12.0	235.28	270.24	317.55	27.66	17.35	8.83
15.0	191.84	217.08	251.25	21.12	13.64	7.95
20.0	145.78	161.37	182.48	14.46	9.81	6.70
30.0	98.75	105.84	115.45	8.22	6.08	4.87
40.0	75.24	79.01	84.13	5.51	4.36	3.62
50.0	60.99	63.22	66.23	4.07	3.40	2.75

FIGURE 2 (b) (Continued)

Year	Other Costs and Benefits	M/L 1	M/L 2	M/L 3	Daily Volume
67	0.	32.001	32.001	32.001	239
68	0.	34.187	34.187	34.187	250
69	0.	36.523	36.523	36.523	261
70	0.	52.921	52.921	52.921	273
71	0.	22.763	26.262	31.225	295
72	0.	23.851	27.531	32.749	309
73	0.	24.991	28.861	34.347	323
74	0.	26.186	30.256	36.023	338
75	0.	27.439	31.719	37.781	358
76	0.	29.120	33.676	40.131	374
77	0.	30.909	35.759	42.631	397
78	0.	32.812	37.975	45.293	421
79	0.	34.836	40.335	48.128	446
80	0.	36.992	42.847	51.147	473
81	0.	39.286	45.523	54.364	501
82	0.	41.730	48.374	57.793	531
83	0.	44.333	51.411	61.446	563
84	0.	47.107	54.649	65.342	597
85	0.	50.063	58.102	69.498	633
86	0.	53.214	61.784	73.932	671
87	0.	56.574	65.713	78.666	711
88	0.	60.159	69.906	83.720	754
89	0.	63.985	74.384	89.118	799
90	0.	68.069	79.165	94.887	847

Present Values

Disc Rate				
5.0	0.	516.36	576.61	662.01
8.0	0.	380.28	420.37	477.19
10.0	0.	318.47	349.66	393.87
12.0	0.	271.78	296.42	331.34
15.0	0.	220.91	238.68	263.85
20.0	0.	166.94	177.88	193.40
30.0	0.	111.83	116.79	123.82
40.0	0.	84.36	87.00	90.74
50.0	0.	67.81	69.36	71.56

FIGURE 2 (Continued)

(c) Optimization of Link Between 10 (Pobe) and 115 (Ikpin)
Mode 23 - Alternative No. 2 - Construction Class 6

Link Characteristics: Distance (km): 12.30; Design Speed (kph): 100.00; Rise-Fall: 290.00 ft.; Region: South; Delay Season: 1; Delay Factor: 1.00.

Interpolations: as for (a)

	Operating Cost			Maintenance Cost		Capital
Year	M/L 1	M/L 2	M/L 3	M/L 1	M/L 2	Cost
67	30.458	30.458	30.458	1.544	1.544	0.
68	32.580	32.580	32.580	1.607	1.607	0.
69	34.851	34.851	34.851	1.673	1.673	27.600
70	37.279	37.279	37.279	1.741	1.741	27.600
71	17.978	27.140	34.777	2.282	1.602	0.
72	18.960	28.621	36.677	2.300	1.669	0.
73	19.995	30.183	38.680	2.318	1.739	0.
74	21.086	31.831	40.792	2.337	1.812	0.
75	22.237	33.568	43.020	2.357	1.888	0.
76	23.785	35.904	46.014	2.385	1.992	0.
77	25.452	38.420	49.239	2.414	2.103	0.
78	27.248	41.133	52.715	2.444	2.220	0.
79	29.186	44.058	56.464	2.512	2.477	0.
80	31.277	47.215	60.510	2.512	2.477	0.
81	33.536	50.625	64.880	2.548	2.616	0.
82	35.978	54.311	69.604	2.587	2.764	0.
83	38.619	58.298	74.714	2.628	2.922	0.
84	41.479	62.614	80.246	2.672	3.088	0.
85	44.577	67.291	86.239	2.718	3.264	0.
86	47.936	72.362	92.738	2.768	3.451	0.
87	51.582	77.865	99.791	2.820	3.650	0.
88	55.541	83.841	107.450	2.875	3.860	0.
89	59.845	90.338	115.776	2.933	4.082	0.
90	64.526	97.405	124.834	2.995	4.319	0.

