ROAD TRANSPORT RESEARCH

road maintenance and rehabilitation: funding and allocation strategies

REPORT PREPARED BY
AN OECD SCIENTIFIC EXPERT GROUP

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

The Programme centres on road and road transport research, while taking into account the impacts of intermodal aspects on the road transport system as a whole. It is geared towards a technico-economic approach to solving key road transport issues identified by Member countries. The Programme has two main fields of activity:

-- International research and policy assessments of road and road transport issues to provide scientific support for decisions by Member governments and international governmental organisations;

-- Technology transfer and information exchange through two databases - the International Road Research Documentation (IRRD) scheme and the International Road Traffic and Accident Database (IRTAD).

The scientific and technical activities concern:

-- The management, rehabilitation and environmental assessment of road and bridge infrastructure;

-- The formulation and evaluation of targeted road and traffic safety programmes;

-- The development and management of road traffic technology and advanced driver communication systems;

-- The assessment of urban and inter-urban road transport strategies, freight operations and logistics approaches;

-- The strategic planning and management of research and joint projects as well as technology diffusion, both in OECD countries and economies in transition;

-- The maintenance management of road infrastructure and the evaluation of traffic safety measures and strategies in developing countries.

ABSTRACT

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The study evaluates methods used in resource allocation and distribution for maintenance and rehabilitation works, taking due account of the prevailing political, economic and social context and perceived problems in OECD Member countries. It proposes guidelines for best and flexible practices to be instituted in widely differing institutional frameworks of Member countries. Chapter I describes the technical, social, political and economic factors in the decision making process. In Chapter II road systems, funding practices and organisational structures of OECD countries are surveyed. Chapter III reviews road programme preparation, and funding allocation and Chapter IV discusses the analytical background needed to support an engineering-economic approach to road maintenance. Calculating of benefits and costs are presented in Chapter V, characterisation and measurement of road conditions in Chapter VI, and environment and other externalities in Chapter VII. Chapter VIII presents a recapitulation of best practices, and Chapter IX gives ten "commandments" for implementing effective resource allocation policies for road rehabilitation and maintenance works. Under current budget constraints for new road construction projects, road maintenance and rehabilitation has a key position in preserving the value of the road asset, and ensuring improved service to road users. The Report provides road administration managers and engineers with rational resource allocation methods based on rigorous scientific and technico-economic analysis.

Field Classification: Economics and administration; equipment and maintenance methods.

Field Codes: 10, 61.

Keywords: Maintenance; administration; cost benefit analysis; decision process; pavement management system; road user; environment; financing; repair; distribution (gen).

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EXECUTIVE SUMMARY

A NEW CONCEPT FOR REHABILITATION AND MAINTENANCE

The OECD Expert Group on *Resource Allocation for Road Rehabilitation and Maintenance Programmes* was established in 1992 to evaluate methods used in resource allocation and distribution for maintenance and rehabilitation works, propose improvements to these methods and, if possible, seek common approaches for road system management.

Road maintenance and rehabilitation, traditionally viewed as a mundane topic for second rate engineers, operates today in a changed context and with a changed concept. It has now a key position in preserving the value of the road asset, providing improved service to road users and contributing to environmental quality. In fact, during the life cycle of a road the responsibilities and life styles of people, their travel demands as well as communities will change and the road network has to be adapted to the new circumstances.

The objective of maintenance and rehabilitation is no longer to simply keep the road in appropriate condition as a structure. Road Administration management and its analytical procedures need to be broadened toward environmental and aesthetic milieu assessment recognising opportunities for improvements and including affected interests in the early phases of highway studies.

To restate, rehabilitation and maintenance have experienced a change in concept and content: they are meant to preserve the value of the investment and to improve the environment.

ROAD ADMINISTRATION OPERATES IN A COMPLEX ENVIRONMENT AND FACES CHALLENGING ISSUES

A country's transport system is an enormous national asset. Management of the system is a highly sensitive and complex task, entrusted to a country's Road Administration and shaped by a constellation of political, technical, environmental, managerial and historical forces. In addition to transport sector objectives, roads are often used to achieve social objectives which lie outside the road transport sector, to help implement a vision for the future.

The political environment in which the Road Administrations' managers and professionals work is complex, even hostile. Managers are asked not only attempt to minimise the society's expenditure on transport but also to meet user needs. These user needs range from an acceptable level of service, to a desire for clean environment and sustained economic development and to a low share of user taxes to provide for the agency's funding. The everyday reality for Road Administration professionals is that they must increase their effectiveness and productivity in accomplishing a mission that grows in complexity while budgetary constraints become increasingly sever. Issues challenging every road manager in every country are elaborated in Chapter I.

Since management practices and organisation structures depend on each other, the study of the Group started with a survey of institutional settings, trends in Road Administrations and resource allocation and funding practices in Member countries. This laid a solid foundation for the Group's work and enables a proposal for a framework that is generic and flexible could be put forward, in spite of the great variety in organisational structures and administration styles in Member countries. The key results of this survey are presented and discussed in Chapter II and III.

THE CONCEPTUAL APPROACH: A COMPREHENSIVE ASSESSMENT BASED ON LIFE CYCLE COSTS AND BENEFITS

The situation faced by the Road Administrations involves a difficult trade-off between on the one hand, the adverse consequences of traffic on the environment and on the other, the beneficial effects of good roads on the economy and social well-being.

The management needs a conceptual approach which is broad and comprehensive, yet responds to decision-makers' needs and supports the dialogue with the politicians and the public. The management is also required to ensure that most effective use is made of the taxpayers monies to serve the motorists and deter deterioration of the environment. The technical staff, for its part, needs a tool which can be employed to implement the physical works in an efficient manner and which is of course consistent with the managerial directives.

The commonly accepted objective of road resource allocation is the minimisation of administration plus user costs over the life time of the facility or the network. A more restricted objective of minimising only the administration's costs is often employed. This latter objective requires standards which however, imply economic and social choices and should indeed be part of the analysis. For this reason and because the user costs are overwhelmingly large as compared to the administration's cost, the broader objective of minimising the sum of the administration and user costs is adopted as the organising concept in the Report. This scientific approach is described both in technical and non-technical terms in Chapter IV. The operational implementation of the method is dependent on institutional structures, managerial styles, methods of financing and criteria Road Administrations use in formulating their multi-year programmes.

The proposed approach embodies a three-tier hierarchy, network-programme-project, found in every Member country. The network level resource allocation and distribution is done at the highest managerial level and focuses on the network and sub-networks without a specific project in mind. The programme level is an intermediate activity which ties together the network level resource distribution with the project level expenditures. This is a necessary feature of resource allocation and distribution. The hierarchy helps ensure fairness, avoid mis-allocation or mis-distribution of monies, and, over time, ensures a consistent and well-justified level of funding for maintenance and rehabilitation.

The OECD countries and also developing countries, can derive advantages of economies of scale and scope from road maintenance management methods which have common rationale and enjoy widespread acceptance among professionals. International co-operation is desirable to exchange experience, survey the best practices available and identify steps to make major gains in managing resource allocation and distribution in road administrations.

IDENTIFICATION OF BENEFITS AND COSTS REQUIRES AN EXCELLENT INFORMATION DATA BASE

The Road Administration's information system serves multiple purposes, such as Central Administration's needs regarding planning and investment, rehabilitation strategies, or the Regional Administration's needs for organising routine maintenance activities. The greater the complexity of the objectives, the more elaborate are the management's information requirements.

The main aim of benefit and cost calculations is to enable managers to give informed input to the budget negotiations and political dialogue and to identify the most advantageous rehabilitation and maintenance strategy. A corollary aim is to enable the design engineers, at the project level, to associate with it the most economical maintenance works over the life cycle of the facility subject to policies established at the network level.

Different rehabilitation and maintenance management strategies will have a direct effect on the experienced costs and benefits. Some of these costs and benefits will be of a quantifiable and others of a non-quantifiable nature. Chapter V sets out the various costs and benefits of maintenance and rehabilitation split between those that are internal to the administration and road users and those that are external; some will be quantifiable and others non-quantifiable.

Enumeration of benefits and costs requires an excellent information system *to enable management to strengthen the decision-making process and increase productivity.* Chapter VI of the Report discusses how information Road Administration's systems relate to the road manager's needs in resource allocation and distribution and what approaches may be used in measuring the road network's conditions.

ENVIRONMENT AND MILIEU: KEY ELEMENTS IN DECISIONS

Environmentally sensitive construction and maintenance of roads provide tangible benefits: cleaner air and more pleasing appearance of road space; protection of neighbourhoods from roads and traffic; increased quality of life; higher value of land and homes; and aesthetic milieu of urban business centres. Access without the visible nuisance due to roads is a highly valued commodity. Environmental investment in the framework of road works is already substantial; presently 5-15 per cent of road costs are environment related expenditure.

Quantitative consideration of the environment is difficult even in the context of new construction, but is the most common theme discussed in public hearings. Take an example from Switzerland; a section of a national highway, 24 km long, currently under construction had an initial cost estimate

US$165 million in 1967. Because the road traverses an ecologically difficult zone on a lake shore, changes in alignment and adaptations to the different environmental obligations pushed the final cost estimate to US$735 million! In this instance the external costs have been internalised in the plan, in the design and construction.

For rehabilitation and maintenance the situation is much more difficult. The status quo is a road in use and the traditionally quantifiable costs of maintenance works may suggest negligible impacts. However, the reality may differ. Indeed, any attempt to construct an index for environmental quality, -- such as a benefit/cost ratio -- will hide the issues rather than bring them out to be discussed.

Public participation is again, recognised as an important element in all transport planning. Actions and measures conceived in this way gain political and public acceptance. The public is willing to pay for the higher costs of the more extensive environmental rehabilitation and, at the same time, the existing road itself can be effectively maintained and rehabilitated.

TEN COMMANDMENTS FOR RESOURCE ALLOCATION IN ROAD REHABILITATION AND MAINTENANCE

Resource distribution for rehabilitation and maintenance should -- indeed must -- be done with a good understanding about the trade-offs with development investments. Roads and bridges should not be kept in good or excellent condition for their own sake, but for the sake of the users. Thus, there may be instances in which disinvestment, or some lack of rehabilitation or maintenance, may be a wise action, obviously within the legal constraints for safety and environment, allowing for redirecting of these funds to new facilities where they better satisfy the needs of the users. Consistent with this concept, the objective of road rehabilitation and maintenance is to preserve the value of the investment **and** to improve the milieu and the environment. This conclusion sets new requirements for decision-aiding systems.

Regardless of the specific administrative and organisational structure of a country, the survey conducted as part of this Report shows that there is consistency in how road funds are allocated and distributed. For "best practice" (as discussed in detail in Chapter VIII) to accomplish this allocation and distribution, countries have developed -- or should develop -- an integrated Road and Bridge Management System as proposed in this Report.

In outline, the management system should be capable of assessing the physical and operating conditions of the current road network with the accuracy and detail desired by the Road Administration. By using estimates of travel demand -- disaggregated geographically and functionally -- the management system should provide forecasts about future requirements, both in capital and rehabilitation outlays as well as routine maintenance to achieve varying levels of system performance. It should also provide input to allocation of costs among road users to help develop equitable funding of the road network over the long run.

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For 'best practices' in resource allocation and distribution decisions, a unified analytical framework is proposed -- minimisation of user and administration costs. However, a clear distinction is made between network, programme and project level. The first serves policy applications by the Central Administration and the latter two project prioritization and design, normally applied by the regional executing agency. All these applications must be based on the same data.

During the course of its work, the Group developed a consensus on 'Ten Commandments' which governments and Road Administrations should observe in developing a method for resource allocation and distribution for road maintenance and rehabilitation programmes and the process to be followed. These 'commandments' are:

I. *Maintenance is an Opportunity for Enhancing the Environment as well as Safeguarding the Road Network Asset.*

II. *Road and Bridge Maintenance Should be Pursued for the Sake of the Users. Therefore, Public Participation is an Essential Part of Developing the Road Maintenance Programme.*

III. *Road and Bridge Assets Should be Maintained in an Economical Way.*

IV. *A Sound Analytical Framework is Important for Delivering an Economical and Environmentally Sound Product.*

V. *User Costs Must Be Treated as Important Costs and Included in the Analytical Framework.*

VI. *Budget Constraint on the Administration's Expenditures is an Important Feature of the Analytical Procedures. Competitive Maintenance and Rehabilitation Programmes are One Important Means to address these Constraints.*

VII. *The Entire Road Budget and Trade-offs Between Alternative Uses Must be Considered when Allocating and Distributing Resources.*

VIII. *The Management Systems Used in Allocating a Distributing Resources Must Be Compatible with the Road Administration's Organisation and Management Style.*

IX. *The Methods Used at Network, Programme and Project Levels must be Different but Interlocking and Utilise the Same Data Base.*

X. *Data Systems which Support the Road and Bridge Management Systems Must be Timely and Reliable.*

CHAPTER I

INTRODUCTION

I.1. BACKGROUND

A country's transport system is an enormous national asset. As the circulation system of the body politic, it facilitates commerce, communication, and economic and social growth. Management of the system is a highly sensitive and complex task, entrusted to a country's road administration and shaped by a constellation of political, technical, environmental, managerial and historical forces.