Present Values

Disc Rate						
5.0	445.71	612.02	750.75	31.54	31.14	46.55
8.0	327.04	437.02	528.76	23.31	22.41	42.20
10.0	273.52	358.74	429.83	19.49	18.47	39.59
12.0	233.30	300.37	356.32	16.56	15.51	37.19
15.0	189.76	237.86	277.98	13.32	12.31	33.93
20.0	143.92	173.35	197.90	9.83	8.98	29.28
30.0	97.55	110.76	121.77	6.25	5.70	22.23
40.0	74.49	81.47	87.29	4.50	4.16	17.24
50.0	60.51	64.61	68.02	3.50	3.28	13.63

FIGURE 2 (c) (Continued)

Year	Other Costs and Benefits	Total Cost M/L 1	M/L 2	M/L 3	Daily Volume
67	0.	32.001	32.001	32.001	239
68	0.	34.187	34.187	34.187	250
69	0.	64.123	64.123	64.123	261
70	0.	66.621	66.621	66.621	273
71	0.	20.261	28.742	34.777	295
72	0.	21.259	30.290	36.677	309
73	0.	22.313	31.922	38.680	323
74	0.	23.423	33.642	40.792	338
75	0.	24.594	35.456	43.020	353
76	0.	26.169	37.897	46.014	374
77	0.	27.865	40.524	49.239	397
78	0.	29.693	43.353	52.715	421
79	0.	31.663	46.402	56.464	446
80	0.	33.789	49.691	60.510	473
81	0.	36.085	53.241	64.880	501
82	0.	38.565	57.075	69.604	531
83	0.	41.248	61.219	74.714	563
84	0.	44.151	65.702	80.246	597
85	0.	47.295	70.555	86.239	633
86	0.	50.704	75.813	92.738	671
87	0.	54.401	81.514	99.791	711
88	0.	58.416	87.701	107.450	754
89	0.	62.778	94.420	115.776	799
90	0.	67.522	101.724	124.834	847

Present Values

Disc Rate				
5.0	0.	523.80	689.71	803.10
8.0	0.	392.54	501.62	576.37
10.0	0.	332.60	416.80	474.60
12.0	0.	287.05	353.07	398.46
15.0	0.	237.01	284.10	316.56
20.0	0.	183.03	211.16	231.39
30.0	0.	126.02	138.68	147.51
40.0	0.	96.23	102.87	107.52
50.0	0.	77.64	81.52	84.24

FIGURE 2 (Continued)

(d) Optimization of Link Between 10 (Pobe) and 115 (Ikpin)
Mode 23 - Alternative No. 3 - Construction Class 7

Characteristics and Interpolations as in (c)

Year	Operating Cost M/L 1	Operating Cost M/L 2	Operating Cost M/L 3	Maintenance Cost M/L 1	Maintenance Cost M/L 2	Capital Cost
67	30.458	30.458	30.458	1.544	1.544	0.
68	32.580	32.580	32.580	1.607	1.607	0.
69	34.851	34.851	34.851	1.673	1.673	35.000
70	37.279	37.279	37.279	1.741	1.741	35.000
71	15.799	23.904	30.601	2.288	1.627	0.
72	16.570	25.073	32.096	2.294	1.693	0.
73	17.378	26.298	33.664	2.300	1.763	0.
74	18.225	27.583	35.309	2.306	1.836	0.
75	19.113	28.930	37.034	2.313	1.913	0.
76	20.302	30.729	39.337	2.322	2.017	0.
77	21.567	32.644	41.788	2.331	2.128	0.
78	22.914	34.683	44.397	2.341	2.245	0.
79	24.348	36.853	47.176	2.352	2.369	0.
80	25.875	39.165	50.135	2.363	2.641	0.
81	27.502	41.628	53.288	2.375	2.789	0.
82	29.236	44.253	56.648	2.387	2.946	0.
83	31.085	47.051	60.230	2.401	2.946	0.
84	33.056	50.034	64.049	2.415	3.113	0.
85	35.159	53.217	68.123	2.430	3.289	0.
86	37.402	56.612	72.470	2.446	3.476	0.
87	39.796	60.237	77.109	2.462	3.674	0.
88	42.353	64.107	82.063	2.480	3.884	0.
89	45.084	68.241	87.355	2.499	4.107	0.
90	48.003	72.658	93.010	2.519	4.343	0.