Despite its complexity, the mission of a country's road administration is typically stated in broad simple terms, e.g.: "*Effectively manage the transport system that serves the country*". In addition "serving clients", delivering "quality products", "environment", "the economy", and recognising the "value of the employees" are increasingly emphasised goals and add to the managerial dimension of a road administration's mission.

In addition to these transport sector objectives, roads are often used to achieve social objectives which lie outside the road transport sector, to help implement a vision for the future. One historical manifestation of this tendency occurred at the beginning of this century when farmers were "pulled out of the mud" by paving roads. Today, environmental enhancement is sought, in part, through effective use of road rehabilitation and maintenance resources. Recently, with the decline of funds available for road management, rehabilitation and maintenance of roads have gained a position of paramount importance.

The objective of the OECD Scientific Expert Group on 'Resource Allocation for Road Maintenance and Rehabilitation Programmes', a component of the OECD's *Road Transport Research Programme* was two fold. First, the Group set out to examine the operational dimensions of managing a country's road system. Second, its aim was to provide a framework of analysis for road administration managers and engineers. This framework should incorporate both the vision for the future as well as the verifiable facts and details about roads as an engineering product, and -- most importantly -- be flexible and general enough to serve the different administrative circumstances prevailing in the OECD countries.

It might appear on the surface to be a contradiction, but in fact the "big picture" -- the vision of a country's road system -- can only be implemented by attending to a multitude of small details. The central question of the operational aspect of road management is the way in which allocation and distribution of resources for various purposes accomplish the road administration's mission.

At the outset it is useful to define several key terms as they are applied in this report. The term (resource) 'allocation' in this report is used to mean apportioning of funds to road purposes by an elected body, such as Parliament, often on the basis of a recommendation by the road administration. The term 'distribution' is used to mean the apportioning of (politically) allocated budgets between programmes, objectives, and projects in the road sector. This distribution is normally done by a road administration (agency). The word 'agency' is used nearly interchangeably with the word 'administration'. If there is a difference it is the following: 'agency' is associated with the execution or management of road improvements, while 'administration' with the discharge of duties specified in the country's laws.

Another set of definitions which recur throughout this report concern 'development', 'rehabilitation', 'periodic maintenance', and 'routine maintenance'. The definitions of these terms are: (1) 'development' means construction of new roads, capacity increases by means of adding lanes, and substantial realignment of a road which may or may not increase capacity; (2) 'rehabilitation and maintenance', or simply maintenance, means reconstruction or rehabilitation of existing roads and periodic maintenance, such as surfacing or resurfacing, of these roads; and (3) 'operations' means keeping roads passable every day. These activities are often called 'routine maintenance' and include snow and ice control (if applicable), upkeep of traffic signs and markings, road side care, and patching and sealing road surface.

The operational objectives to which road administrations' professional staffs attach importance are among the following: traffic safety, capacity increases to sustain or enhance current operating speeds as well as respond to changing traffic demand, rehabilitation of existing roads, and environmental amelioration. In some countries and States improved farm to market accessibility, congestion management, and promotion of carpooling and public transit are also important objectives.

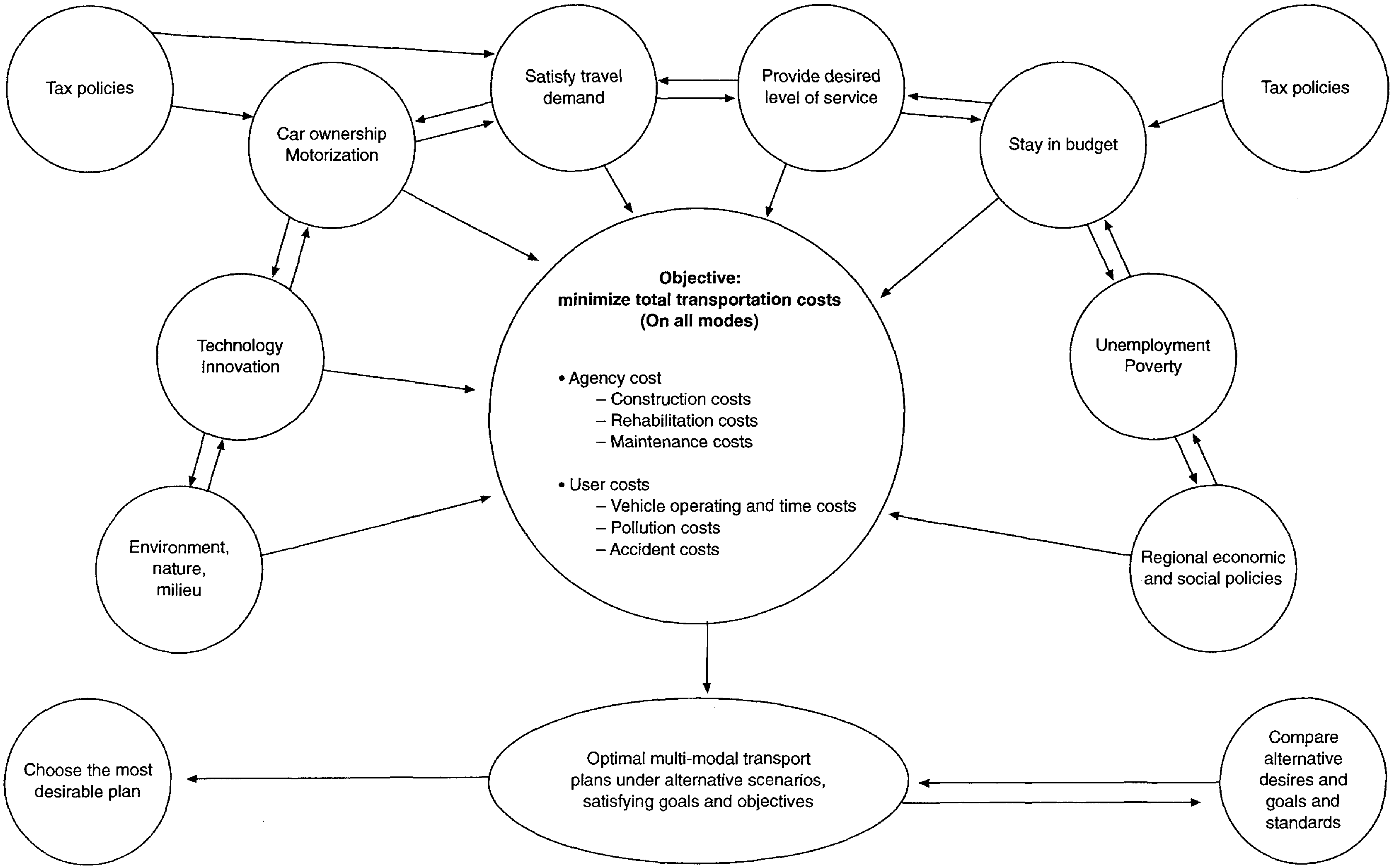
The issues and problems surrounding these objectives constitute a familiar, well trodden ground for road professionals in every country, and most transport managers anticipate them in the normal course of their work. However, what makes dealing with them technically difficult is their intricate relationship with a full range of socio-economic parameters and nearly every facet of life, and the complications they introduce to decision-making in road management.

The political environment in which the road administrations' managers and professionals work is complex, even hostile. Managers are asked not only to attempt to minimise the society's expenditure on transport but also to meet user needs. These range from an acceptable level of service, to a desire for clean environment and sustained economic development, and to a low share of user taxes to provide for the agency's funding. The everyday reality for road administration professionals is that they must increase their effectiveness and productivity in accomplishing a mission that grows in complexity while budgets constraints become increasingly severe. Figure I.1 portrays the constellation of often competing and contradictory forces and demands which the transport decision-maker faces.

In this complex 'universe' in which everything depends on everything else, the road administrations are called upon, and used by others, to serve multiple objectives. A 1984 survey of the U.S. State highway professionals (1) led to the conclusion that transport is perceived and used by State (country) policy makers as means to ends other than those directly impacting transport, "sometimes to the discomfort of transportation professionals."

Larson and Rao (2), who undertook a comprehensive study of the U.S. State Highway Agencies' capital programme management practices, describe the complexity of these practices and venture to guess that "in a more competitive environment for resources, highway capital programmes will likely

Figure I.1. **Decision making considerations in road rehabilitation and maintenance**



require a new focus and broader ranging goals". They claim that there is no "right way" to manage the highway capital programme and argue for "directed autonomy" to allow creative approaches to be developed by individual States. Larson and Rao suggest, further, that the best results are achieved when there is a balance between the need for direction and control on the one hand and freedom and flexibility on the other, depending on the political, cultural, and demographic circumstances of each State.

I.2. AIM

The present report is part of a long-standing series of OECD Road Transport Research reports on maintenance and rehabilitation issues of road infrastructure[1]. The report, dealing with fund allocation and distribution for road and bridge rehabilitation projects seeks to be sensitive to overall political, economic and social circumstances in Member countries. Its starting point was a survey of current practices and perceived problems. The report discusses issues, concepts and methods involved in the processes of critical concern to the road agency management and key ministerial officials and politicians.

The orientation in the document is a managerial one. It seeks to address three central questions. First, of what service can a systematic model be -- a road and bridge management system model, that offers a basic conceptual structure but can be adapted and quantified to suit each country's unique needs? Second, what kind of information can managers expect from their policy staff? And finally, what kinds of questions can and should managers ask and expect adequate responses to?

I.3. ROAD ASSET

The highway network of any country, but especially of a developed country, is a major public investment designed to support the national economy by enabling industry, business and commerce to transport goods and people. The investment itself is usually undertaken as a result of balancing the various competing costs and benefits. When developed, the road network is expected to meet the national objectives for road transport and at the same time minimise whole life costs (or life cycle costs) of facilities and the transport costs of goods and persons.

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1 Previous OECD studies addressing a range of technical, economic and management aspects include: *Maintenance of rural roads* (1973), *Road strengthening* (1976), *Maintenance techniques for road surfacings* (1978) and *Catalogue of road surface deficiencies* (1978), *Road surface characteristics: their interaction and their optimisation* (1984), *The maintenance of unpaved roads in developing countries* (1987), *Freight vehicle overloading and load measurement* (1988), *Pavement management systems* (1987), *Traffic management and safety at highway work zones* (1989), *Road monitoring for maintenance management: Manual and damage catalogue for developing countries* (1990), *Dynamic loading of pavements* (1992), *Road strengthening in Central and Eastern European countries* (1993), *Road maintenance management systems in developing countries* (1994).
Likewise, on bridges and engineering structures, the following OECD reports are noteworthy: *Bridge inspection* (1976), *Evaluation of load carrying capacity of bridges* (1979), *Bridge maintenance* (1981), *Bridge rehabilitation and strengthening* (1983), *Durability of concrete road bridges* (1989), *Bridge Management* (1992).

Road infrastructure is thus a significant economic asset. The replacement values range from US$ 0.1 million per km for minor roads to US$ 1-7 million per km for interurban multilane motorways. The asset value of a road network is in the order of one half to three times the annual GNP (Gross National Product) of a country (3). The costs borne by road users are typically 10 times that amount, so the share of all road transport costs in the economy is in the order of 2-17 per cent of GDP (Gross Domestic Product): in advanced industrialised economies this may be as low as 2 per cent, but in developing countries it ranges up to 17 per cent of GDP. These costs are reflected in the prices of commodities and services.

Equally striking, and giving concrete meaning to a road agency's objective of 'serving the clients', is the significant share of user costs of total transport costs, the latter being the user costs plus the agency costs. As shown in Figure I.2 when the volume on a road is as low as 300 vehicles per day, a volume level exceeded on an average road in every OECD Member country, the road agency's maintenance and rehabilitation costs are merely a fourth of total transport costs. This statement is conditional to a big IF: if the resources committed to rehabilitation and maintenance are adequate to permit "optimal maintenance". This is an elusive concept and will be explored later in this report.

The development of a road infrastructure is a complex, multi-layered, high-stakes endeavor for any country. At each turn, crucial decisions must be made, and each involves expenditure of valuable resources. What can a Road Administration manager do to achieve economic efficiency in the provision of road infrastructure and in road user costs? How is he to determine priorities in highway improvement programmes? What road should be improved? When should the improvement take place? What should be done -- routine maintenance, resurfacing, or reconstruction? What is the benefit to society of another ECU or dollar spent on maintenance or rehabilitation, compared to another spent on new roads or improving alignments? Is it more economical to build a stronger pavement and spend more initially, thereby permitting the use of larger vehicles and saving on maintenance? Or, should the construction be done in stages, economising on the initial construction and paying more for maintenance and upgrading later on, when uncertainties about traffic growth will have been resolved? How much, or how little, should be spent to maintain paved roads, and how much to maintain and upgrade gravel roads? How long can maintenance be deferred in times of financial stringency? In short, what should be the highway budget for various purposes, where should the money be spent, and what exactly should be the road improvement action?

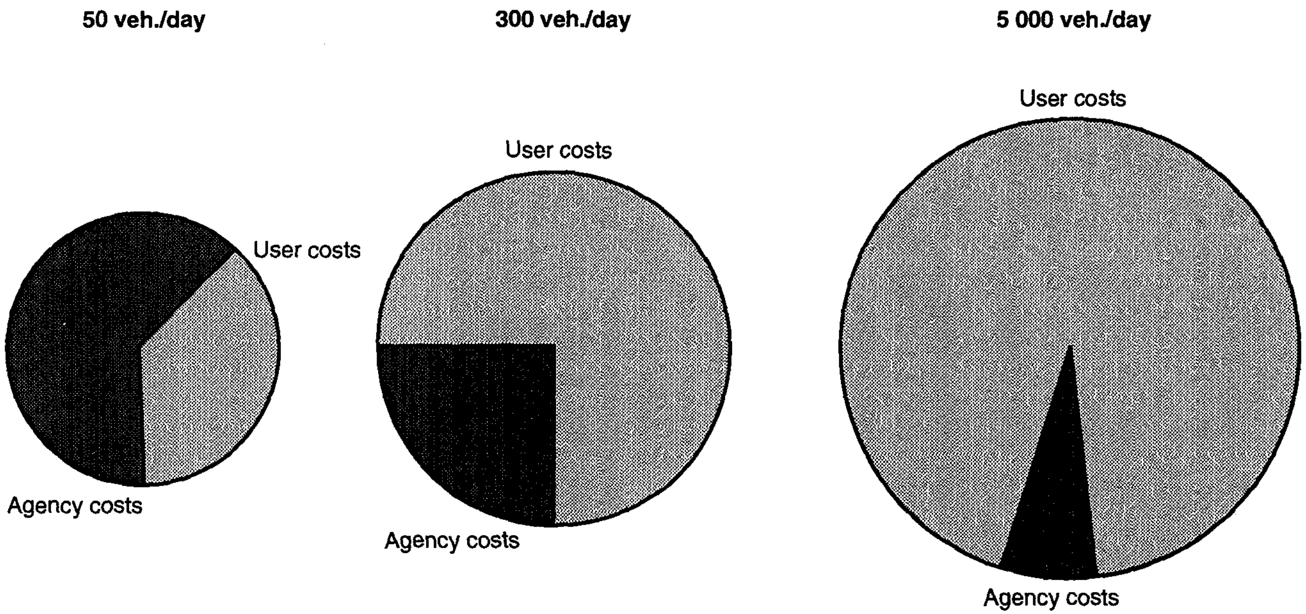
These are difficult but important questions. They are difficult not only technically, as is implied above. But because of the sophistication of the transport system, the extent of the road network, the complexity of relationships, and the political realities which are always present in road system management and decision-making, these are difficult questions from managerial point of view.

I.4. MANAGEMENT ISSUES

I.4.1. Three main activities and three levels of decision-making

A Road Administration's work encompasses the management, planning, and execution involved in the development, rehabilitation and routine maintenance of the road system.

Figure I.2. **Cost-shares under optimal maintenance**



From a managerial perspective and as pointed out in Section I.1, 'development' consists of new investments or marked improvements in road level of service; 'rehabilitation' denotes periodic resurfacing or strengthening of structural capacity; and, 'operations' means routine maintenance, snow and ice removal (in certain countries), care of roadside and service areas, guardrails, upkeep of traffic signs and markings, and other minor repairs -- potholes, shoulders -- to keep pavements smooth and safe to the motorists.

These three main activities are shown as columns in Figure I.3. This three-part division corresponds to the policy and budget making practices of most public infrastructure agencies. It also corresponds to the time horizon of decisions: development for long range ("new constructions"), rehabilitation for intermediate range, and operations for the short range and emergency interventions. In general it has been very difficult to make transfers of funds between operations, rehabilitation and investment budgets.

There are three administrative decision making levels in each road programme area. They are shown as rows in Figure I.3; this Figure illustrates in compact form the domain of resource allocation and distribution in a road administration. The first level -- the network level -- deals with policy and is usually exercised by the central management in the Administration or the Ministry. The third -- the project level -- is normally performed by the district office's engineers charged with execution of the policies including project design. The second level -- the programme level -- lies between the network and project levels; its function is to programme the actions over years to implement the policies set at the network level, in the form of a multi-year road programme.

I.4.2. Road and Bridge Management System (RBMS) - An integrated comprehensive management tool

Road agencies routinely face both important policy questions and increasing demands upon the monies allocated to them. Among the most pressing policy questions confronting road agencies are road rehabilitation and maintenance:

-- What is the optimal level of rehabilitation and maintenance funding nationwide, and what is the corresponding level of road surface condition;

-- What choices of rehabilitation and maintenance actions and budgets will most effectively bring pavement conditions toward an optimal level in long term (in 5 years?, in 10 years?);

-- How are limited funds best distributed between geographical areas of a country and functional classes of roads;

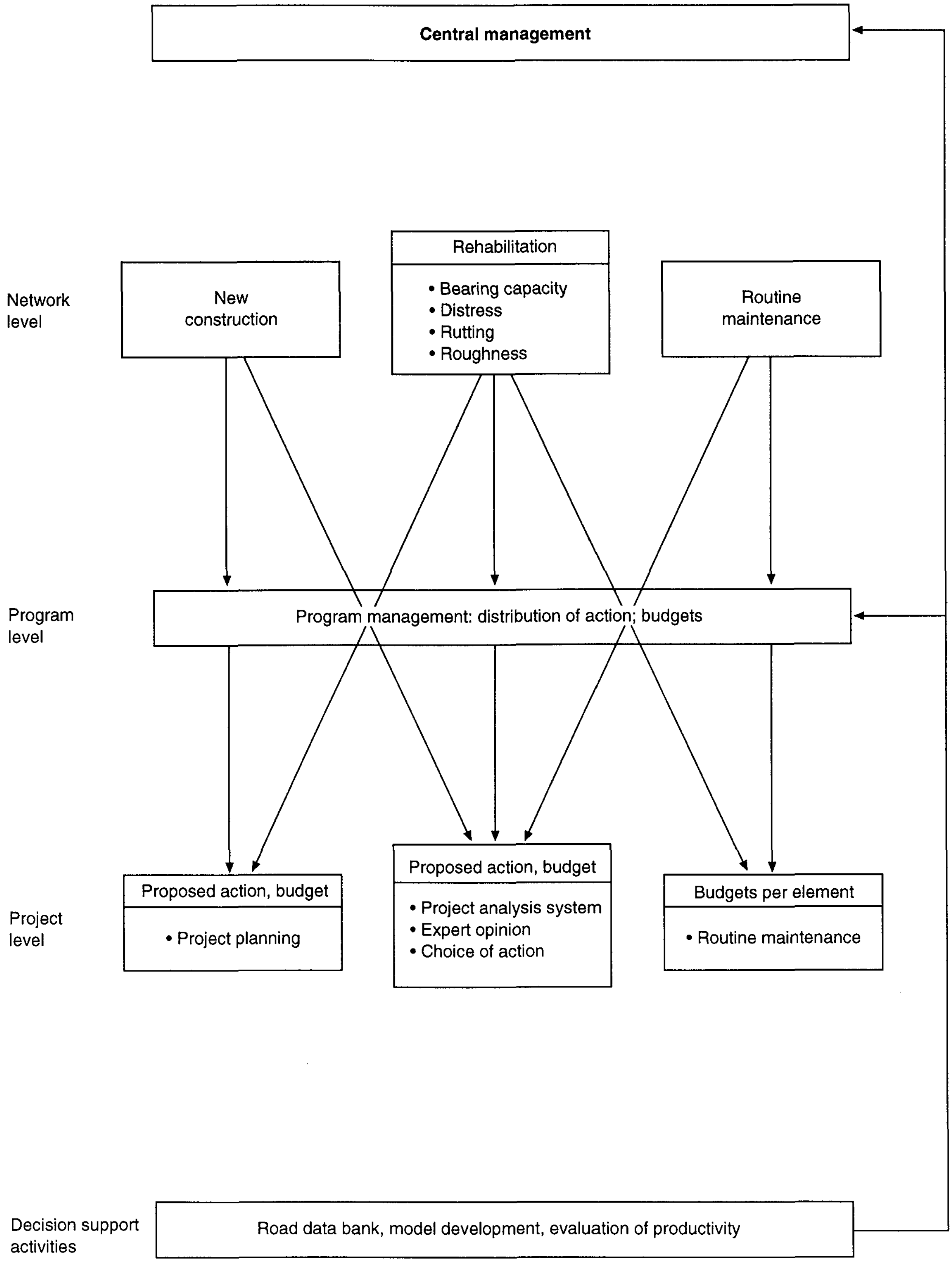
-- What will happen to road surface conditions and structural capacity considering the present budget level;

-- What is the excess user cost linked to the present level of highway budget;

-- What is the excess cost to users and/or to the agency of the present maintenance/condition standards;

-- How are funding requirements and user costs affected if certain roads are allowed to meet standards less than, or different from, the optimal.

Figure I.3. **The road agency - levels of decision-making and main programme areas**



Road agencies do not grapple with these questions in a vacuum; Central and District Administrations (or their equivalent) interact with the road agency in a variety of ways. To address some of these issues, some countries and organisations have implemented Pavement and Bridge Management Systems (4,5,6,7). However, as the environment surrounding road management has become more complex, various inputs, actions, outputs and decisions must be accounted for at all levels. Thus, an extension of these systems, the concept of a Road and Bridge Management System (RBMS) has emerged. It is based on an approach to determining road and bridge standards and expenditure priorities which is different from the often practised conventional management and planning approach.

As a decision-making tool, the RBMS has been designed to include all the components (boxes) of Figure I.3; development, rehabilitation, operations at the network and project levels. The RBMS is thus a modular system which includes pavement management, bridge management, (routine) maintenance management systems, and so forth. It provides decision support from management to engineering. An important feature of this system is that it uses **the same data source and the same overriding objective** (minimisation of total transport costs) in all modules even when the immediate purpose of the decisions is different (e.g. to apportion monies or to choose the most appropriate rehabilitation action).

From the management's point of view a useful Road and Bridge Management System would accomplish the following objectives:

(i) The system should assist in both long term and short term decision making in managing roads in all traffic classes[1] and with all kinds of surfacings;

(ii) The system should be both integrated and differentiated, capable of being separately applied at three different levels of highway management: policy (network), programme (project selection, prioritising, and timing), and project (specific action, design); the degree of detail should vary between the three levels;

(iii) The system should include actions from routine maintenance to resurfacing to rehabilitation to additions of new capacity[2];

(iv) The system should recognise the agency management style. For example, many agencies practice management by objectives (MBO). This means that goals, policies, standards and guidelines are issued from the Central Administration and decisions relating to choice of specific design, mode of execution, etc. are made at the local level;

(v) The system should have connections to other relevant agency functions (e.g. manpower planning, equipment, etc.);

(vi) The system should also serve the overriding goals of the agency relating to environment, economy, safety, technology, accessibility, and management accountability;

As these guidelines imply, the Central Administration is most interested in the policy (network) level and the Regional Administrations are most concerned with the project level. The programme level is of interest to both, but from different perspectives. For the Central Administration the road

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1 Road classification systems - administrative and functional - will be discussed later.

2 The framework to capacity addition decisions should ideally be multimodal.

programme is blueprint for achieving national goals; its performance will be evaluated on the basis of delivering promised services to users with the allocated monies. For Regional (or district) Administrations the road programme is a plan for execution; its mission is to deliver the products at minimum agency costs. In practice this means that the Central Administration is occupied with policy goals, and distribution of actions and budgets by functional road class[1] for each District Administration. The districts are occupied with the engineering and efficient implementation of these policies.