Present Values

Disc Rate						
5.0	385.15	521.66	634.36	30.02	31.39	59.03
8.0	288.45	379.47	454.62	22.39	22.59	53.51
10.0	244.34	315.25	373.79	18.82	18.61	50.20
12.0	210.88	266.97	313.27	16.07	15.62	47.16
15.0	174.22	214.72	248.16	13.01	12.40	43.02
20.0	134.89	159.91	180.57	9.67	9.03	37.13
30.0	93.79	105.18	114.58	6.19	5.73	28.19
40.0	72.60	78.66	83.67	4.48	4.18	21.87
50.0	59.44	63.01	65.96	3.49	3.29	17.28

FIGURE 2 (d) (Continued)

Year	Other Costs and Benefits	Total Cost M/L 1	M/L 2	M/L 3	Daily Volume
67	0.	32.001	32.001	32.001	239
68	0.	34.187	34.187	34.187	250
69	0.	71.523	71.523	71.523	261
70	0.	74.021	74.021	74.021	273
71	0.	18.088	25.531	30.601	295
72	0.	18.864	26.766	32.096	309
73	0.	19.678	28.061	33.664	323
74	0.	20.531	29.419	35.309	338
75	0.	21.426	30.843	37.034	353
76	0.	22.624	32.746	39.337	374
77	0.	23.898	34.772	41.778	397
78	0.	25.255	36.928	44.397	421
79	0.	26.699	39.223	47.176	446
80	0.	28.238	41.666	50.135	473
81	0.	29.877	44.269	53.288	501
82	0.	31.624	47.042	56.648	531
83	0.	33.486	49.997	60.230	563
84	0.	35.471	53.147	64.049	597
85	0.	37.588	56.506	68.123	633
86	0.	39.848	60.088	72.470	671
87	0.	42.259	63.911	77.109	711
88	0.	44.834	67.991	82.063	754
89	0.	47.584	72.348	87.355	799
90	0.	50.522	77.001	93.010	847

Present Values

Disc Rate				
5.0	0.	474.21	612.09	699.19
8.0	0.	364.35	455.57	513.55
10.0	0.	313.37	384.06	429.17
12.0	0.	274.11	329.74	365.38
15.0	0.	230.25	270.14	295.84
20.0	0.	181.69	206.08	221.92
30.0	0.	128.17	139.09	146.27
40.0	0.	98.95	104.70	108.52
50.0	0.	80.21	83.58	85.83

value of total costs than all of the others, at a discount rate of ten percent. The link characteristic file of the transportation model is then revised to show this standard and maintenance level. All proposed new links are retained in the file. The transportation model is then run and the second part of the output, the origin-destination matrix and the new perceived transport costs by commodity, is used to calculate the change in perceived cost for each commodity between each origin and destination. Based on the changes in perceived costs, the supply and demand forecasts are revised and the net value of "other costs and benefits" is calculated for each link, existing and new. However, on some of the existing links where no capital projects were shown to be justified at ten percent, projects may have been justified if they had been credited with a net value of other costs and benefits. Therefore, this net value is also calculated for capital projects on these links which were rejected at ten percent but accepted at five percent and appropriate further revisions are made to the supply and demand inputs.[16]

The revised supply and demand inputs are inserted into the transportation model, and new traffic forecasts are obtained. The optimization program is then run again, using these new traffic forecasts and the exogenously-calculated net

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[16]This leaves the possibility that capital projects which were rejected at five percent may have been accepted at ten percent if the net value of other costs and benefits had been added. This is considered unlikely, but the possibility could be avoided by calculating the net values for every possible construction standard and maintenance level.

values of other costs and benefits, and the resulting least-cost configuration of each link is determined. The link characteristic file is then revised, the transport model run again, new perceived costs by commodity and origin and destination are developed, the supply and demand forecasts are revised, new net values of other costs and benefits are calculated, and the optimization program is run again. This process is repeated until further iterations fail to produce significant changes in the transportation system. In the Dahomey study, this point was reached within five iterations after the new links had been added and tested.[17]

(d) Results

This method of analysis does not permit the traffic on each link to be classified into normal, diverted and generated traffic. However, the transportation costs associated with each type of traffic are included in the analysis, as are the benefits to normal and diverted traffic. The benefits associated with generated traffic have also been measured, except for those associated with generated passenger travel. The benefits of generated passenger travel cannot be determined within the confines of the analysis method, but the vehicle operating costs incurred by the generated travel can be calculated for the system as a whole, and these can be said to

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[17]Additional tests of new links are made by extracting from the transportation model those parts of the system directly affected by the new links, and running these subsystems with and without the new links.

represent the minimum benefits.

When the final optimization has been completed, the following data is available for further analysis:

1. the present values of operating and maintenance costs on each link, and for the whole system, over the period of the analysis, on the assumption that no major changes will be made to the road system;
2. the present values of operating costs, maintenance costs and other costs and benefits on each link and for the whole system, over the period of the analysis, on the assumption that there will be no capital investments, but that optimum maintenance will be carried out, and
3. the present values of operating costs, maintenance costs, capital costs and other costs and benefits for each link and for the whole system, over the period of the analysis, on the assumption that all of the selected capital projects and maintenance improvements will be undertaken and in service by the beginning of 1971.

From a comparison of (1) and (3), the present values of capital costs, incremental maintenance costs, and benefits can be calculated for the whole package of recommended improvements; with all discounting of future costs and benefits at a rate equal to the opportunity cost of capital. A present value of net benefits and a benefit-cost ratio can then be calculated for the whole package. An internal rate of return can be developed by graphing the present values of costs and benefits for the various discount rates used. Thus, criteria of economic justification can be developed for the final package of improvements, with the assurance that each individual improvement within the package is economically justified. In addition, the costs and benefits of each capital investment which is economically justified in the context of the system can be developed by a comparison of (2) and (3) above; therefore the same criteria can be calculated for the individual investments. This is somewhat unrealistic in a systems analysis, where no single link or project is independent of the other links and projects, but on the assumption that the complete package of improvements will be undertaken, it gives an indication of the relative priorities of the projects.

The projects which are economically justified at the assumed opportunity cost of capital should be undertaken as soon as possible; otherwise, economic benefits will be lost. Thus, the total capital cost of the selected capital projects represents the capital budget which should be allocated to road construction and improvement. If financing for all of these projects cannot be obtained, this can be interpreted as an indication that the assumed opportunity cost of capital was understated. In this case, a higher opportunity cost should be assumed and the project selection revised, so that the capital cost requirement is reasonably close to the budget available.[18]

The annual maintenance budget is simply the sum of the annual maintenance costs on each link of the optimized system. However, the capital and maintenance budgets cannot be extracted directly from the outputs of the link optimization program since all costs in the program are economic costs, net of taxes and duties and using shadow prices where appropriate. The financial equivalents of these costs must be calculated in order to formulate realistic budgets. Annual user charge revenue can be estimated from the total number of vehicles registered in the country, the total kilometers travelled by each class of vehicle in each year, and the user charge structure. Increases in revenue resulting from the road improvements are not considered as economic benefits, but they are an important factor in estimating the funds which will be available for road construction and maintenance, assuming that some or all of the revenue is thus applied. Alternative user charge structures can be tested within the framework of the model to determine their effects on traffic flows, economic development, and revenue.

On the basis of the total kilometers travelled by each vehicle class per year as indicated by the transportation

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[18] This point is discussed in detail in Clell G. Harral, Preparation and Appraisal of Transport Projects (Washington: The Brookings Institution, 1965), p. 130.

model, the average lifetime kilometers of the different vehicle types, and the base-year vehicle registration statistics, a rough estimate of the vehicle imports which will be required can be made, and the foreign exchange requirements estimated. This estimate of the yearly additions to the vehicle fleet can also be used in the estimation of user charge revenue as noted above.