I.5. RECOMMENDED APPROACH TO ROAD MANAGEMENT AND ROAD STANDARDS

As distinct from other management and planning approaches, the RBMS approach might be called an *engineering-economic approach*; its defining aim is to quantify and analyse the trade-offs between alternative courses of actions.

A comparison with two other prevalent approaches to analysing needs and priorities will dramatically demonstrate how the engineering-economic approach differs from other methods. With some variations within each, the other methods allocate and distribute resources on the basis of condition and available funds or when crisis occurs:

(i) **Needs based approach**: A road system is designed and built in accordance with physical standards set in relation to: a) perceived technical requirements for the life of the pavement structure; b) acceptable service levels for users (of riding comfort, safety, and speed); and c) affordable budget levels based on historical trends;

(ii) **Zero-maintenance approach**: A road system is designed and built with capital financing, and then operated with little maintenance until a failure occurs, when the road condition causes complaints, structures begin to disintegrate, or service is obstructed. Then expensive reconstruction work is undertaken to reinstate the facility under special programmes and financing arrangements. This is akin to crisis management.

In contrast the engineering-economic approach can be defined as follows:

(iii) **Engineering-economic approach**: A road system is designed and built in light of functional and technical standards that minimise total road transport costs to society, comprising the life cycle costs of facilities to the agency, the users and society. Standards, therefore, are viewed as an economic choice of what can be afforded rather than an imposed technical requirement, without sacrificing safety levels or environmental quality. When budgets are constrained, the tradeoffs between relaxing either design or maintenance standards are evaluated on the basis of long-term consequences of future higher costs for more expensive treatments such as reconstruction.

Existing management styles have often been typified by the first two approaches; the third is viable only after research work is done and applied. The aim of the engineering-economic approach is to

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1 Sometimes by administrative road class, this issue is clarified and discussed from several viewpoints in Chapters II and III because it is intimately tied with how road administrations are organised and road funding arranged in different countries.

minimise the total road system costs, including user costs, within constraints as to technical characteristics and standards, and funding. It must be emphasised, as will later be explained in detail, that this optimisation process determines both the optimal agency budget and the optimal road standard.

The total transport costs comprise five interacting sets of costs: (1) construction, (2) rehabilitation and periodic maintenance, and (3) routine maintenance and system operation costs spent by the road agency, (4) the road user costs (which are primarily vehicle operating costs but also include some accident costs and time delay costs), and (5) external costs to society (including pollution, societal costs of accidents, and development and production benefits).

This discussion amplifies the earlier observation that making transfers between maintenance and investments budgets is extremely difficult. This suggests an important conclusion which was arrived at in the Group's deliberations and which need to be made explicit in the outset:

Resource distribution for "rehabilitation and maintenance"[1] *should - indeed must - be done with a clear understanding about the trade-offs with "development investments". Roads and bridges should not be kept in good or excellent condition for their own sake, but for the sake of the users. Thus, there may be instances in which disinvestment, or a lack of rehabilitation or maintenance, may be a wise action, obviously within the legal constraints for safety and environment, allowing for redirection of these funds to new facilities where they better satisfy the needs of the users.*

Today, road maintenance operates with a new concept. According to this concept, the objective of road maintenance is to preserve the value of the road investment in the changing environment which includes the road, the road milieu, the processes by which roads are improved; simply put: the objective of road rehabilitation and maintenance is to preserve the value of the investment ***and*** *to improve the man-made and natural environment.*

This conclusion sets new requirements, discussed and elaborated in this report, for decision-aiding systems such as the RBMS, the Road and Bridge Management System.

I.6. ORGANISATION OF THE REPORT

Chapter I has opened this report with an introduction to the increasingly complex universe of road management. That both management as well as technical, social, political and economic factors enter into the decision making process within road administrations at three levels -- network, programme and project -- mandates the application of a more effective Road and Bridge Management System as an analytical approach.

In Chapter II includes a brief survey of road systems, funding practices and organisational structures found in several OECD Member countries. The results show a variety of practices but also marked similarities, enabling the concepts presented in the report to have validity independent of national borders.

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1 Routine maintenance, which also can be analyzed in the framework proposed, was seen to lie outside the Group's mandate and is not addressed in the present report.

Chapter III reviews the road programme preparation, allocation and fund distribution processes. It explores the delicate issues of equity in funding, of competing geographic areas, and competing classes of roads. Present methods of financing are also reviewed in this context because they are intimately tied to the distribution of funds between regions and types of roads.

Chapter IV contains a discussion of the analytical background needed to support the engineering-economic approach to road management. Simple graphs are used to illustrate the most important concepts involved in optimising road rehabilitation and maintenance objectives and associated budgets.

Chapters V-VII examine the components for making the engineering-economic approach operational: calculation of benefits and costs in Chapter V; characterisation and measurement of road condition in Chapter VI; and, in Chapter VII, a discussion of environment and other externalities for which there exist no market at present but which yet exert a decisive influence on the road fund distribution process.

Finally, Chapter VIII presents a recapitulation of the 'best practices' in the resource allocation/distribution process for road rehabilitation and maintenance, and Chapter IX gives the 'Commandments' for implementing the 'best practices' in resource allocation for road rehabilitation and maintenance works.

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CHAPTER II

INSTITUTIONAL SETTINGS OF ROAD ADMINISTRATIONS

II.1. BACKGROUND

In order to provide the background for the Expert Group's deliberations, a survey was undertaken of Member countries' road organisation, management, and resource allocation/distribution processes. This Chapter presents the Institutional settings in Member countries as reference for the findings presented in Chapter III "Allocation and Distribution of Funds between Road Classes and Road Improvements" and Chapter VI "Characterisation and Measurement of Highway Condition". The data included in this Chapter are based on replies to a questionnaire sent to OECD countries participating in the study.

All of the data set out in this Chapter are considered in light of three distinct frames of reference.

The first frame of reference deals with the allocation and distribution of the total resources available within the road sector for investments, rehabilitation and maintenance.

The second frame concerns the decision levels at which the allocation and distribution of funds are made. In spite of the differences between countries, this is a general issue relevant at overall **governmental level** (allocation between different public sectors and between different transport sectors) and at the various **road administrative levels**. The individual allocation and distribution methods reflect the political and administrative organisation prevailing in each country. Subsumed in this discussion are the methods through which resources are distributed by the responsible administrative department, i.e. to regions, subnetworks[1] or specified road or bridge projects. In the latter case the distribution will be influenced by the road classification system used in each country.

The third frame of reference, finally, takes into account the influence of the structure of financing road investments, rehabilitation and maintenance on the resource allocation and distribution process.

Key actors in the allocation and distribution process are: Central and District Administrations (or their equivalents); Ministries of Finance and Transport (or their equivalents); and applicable local

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[1] A subnetwork is a well-defined part of a national network. For example, a subnetwork could be all Main Roads, or all Local Roads, or a network of a region, etc.

government organisations. These actors interact in matters dealing with highway resource allocation and distribution with consequences for, or imparted by:

-- Transport (or Construction, Equipment, Public Works) Ministry obligations and its relation to the Road Administration;
-- The Road Administration;
-- Definition and classification of the road network and the distribution of responsibilities;
-- Skill and competence within the planning unit responsible for the preparation of multi-year plans for maintenance and rehabilitation;
-- Criteria and models used for preparing the multi-year plans;
-- System used for monitoring (and evaluating) the maintenance and rehabilitation activities;
-- Restrictions, financial and legal, in distributing resources.

II.2. MAIN ISSUES

The common base for the presentation of data in this Chapter is the road classification in Member countries and a description of the road network system.

Road classification can be made in a number of ways. In this study the basic classification is made from a **functional** point of view. Roads are classified as serving international, national, regional or local functions; in some cases classification is also influenced by existing road standard (for instance, motorways). A second method of classification is based on **administrative criteria** (for instance federal roads versus State, county or city roads).

Based on the road classification a description and use of the road network is presented. The description is made in terms of:

-- **length of the subnetwork** in each classification (in km),
-- **traffic volume** (vehicle km travelled by car and truck on different road classes),
-- **traffic growth** (actual and forecast), again by road class.

The traffic growth figures are given as actual growth (in most cases for 1990 or 1991) and forecast for future growth (1992 - 1996). Consistent with the traffic load data, traffic growth is given for cars and trucks separately (Figures II.1-4). From this basic information on roads and traffic, an outlook is made towards the two main issues of this Chapter, **administration and organisation**, and **funding and taxation**.

The first issue, then, deals with the organisational structure in Member countries and the delegation in decision making, regarding allocation and distribution of resources for road maintenance and rehabilitation. The question of delegation in decision making is in this case presented in terms of planning responsibilities at different levels in the organisation as well as for different road categories.

The second issue, dealing with funding road maintenance and rehabilitation, is closely related to the issue of taxation which in this case concentrates on the influence resource collection may have on the way resources are allocated and distributed.

II.3. BASES FOR RESOURCE ALLOCATION AND DISTRIBUTION IN OECD COUNTRIES

The source for findings regarding resource allocation and distribution is a compilation of answers to a questionnaire from fifteen OECD Member countries involved in the project. The fifteen countries are:

- -- Canada (Ontario only)
- -- Finland
- -- France
- -- Germany
- -- Great Britain
- -- Italy
- -- Japan
- -- Netherlands
- -- Norway
- -- Portugal
- -- Spain
- -- Sweden
- -- Switzerland
- -- Turkey
- -- United States

II.3.1. Road lengths and traffic

The public road network in a country can be concisely characterised by its length and usage. The numbers in Table II.1 give a clear overview of the magnitude, scale and variance among participating countries. The public road network length in OECD countries varies from 3 million kilometres to 20 thousand kilometres, and the overall average traffic volume on that network from one thousand to five thousand vehicles per day. This wide variance explains the -- expected and understandable -- variant road management practice, but is at odds with the surprising communalities.

The road lengths in the fourteen countries for functional and administrative road classifications are given in Annex A along with the traffic volumes.

II.3.2. Traffic growth

The actual annual traffic growths (in 1991) have only in a few cases been estimated for each functional road class. In many cases figures pertain to selected functional road classes. In other cases traffic growth figures are related to a slightly different classification. In Sweden, for instance, the traffic growth is related to "European roads" (E-Roads); "National roads", "Primary County roads" and "Other County roads", i.e. an administrative classification.

The traffic growth in 1991 for the road network as a whole is shown in Figures II.1 and II.2 for cars and trucks, respectively, in the OECD countries.

The forecast figures for annual traffic growth, requested for the period 1992-1996, are in fact for many Member countries predictions for somewhat different time periods; the forecast traffic growth trends in Member countries were annualised and are shown in Figures II.3-4 for cars and trucks, respectively. These forecasts are often accompanied by reservations about their reliability and the dependency of predictions on the economic situation is noted. Nonetheless, there is a convergence of traffic growth trends at 3.5 per cent per annum.

Table II.1. **Road length and traffic loads (1990 or 1991)**

Country	Length of the road network (1000 km)	Vehicle kilometres of travel (million)	Average daily volume (veh/day)
Canada (Ontario)	156	73,000	1280
Finland	77	28,000	1000
Germany	226	360,000	4360
Great Britain	360	412,000	3100
Italy	602	327,000	1490
Japan	1,123	629,000	-
Netherlands	118	96,000	-
Norway	89	28,000	900
Portugal	20[1]	19,000[2]	N.A.
Spain	156	110,000	1930
Sweden	206	62,700	830
Switzerland	28	43,000	4210
Turkey	360	26,000[3]	N.A.
United States	3,048	3,375,000	3030

1. Urban, private and some of the local roads (rural) not included.
2. Only about 9,500 km of State roads data available.
3. on Main roads I

In general it is known from travel trends folklore that traffic growth or decline follows the growth or decline of the Gross National Product (GNP). As shown in Figure II.5, car traffic appears to grow a bit faster than GNP and truck traffic a little slower. Besides the macroeconomy, car traffic is also strongly influenced by car ownership which is expected to show a continued upward trend in the OECD countries (Figure II.6).

The dilemma of increasing car ownership and traffic, economic growth and the diminishing resources available to the road and traffic sector culminates in dilemmas managers experience in relation to resource allocation and distribution. This situation is aggravated by increasing consumer expectations with regard to traffic safety, road condition, and other user services (Figure II.7).

II.3.3. Administration/organisation

Distinctive administrative structures in Member countries provide the mechanisms by which resources are allocated and distributed to a country's road system. The great variety of organisational structures among OECD countries have understandably evolved in response to the needs embedded in the history of the country. No taxonomy or analyses of these often unique organisational structures are

Figure II.1. **Traffic growth (cars) 1991 (%)**

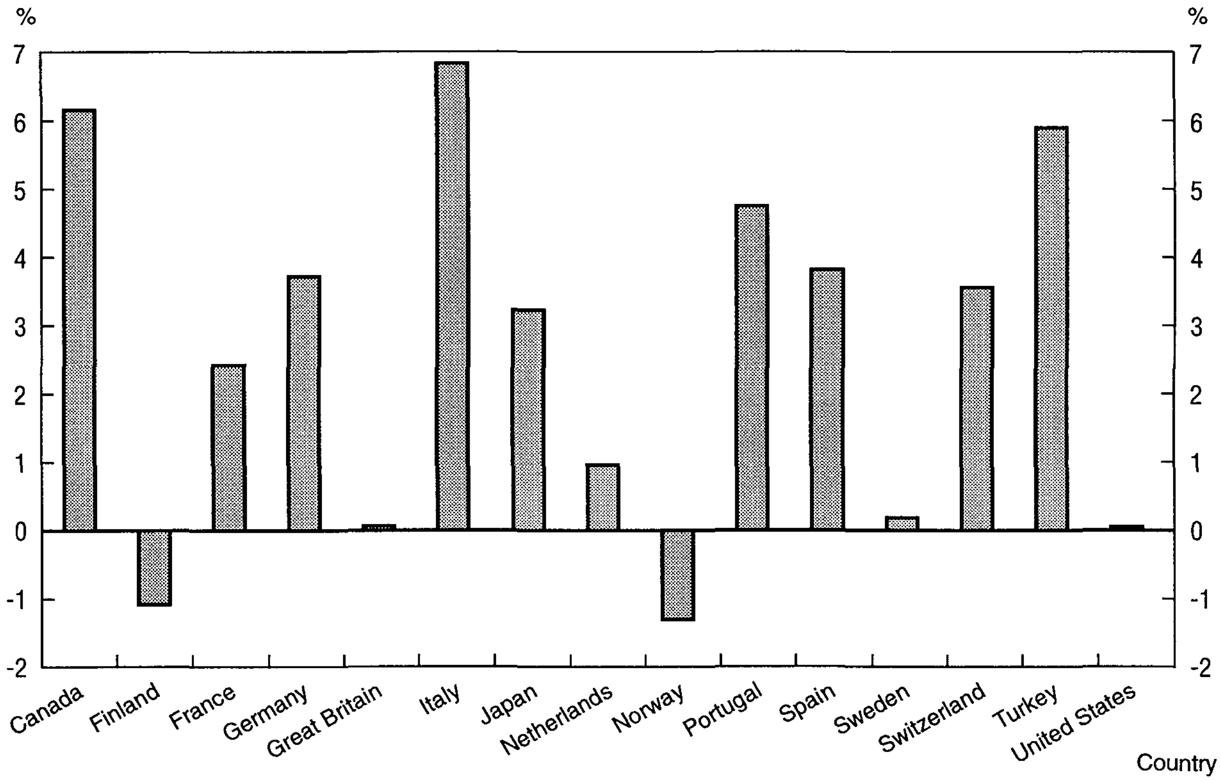


Figure II.2. **Traffic growth (trucks) 1991 (%)**

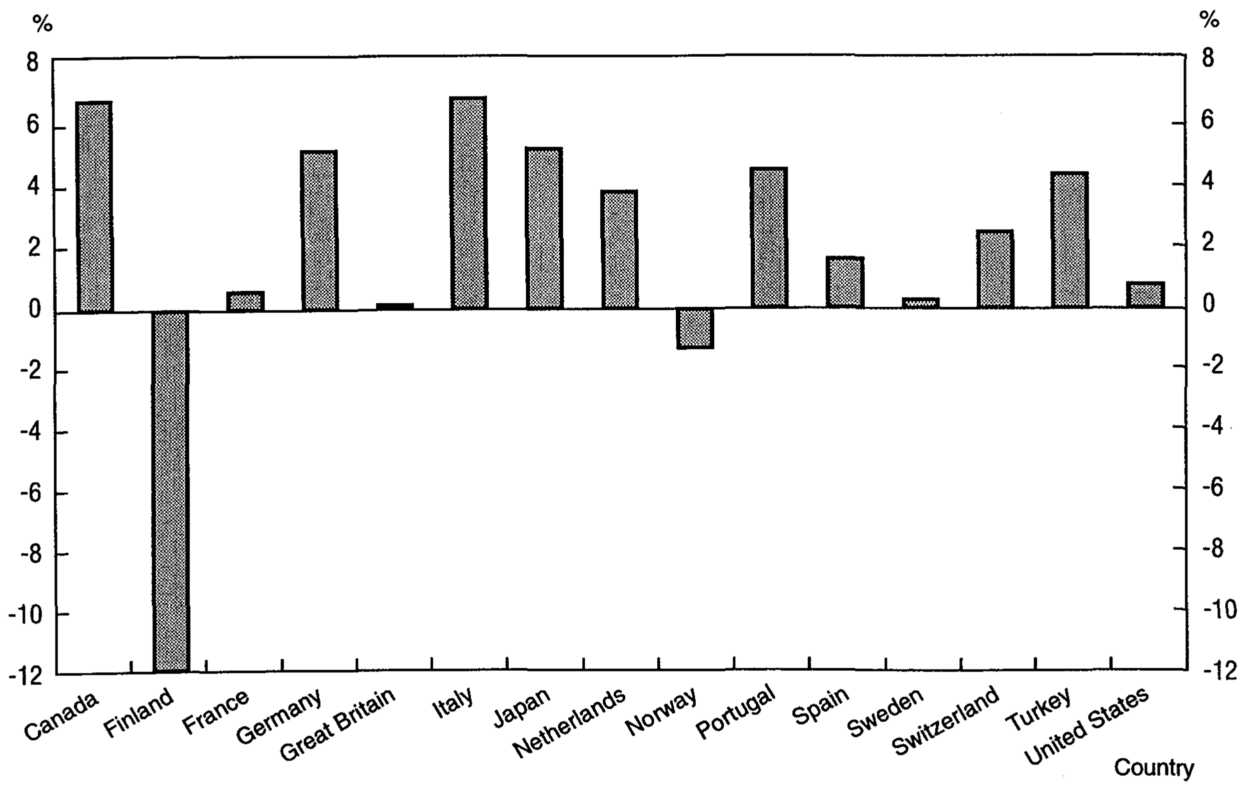


Figure II.3. **Estimated annual traffic growth (1992-1994) (cars, %)**

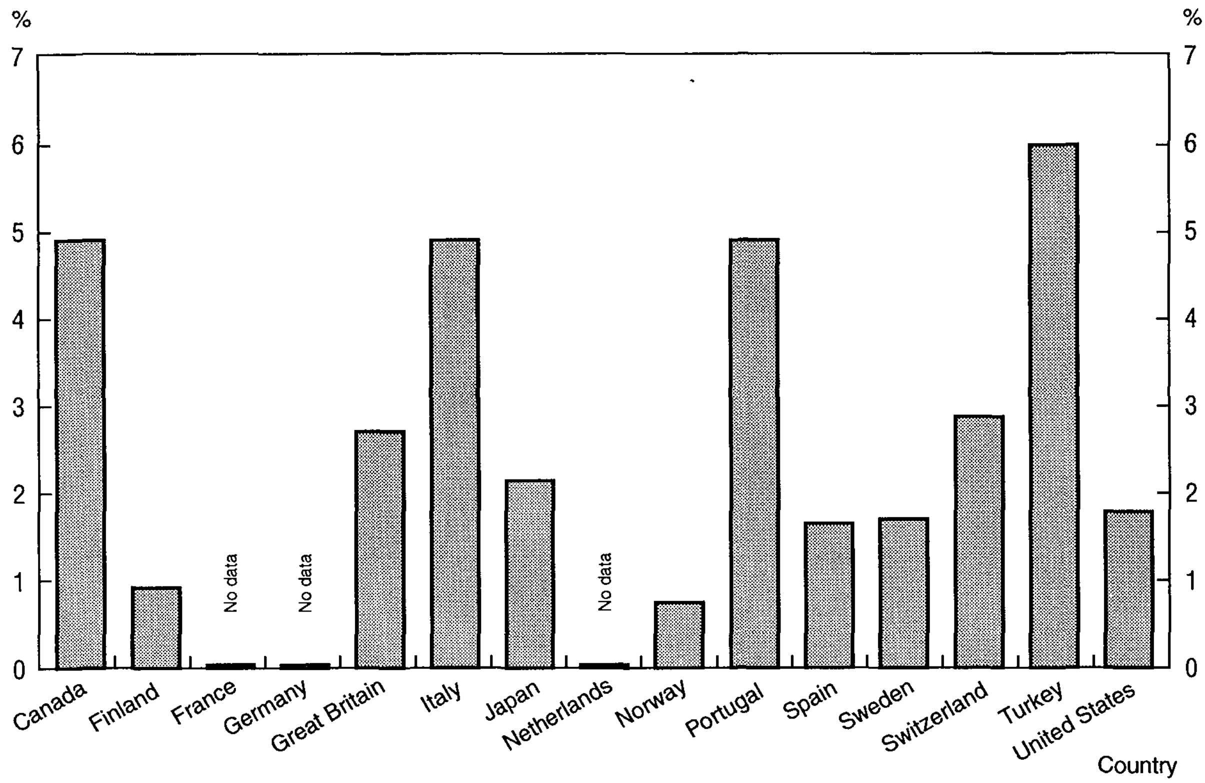


Figure II.4. **Estimated annual traffic growth (1992-1994) (trucks, %)**

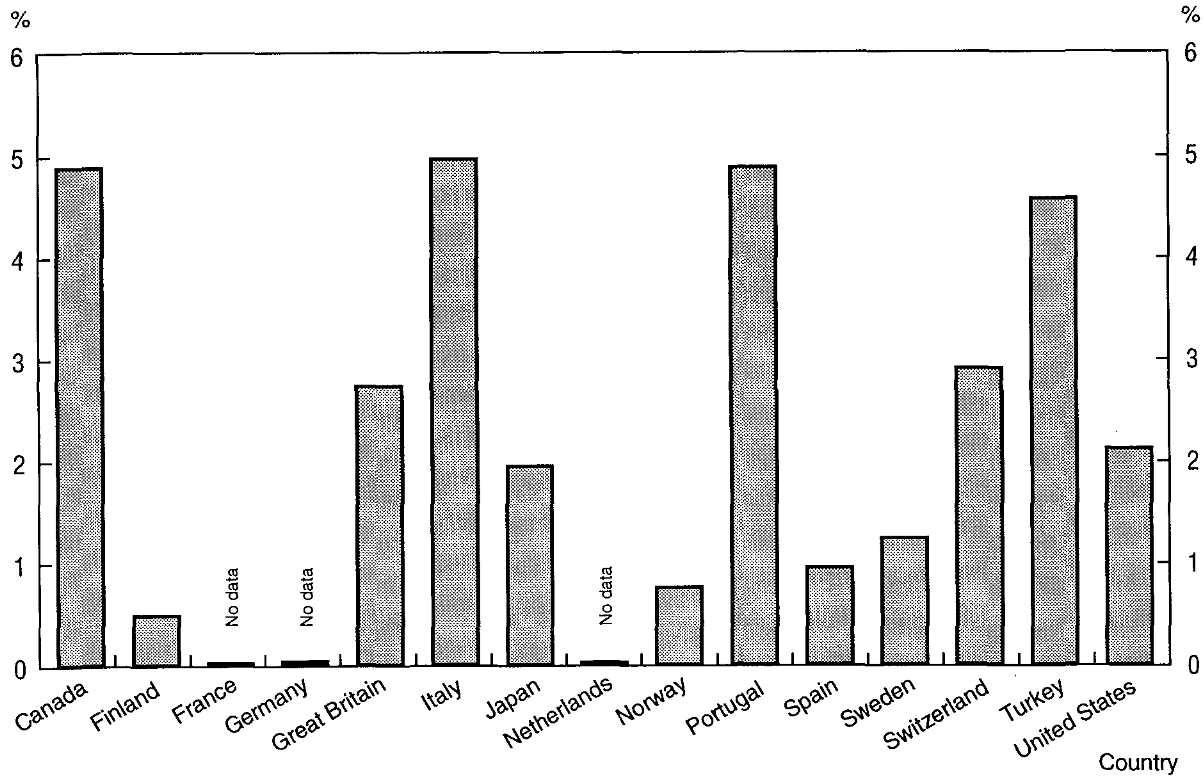


Figure II.5. **Typical relationship between GNP and traffic growth (USA)**

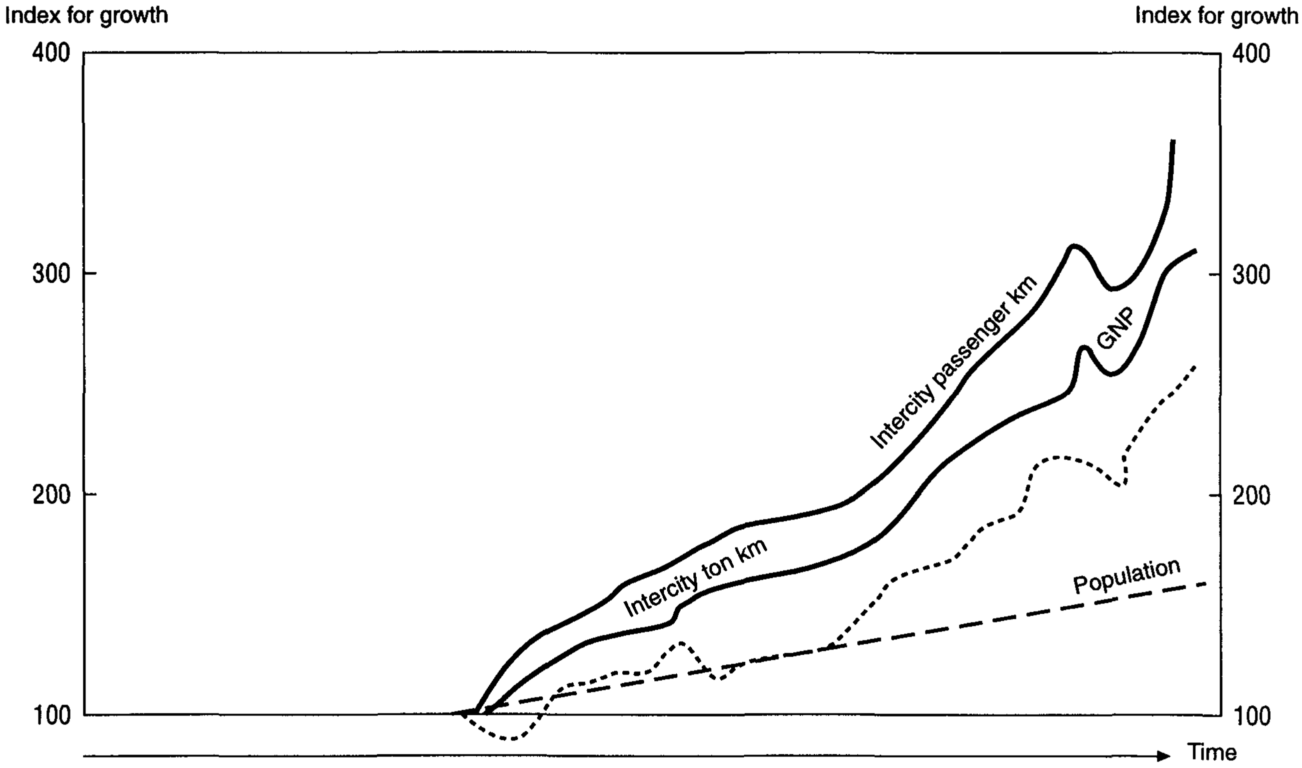


Figure II.6. **Projected growth in car ownership in selected countries**
Number of four-wheeled vehicles per 1000 persons

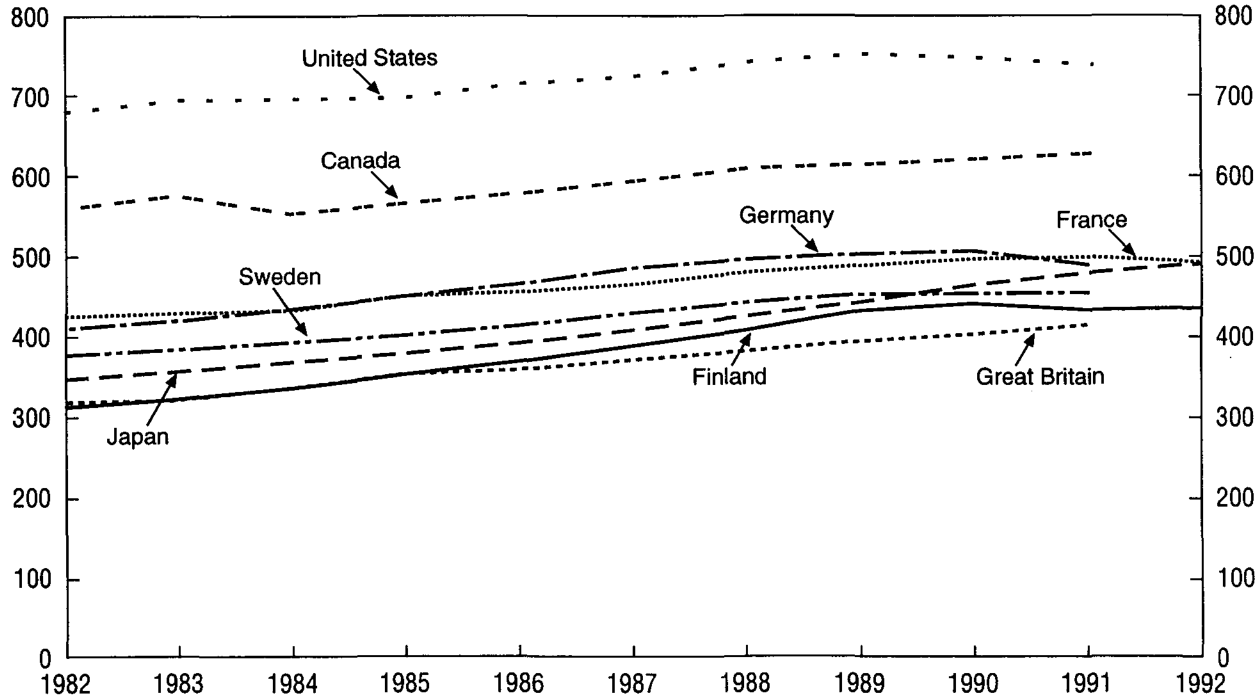
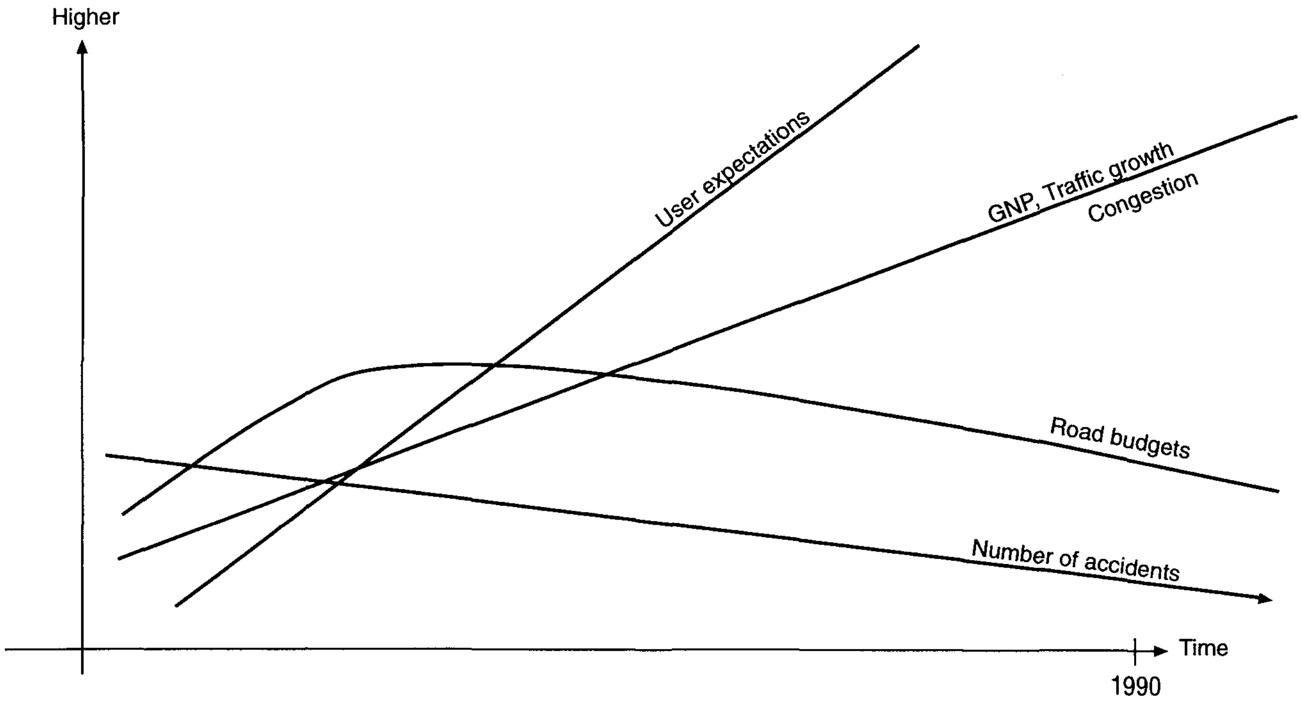


Figure II.7. **Diagrammatic Representation of Past Trends - Reality vs. Expectations**



attempted[1]. Suffice it to say that in each country there exists a hierarchy of decision-makers and decision levels. A more detailed description of this hierarchy follows in Chapter III.

From a road manager's point of view the important distinction between structures is whether each functions at network and project levels. At the former level, funds are allocated and distributed to subnetworks and to a range of actions on that network; at the latter, funds are allocated and distributed to support project specific action decisions. The former have wide political, social, environmental and economic impacts, and are often impinged upon by limited interests (economy vs. environment); the latter have limited social, economic, environmental and political consequences, and are often accompanied by wide and consuming interests (e.g. the 'nimby' -- not in my backyard - phenomenon).

In order to gauge and understand the allocation/distribution procedures in Member countries a number of questions were formulated and put forward in the questionnaire. These questions and the responses to them dealt with:

-- Allocation of road budget;