Thus, the Dahomey Method has a number of useful features apart from its primary objective of evaluating the economic feasibility of public investment in transportation.

(e) Evaluation of the Dahomey Method

The Dahomey Method will be evaluated primarily in comparison with the Harvard Model, but the comparison will be based on the features of each which are relevant to the selection and evaluation of public investments in transportation in underdeveloped countries. Thus, many advantageous features of the Harvard Model relating to its uses in general economic planning will be neglected. Since both methods use the transportation model portion of the Harvard Model, the major differences are those which arise from the use of the link optimization program rather than the macro-economic model.

The Harvard Model evaluates proposed investments directly in terms of their effect on national income, which is in keeping with the objective of investment evaluation assumed in this thesis. The Dahomey Method does not do this; rather, it attempts to measure the effect on national income indirectly, by taking as full account as possible of the costs and benefits of transportation investments. Thus, for example, the multiplier effect is not measured within the framework of the Dahomey Method. Both methods permit a level of decision to be defined, although the Dahomey Method is probably more amenable to being scaled down to a level of decision below the national one. It differs from the Harvard Model in that its basic economic requirement is an abbreviated input-output table, while a full input-output table is only one of the requirements of the macro-economic model. This difference is primarily attributable to the fact that the Dahomey Method attempts to measure only the changes resulting from transportation investments, while the Harvard Model attempts to quantify the whole economy with and without the investments, and measure the difference by a comparison of the two.

Both methods take account of the timing of costs and benefits in that these are calculated year by year. It was suggested that only specific years be analysed in the Dahomey method, and the values for intervening years be developed by interpolation, but this does not preclude the possibility of a year-by-year analysis. Both simulate traffic on the basis of the production, consumption and other economic factors which produce the traffic, and on the basis of total transportation costs as perceived by the shipper, and both distinguish among the various types of vehicles in the traffic stream. The differences among normal, diverted and generated traffic are accounted for by both methods, although neither specifically identifies each type of traffic in the total flows on the various links.

In both the Harvard Model and the Dahomey Method, changes in the transportation system are reflected in changes in the economy, which in turn, act back on the transportation system. However, the relationship between the transport system and the economy is more fully recognized in the Harvard Model, in that the requirement of internal consistency is more rigorous than in the Dahomey Method, thus tending to ensure that all facets of the relationship are taken into account. Both methods consider all links simultaneously, taking account of the interdependencies among the links.

In terms of input requirements, the Dahomey Method is considerably less stringent than the Harvard Model, partly because it aims at a less rigorous analysis, and partly because it is directed more specifically to a relatively narrow objective than is the Harvard Model. Although cost comparisons are not available, it would seem that the data collection phase of the study would be considerably less costly using the Dahomey Method, and problems related to the availability of data would be less serious. In both cases, the collection of sufficient historical data to permit the calibration of the transportation model is a serious problem, but the Harvard Model presents the even greater problem of calibrating the macro-economic model.

Past traffic counts in different sections of underdeveloped countries are frequently available, but past economic data which could be used as a basis for estimating regional income are generally less common.

The basic different between the two methods in their use as tools of investment evaluation and selection is that the Dahomey Method involves a search and evaluation procedure, whereas the Harvard Model is strictly a simulation procedure which cannot be used to evaluate numerous investment possibilities individually, except at prohibitive cost. It does not attempt to select an optimum package of economically justified investment proposals; it merely tests the effect of packages which are selected primarily by judgment and introduced exogenously. The Dahomey Method also relies on judgment in the formulation of proposed new links, but the need for subjective judgment is greatly reduced in the selection of proposed improvements to existing links, and in the selection of a final package of investments. The judgment factor is still present, however, and it is not suggested that the Dahomey Method "optimizes" in the sense that no further improvements could be made to the system, or that no better combination of investment proposals could be identified.