-- Division of road budget;
-- Choice of road sections and type of actions;
-- Responsibility for road maintenance and rehabilitation;
-- Responsibility for multi-year plans;
-- Criteria in preparing the multi-year plans.

1 Present organisations of road administrations in the participating countries is shown in Annex B.

These dimensions of the resource allocation/distribution process will be elaborated later in this chapter and the other chapters that follow.

II.3.4. Present funding

Allocation and distribution of road funding is often -- and this study is no exception -- related to functional and/or administrative road class and type of action. The road class related information presented below refers to 1991 data (in most cases and to forecasts for the five year period 1992 - 1996).

The funding in the participating fourteen OECD Member countries is illustrated in Table II.2, in Million US dollars per 1000 km by administrative road classes in 1991 (Italy 1989 and the US 1990). It is seen that there is a wide variance. This may be due to the differences in road classification, terrain, costing and extent of environmental protection, or be merely a reflection of some country specific unusual circumstances in 1991.

Table II.2. **Funding and road length (millions US$ per '000 km)**

	Federal	**State**	**County/City/ Rural&Other/ Prefecture**	**Total**
"Canada"		29.1	9.4	12.2
Finland	-/-	15.6	12.0	13.9
Germany	105.7	71.3[1]	39.9[2]	88.4[1,2]
Great Britain	-/-	253.9[3]	14.4	23.9
Italy [4]	366.7	26.1	7.7	12.7
Japan	-/-	483.0	41.0	49.0
Netherlands	100.0	-/-	-/-	-/-
Norway	-/-	56.4	14.6	27.1
Portugal [5]	-/-	43.5	-/-	-/-
Spain	21.4	5.1	4.6	7.1
Sweden	-/-	48.6	6.0	9.4
Switzerland	600.0	72.2	-/-	56.3
Turkey	(Total for all categories 10.1)			
United States	2.4	34.2	20.1	24.5

" " Canada stands for Ontario
1. Data refer to Lower Saxony
2. Data refer to Lower Saxony and City of Munich only
3. Motorways and trunkroads
4. "Federal" for Italy concerns "motorways"
5. Figures only given for Federal roads

A summary of funding by type of action, (Million US $ 1991, the US 1990) is shown in Table II.3 and the distribution of funding for New Construction, Rehabilitation, Periodic and Routine Maintenance and Miscellaneous is shown in Figure II.8 for thirteen of the fourteen countries. The total road funding as a percentage of GNP is shown in Figure II.9 for twelve countries.

Table II.3. **Funding by type of actions (millions US$)**

	New construction	**Rehabilitation**	**Periodic main-tenance**	**Routine main-tenance**	**Miscel-laneous**
"Canada"	54	234	11	220	158
Finland	411	196	234	120	238
Germany[1]	4 194	2 419	-	146	211
England & Wales	3 480	1 414	845	529	640
Italy	no data available				
Japan	28 961	3 507	-[2]	-[2]	829
Netherlands	390	320	-[3]	-[3]	80
Norway	1 169	133	33	156	308
Portugal[4]	705	83	14	23	44
Spain	-	459	-[5]	364	224
Sweden[7]	397	172[6]	323	351[8]	187[8]
Switzerland	985	1 065	505	1 138	360
Turkey	2 128	33	no data	46	24
United States	5 810	12 117	-[9]	7 001	6 772

"" Canada stands for Ontario
1. Federal trunk roads only
2. Periodic and Routine maintenance are included in Rehabilitation.
3. Periodic and Routine maintenance are included in Rehabilitation.
4. Figures for ferries (63 M US $) are included.
5. Periodic maintenance is included in Routine maintenance.
6. Rehabilitation includes measures for increasing bearing capacity.
7. Figures include only funding for state roads (national roads and county roads).
8. More than half of the budget is related to new wearing courses/new pavements. The main part of the rest is for winter road operation.
9. Preventive maintenance is included in the first two categories.

Figure II.8. **Distribution of road funding**

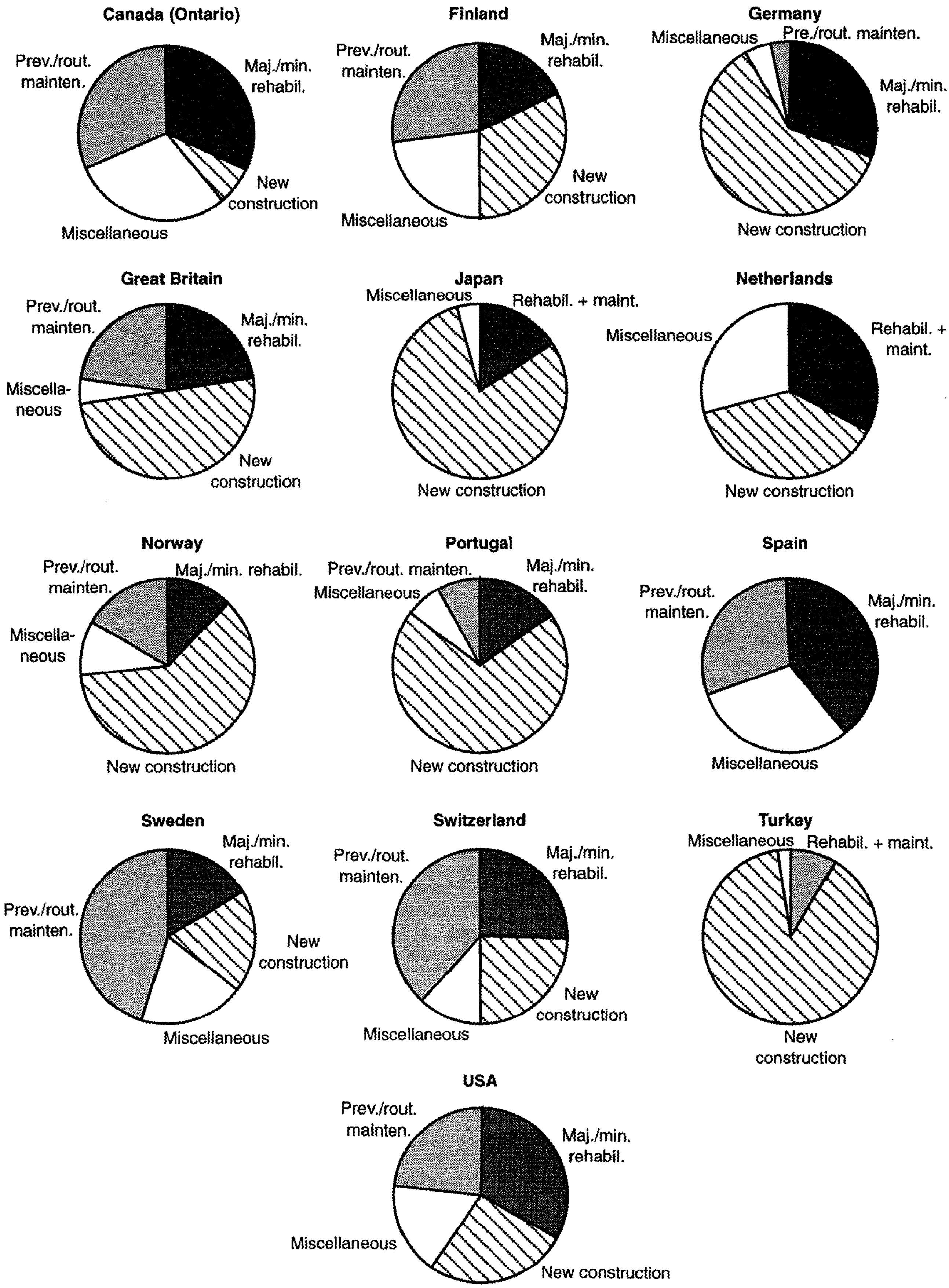
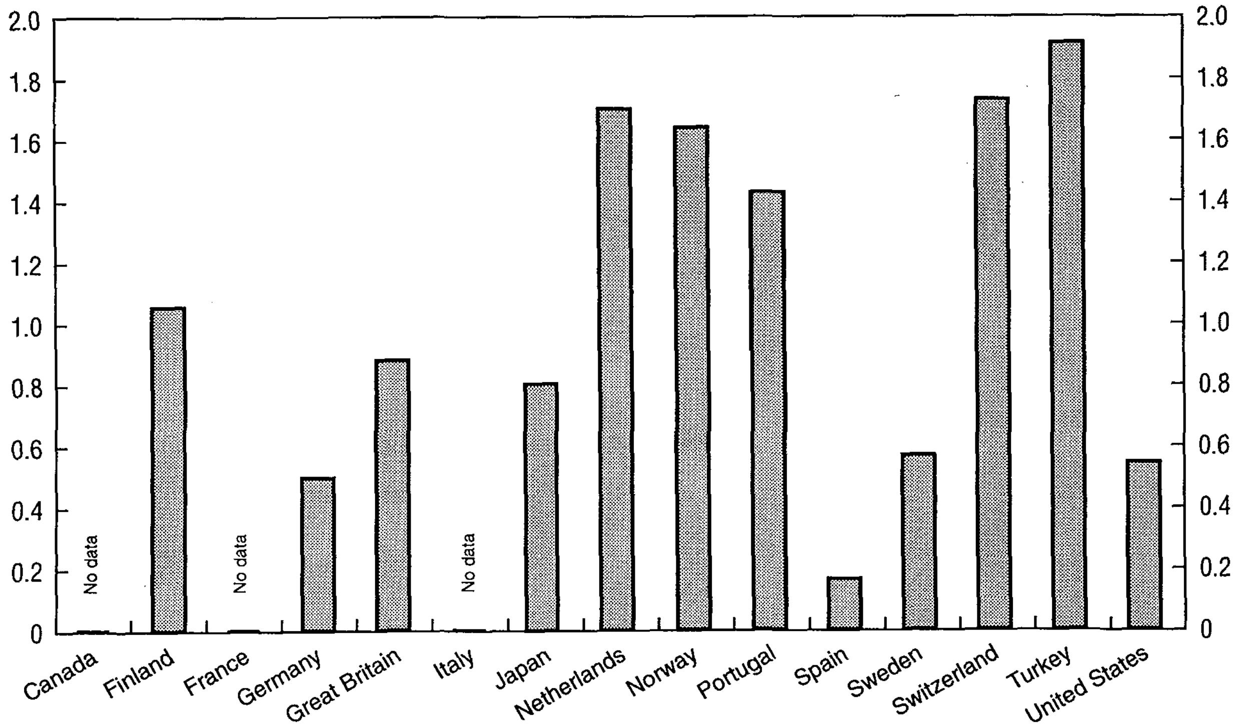


Figure II.9. **Total road funding - % of GNP**



Again, the pie-charts in Figure II.8 confirm what already was known from the preceding tables and graphs: the OECD Member countries have different kinds of road organisations, apparently face different specific issues, and tackle these issues in their own distinct fashion. The basic data shown in this Chapter generate the following conclusions:

i. the OECD Member countries practice different policies in distributing road monies to road classes;
ii. the OECD Member countries have different criteria and different policies in distributing road monies to activities (investment, rehabilitation, operation) and actions;
iii. the OECD Member countries allocate a different portion of their GNP to roads.

It was observed that the necessary prerequisites for a detailed scrutiny and analysis do not prevail for the judicious examination of data and comparison of information from different countries. The main obstacle is the lack of data from some important European countries and the conspicuous differences in data accuracy for the participating OECD countries. In this respect the differences between countries could give an impression that the differences are greater than they in fact may be.

It would be beneficial to OECD Member countries if rules for classifying roads **functionally** (not administratively, because of widely differing administrative structures in the Member countries) were compatible and consistently applied, and data collection was based on similar principles to permit comparisons between countries.

The substantial differences in resource allocation and distribution in Member countries raise the question of whether the conclusions proposed above are the result of calculated actions on the part of the decision-makers and are a true reflection of the differences between the countries, or, if the numbers and figures merely reflect historical trends and not rational decision-making in response to real world problems.

The information collected also raises the question of whether or not the Member countries would benefit from improved resource allocation and distribution methods of road funds between road classes, between major activities of investment, rehabilitation and maintenance[1], and between regions of country. In order to accomplish this, consistent but parsimonious methods of data collection need be agreed upon and developed to be used together within a flexible but common analytical framework.

The proposal in this report for "best practice" in resource allocation to road rehabilitation and maintenance aims to contribute toward such an ambitious objective, in addition to reporting on the current practices in Member countries.

II.4. TYPES OF ROAD CLASSIFICATIONS AND ROAD ORGANISATIONS

Although the fifteen countries did not present fully conclusive and comprehensive answers to all questions, the information they did provide can be used for some analysis. Combined with data on population and population density, and GNP, extremely useful data on road classification, road organisations, resource allocation and distribution methods in different countries can be presented. The comparisons will be made on aggregated data and in general terms rather than focusing on each country individually, excepting to illustrate a point or principle.

Of particular use is an examination of the road classification system and the types of road administration organisations used in OECD countries. These impact upon the resource allocation/ distribution methods used and discussed at length in Chapter III.

II.4.1. Road classification

Most of the countries use a functional as well as an administrative road classification. The most common **functional road classification** divides the roads into the following classes:

-- Motorways;
-- Main roads (sometimes divided into two sub-classes I and II);
-- Collector roads;
-- Local roads;
-- Urban roads (not considered in this report);
-- Private roads.

Some countries aggregate two or more classes in the presentation of funding and of other data. Canada, for example, presents interpretations of each functional road class and thereby creates a link between the functional and administrative road classifications. Thus, in Canada, "Motorways" are understood as "Provincial Freeways", "Main roads" as "Provincial Arterial Highways" and "All other Provincial Highways"; "Collector roads" as "County roads"; "Local roads" as "Township roads"; and "Urban roads" as "Roads for separated Cities, Towns and Villages". Turkey uses a classification which can be seen as a combination of a functional and an administrative classification. Thus roads there are

[1] Or "development", "rehabilitation and maintenance" and "operation", as defined in Chapter I.

classified as motorways, state roads, provincial roads, tourist roads, village roads, forest roads and urban roads.

The **administrative road classification** most commonly used has the following classes:

-- Federal (national) roads (when relevant);
-- State/Provincial roads;
-- County roads;
-- City roads (not considered in this report);
-- Rural community roads;
-- Other roads (when relevant).

Data on funding are more often based on an administrative classification than on a functional one. This may be due to the way funds are either collected or distributed. Federal-State classification is relevant only in countries where Federal and State governmental levels exist. In Italy an autonomous body (ANAS) is responsible for national roads and motorways. Consequently Italy presents "Motorways" as the highest road administrative class.

As already mentioned it would be desirable for the OECD countries to establish consistent and compatible concepts and procedures for functional classification of roads. A generic model is shown in Table II.4.