In summary, the Dahomey Method overcomes the major deficiencies which have been identified in this thesis. It takes account of the relationships between the transportation system and the economy, and the interdependencies among the individual links in the system. The procedures recommended to remedy the minor deficiencies identified can be accommodated within its framework, and it has the capacity to handle the large number of variable factors involved in a comprehensive transportation analysis. Like the Harvard Model, it is still in an experimental stage in that no transportation analysis has been successfully completed using the method, but the Dahomey study is now nearing completion, and no conceptual problems have been identified which would prevent its successful application to future studies of this nature.

CHAPTER V

CONCLUSIONS

In the review of the methods commonly used to evaluate proposed public investments in transportation, two major problems have been identified. The first is the failure to relate the transportation system and proposed changes in the system, to the economy as a whole. The second is the failure to relate individual links in the transport system to the whole system, taking full account of the interdependencies among the links. It is considered that the solution to these problems can be found in a method of analysis which incorporates a national income approach and a systems approach to investment evaluation.

Two analyses methods which incorporate these features have been described and evaluated. One, the Harvard Model, overcomes the major problems and can also accommodate the procedures suggested to remedy the minor deficiencies identified in the usual methods and their applications. However, there are a number of problems involved in the practical application of the Harvard Model, and it is concluded that the model has not yet reached a stage of development where it can be applied with confidence to a practical situation. Even if it were at such a stage of development, it would still be incapable of testing a large number of alternative investment possibilities and selecting the optimum combination, except at prohibitive cost. It is therefore concluded that the Harvard Model is not now an appropriate method of investment evaluation, nor will it ever be in its present format.

The other method of investment evaluation, the Dahomey Method, also overcomes the major problems and is also able to accommodate the procedures required to overcome the minor deficiencies. It is specifically designed to test a large number of investment possibilities and indicate the best package of investments from among those considered. Its cost of application is reasonable in relation to the budgets normally available in such studies, and its data requirements are less stringent than those of the Harvard Model. It is a relatively simple method, which can be applied with reasonable assurance that it will produce the desired results. It is therefore concluded that the Dahomey Method is the best currently available for the economic analysis of proposed public investments in transportation facilities.

The above methods are not really alternative ways of reaching a common objective; they were designed to serve different purposes. In the future, as more progress is made in the development and application of the Harvard Model, it is possible that the two methods could be combined, using the transport model to simulate commodity and vehicle flows, the link optimization program to evaluate and select possible investments and formulate a transportation investment program, and the macro-economic model to simulate the effect of the investment program on the whole economy. This combination of methods would provide an excellent basis for general transportation planning as well as for transportation investment analysis, and it would also be an invaluable tool for general economic planning.

The Harvard Model and the Dahomey Method constitute significant advances in the techniques of transportation evaluation, and further advances can be expected as the development of these methods continues. The review of past studies and discussions with people involved in transportation analysis have also suggested ways in which the quality of analysis could be further improved. In spite of the large number of studies done, little attempt has been made to review past studies to determine how accurate the forecasts made in the studies were, and to determine the reasons for inaccurate forecasts. Testing of this nature could be most productive in terms of improving forecasting techniques. One of the results of such testing may well be the indication that non-economic factors--tradition, attitudes, social structures, and similar factors--are at least as important as the economic factors commonly considered in the estimation of the effects of changes in the transportation system. This would suggest that investment study groups should be expanded to include disciplines such as sociology as well as the usual engineering and economic disciplines.

The lack of traffic and economic data in underdeveloped countries is often an obstacle to the completion of a comprehensive analysis. This situation cannot readily be improved in respect to past years, but hopefully, the application of methods such as the Harvard Model and the Dahomey Method will indicate more precisely the nature of data deficiencies, and lead to programs of data collection and publication of statistics on a continuing basis, designed to remedy the deficiencies.

As noted in the Introduction, the recent emphasis given transportation investment evaluation has resulted in significant improvements in methods of evaluation. The application of electronic computers to investment studies has made approaches such as the Harvard Model and the Dahomey Method possible, and can be expected to contribute significantly to the continued improvement of public transportation investment analysis. Thus, the Harvard Model and the Dahomey Method are considered to be only the first of a whole new generation of improvements in methods of analysis.

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