Table II.4. **A functional classification of roads: percentage ranges of vehicle kilometres of travel and kilometres of roads in each system**

SYSTEM	RANGE (%) RURAL		RANGE (%) URBAN	
	Veh-kms	**Kms**	**Veh-kms**	**Kms**
PRINCIPAL ARTERIALS (motorways and principal arterials)	40 - 60	3 - 4	40 - 60	5 - 10
PRINCIPAL ARTERIALS plus MINOR ARTERIALS	45 - 75	7 - 10	60 - 80	15 - 25
COLLECTOR ROADS	20 - 35	25 - 30	10 - 15	10 - 15
LOCAL ROADS	10 - 20	60 - 75	10 - 30	60 - 80

II.4.2. Road network description

The road network description, in terms of road lengths for different road classes, is given by almost all the countries. The descriptions allow for comparisons of funding related to road lengths. The funding comparison was best made on an aggregated level (total funding compared to total road length).

Most countries presented data on annual traffic growth. The differences between the countries are tangible. While declining tendencies are noted in Finland and Norway, growth is noted for Canada, Germany, Italy, Japan, Netherlands, Portugal, Spain, Sweden, Switzerland and Turkey. Great Britain and the United States present almost unchanged levels.

Official forecast figures, in terms of expected annual traffic growth, are presented by twelve of the fourteen countries. The differences between the twelve countries may be of only limited interest. More noteworthy is the fact that all the eleven countries expect a traffic growth - despite the present economic recession in Europe.

II.4.3. Administration structures

The description of administration/organisation and the responsibility for allocation/distribution of the road budget can easily develop into a battle of words. To avoid this we put forward the general notion that it is the politicians in democratic societies that have the ultimate responsibility for funding/taxation and the allocation of resources. They purposefully use structured administrations for the distribution and transfer processes. These structures are basically the same in the Member countries, although they differ in terms of the number of administrative levels (federal, state, etc) and in the interaction and delegation of authority between levels.

Even though organisations have wide variety in their structures (see Annex B) two main types can be detected: the line organisation and the fractal organisation. In the former responsibilities are divided functionally -- construction, maintenance, planning and design, administration. This is the most common type of organisation. In this model the Road Agency has a centralised line organisation and decision making structure. The regional organisations, also organised along functional lines, are executing arms of the programmes made by the central planning and programming staff. In the fractal organisation model, delegation of responsibility is comprehensive; both the Central Administration[1] and the Regional Administrations, which again are responsible for executing the national programmes and policies, have *comprehensive responsibility regardless of the size of the region* to creatively manage all their outputs. These latter types of organisations are found in Sweden and Finland.

II.4.4. Methods for allocating and distributing road budget

As noted, the responsibility for resource allocation for road maintenance and rehabilitation rests with politicians within national, regional and local governmental jurisdictions. On the national level the main responsibility for preparing the budget proposal traditionally lies on the Ministry/Department of Transportation. This allocation responsibility may also to a variable extent incorporate the concept of *shared power* between several governmental bodies. That is especially the case when the "managing by objectives" (MBO) philosophy is adopted and when funding is totally or in part achieved by road pricing or tolls.

The responsibility for the resource distribution normally rests with each governmental jurisdiction having authority over roads. In as many cases as not, this responsibility is transferred directly to the (Central) Road Administration which, based on needs studies, distribution formulae or criteria budget-frames, may further delegate the responsibility to regional road administrations, which in cooperation with local general purpose governments distribute the monies to projects.

1 In Belgium there is no central administration.

To this "standard" procedure variations can be added, especially when there are more than one source for funding road maintenance and rehabilitation. Some countries, consequently, have adopted special allocation/distribution models for tolls or earmarked fuel taxes.

The allocation/distribution methods may also differ with the type of functional or administrative road class. Thus detailed multi-year plans normally are the bases for distribution of funds for the national road network while the distribution may be less specified on regional or local levels, and depend on criteria which have only local significance. In some countries resources are distributed to subnetworks as lump sums based on rough parameters as number of kilometres of road and/or number of vehicle-kilometres travelled.

This brief summary of methods used in allocating and distributing resources, which are further examined in the next chapter, shows clearly the 'ad hoc' nature of the present procedures. It is precisely in this area in which the Group sought to make a contribution by proposing a comprehensive and consistent, yet flexible method for approaching the resource allocation/ distribution issues.

II.4.5. Funding levels

An important question in resource allocation/distribution is the impact which different sources of road financing may have on the way fund allocation and distribution is made. The answers to the questionnaire show, for instance, that there is a strong interest in adding "earmarked sources" to the traditional financing in the national budgets - and destined directly for road investments, maintenance and rehabilitation. Another question of interest is how resources can best be distributed to different road classes or different types of actions and in what way Federal and State governments should be involved in this more detailed division to lower levels.

Comparisons between countries in terms of total funds spent on roads on a per kilometre basis, show significant differences between countries. While Switzerland annually spends approximately US$ 56 000 per km of road, the corresponding figure in Spain is only US$ 7 000 per km of road. Most countries spend between US$ 15 000 and US$ 45 000 per km of road.

Comparisons between countries as to the division of funds for different kinds of action show that Portugal in 1991 spent over 80 per cent of the total funds on new construction. The United States spent (1990) less than 20 per cent of the total funds on new construction. Canada (Ontario) spent less than 10 per cent of the funds on new construction as far as Motorways and Main Roads under Provincial jurisdiction are concerned. The other countries' expenditures for new construction represent 25 - 65 per cent of the total budget.

II.5. GROUPING OF STRUCTURES: ALLOCATION/DISTRIBUTION METHODS AND ADMINISTRATION/ORGANISATION

The issues of finding communalities and grouping existing structures are examined thoroughly in the next chapter, and only two general and a third not-so-general observation are made here.

The first observation is that, although most countries present similar administrative/organisational structures, the governmental levels and the road administrative bodies do not have a similar distribution of responsibilities. However, one thing is common to all the countries: elected officials and their trusted civil servants, have the main responsibility for resource allocation. This responsibility is reflected by the fact that most of the resources for allocation emanates from the State budget -- in Great Britain, from Her Majesty's Treasury.

The second general observation is that administration/organisation structures for resource allocation and distribution reflect the governmental structures prevailing in each country. Thus a Federal as well as a State level for resource allocation for road maintenance and rehabilitation are relevant in Germany, Italy, Spain, Switzerland and the United States. Canada also has a Federal governmental level, but this level is not involved in allocating road budgets. In other countries the Federal-State hierarchy is missing or replaced by another administrative organisation or procedure.

The third not-so-general observation, and one which seems to generate keen interest in many countries, is that pervasive traffic problems in many countries are a motivation for creating totally new kinds of administrative structures. A good example are the motorway concession companies in France (Box II.1)

II.6. INTERNATIONAL TENDENCIES

This Chapter on "Institutional Settings" presents the State of the Art for Road Classification and Road Administration/Organisation. These classifications tend to persist. Internationally, changes of tendencies are not ordinarily expected in these areas because -- almost as a contradiction -- they develop slowly but occur suddenly.

The functional and administrative road classification in use has generally been in effect for several years and will probably prove to be relevant for many years to come. In spite of the "healthy inertia" it would be good to keep the classification system current and tuned to the macroeconomic directions of the country.

In the administrative/organisational structures, on the other hand, changes can be noted in spite of the same inertia against change. Different actors play defined roles in the process of change. Thus, the politicians will formulate the overall objectives, while Road Administrations may be given wider executive responsibilities. This is to say that the Management by Objectives (MBO), Planning Programming and Budgeting System (PPBS), or Zero Based Budgeting (ZBB) philosophies may be beneficially adopted and further developed in many of the Member countries.[1]

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1 MBO, ZBB and PPBS are strategic planning tools developed in the 1970' to integrate programme and budget development and programme delivery.

MBO: Management by Objectives is a "top-down" management tool that requires the development of programme goals, objectives, and milestones. Every agency activity is monitored for achievement of goals and objectives in terms of chronological interim milestones of all agency activities.

ZBB: Zero Based Budgeting is a "bottom-up" management tool that requires agencies to begin the programme budget development process at "0". The agency must define until an overall budget and programme is defined. "Sunset provisions" are an outgrowth of ZBB with the goal to discourage creation of programmes that cannot be abolished once they have outlined their usefulness.

Another trend is the growing participation of additional funding sources, particularly private investors, in the road maintenance and rehabilitation arena. Insufficient resources for new investments, and for maintenance and rehabilitation make it necessary to adopt new funding strategies. Private investors and sponsors on the scene -- in the road market -- make it important to define the roles of different actors. Specifying objectives for different road classes and for different types of actions will gain increasing importance. It is to be expected that functional classification of roads also grows in importance.

At the same time the traditional role of the Road Administrations is changing. One influential force in the process of change is the international wave of privatisation. Duties outside planning and control do not any longer have to stay within the Road Administration itself. On the other hand the participation in financing from private enterprises will require for the creation of new partnerships and new autonomous administrations. Inevitably, before long, questions will arise as to how planning will or should be done in this new environment.

While the responsibilities in each transport sector might be transferred to Road Administrations having substantial autonomy, the government jurisdictions will have to focus on multi-modal transport planning based on politically defined objectives.

In concluding this Chapter three more significant international tendencies can be pointed out:

-- In characterisation and measurement of highway condition there is an overwhelming national preference being expressed to develop Pavement Management Systems -- which is a component of the Road and Bridge Management System. This system is the essential backbone for improved engineering practices in rehabilitation and maintenance; it is essential that it is framed in the terms described in this Report. There is significant potential for international cooperation; substantial benefits from the economies of scale, and in data collection can be obtained in producing these systems.

-- Significant developments and changes are also occurring in staff and labor relations owing to increased demands for accountability and commercialisation of the road agencies.

-- The same is true in contracting practices and methods and in the usage and improvement of initially substandard materials.

In time, these trends will be reflected in how road agencies are organised and organise their work.

PPBS: Planning Programme Budgeting System integrates programme and budget development with a "critical path method" (CPM) of evaluation for implementing programmes and tracking expenditures. The use of CPM chart represents a complex project as a series of interconnected jobs that must be accomplished in specific sequence to minimize wasted assets or redundancy.

CHAPTER III

ALLOCATION AND DISTRIBUTION OF FUNDS BETWEEN ROAD CLASSES AND ROAD IMPROVEMENTS

III.1. INTRODUCTION

As outlined in the two preceding Chapters, the purpose of resource allocation is to determine the appropriate total level of capital and maintenance investment that is to be made available for road repair and rehabilitation, bridge reconstruction and rehabilitation, and new construction, usually on an annual basis. Distribution is the manner in which total funds allocated for highway and bridge repair are made available to subnational jurisdictions, road systems, and types of improvement.

This Chapter considers both the allocation and the distribution of the overall budget established for national road maintenance and rehabilitation. It describes the methods commonly used for **(1) the determination of total funds to be allocated; and (2) distribution of those funds (a) by roadway system; (b) by governmental unit; and (c) by highway and bridge improvement type.**

This Chapter also summarises the systems currently in use by the countries participating in the preparation of this report, describes the common elements and suggests potential improvements to facilitate more cost-effective and efficient distribution of scarce resources for highway and bridge rehabilitation and maintenance through the development of a systemic data and analytical structure. Specific recommendations for data and analytical development are included in the report conclusions.

Observations, comments and conclusions in this Chapter are based on the survey data presented in Chapter II and the Expert Group's Discussions.

III.2. RESOURCE ALLOCATION PROCEDURES

III.2.1. Basic patterns

Among the participating countries, four identifiable patterns of resource allocation can be identified. The defining characteristic of these four patterns is the degree of shared responsibility between the Ministries of Finance and Transport (or their equivalents) in the allocation process.

In the first pattern, the responsibility for allocation, especially for the national road system, is retained in governmental hands. For example, the Ministry of Transport in Canada is totally responsible for resource allocation on the national road network. In Great Britain, the Department of Transport has the responsibility on a central as well as on a regional level. In Turkey, the allocation/distribution procedure is maintained on a governmental level through the General Directorate of Highways (KGM) of the Ministry of Public Work and Settlement. The procedure for resource allocation in the United States is very much reflected by the interaction of responsibilities between the Federal and State levels.

In the second pattern governmental jurisdictions are still in charge of allocation, while the distribution procedures are transferred to national, regional, and local road administrations. Germany, Japan, Norway, Portugal, Spain, and Switzerland belong to this allocation/distribution category.

In the third pattern, autonomous bodies are involved. This describes the allocation/distribution process in Italy, with the Autonomous State Roads Administration (ANAS).

Finland and Sweden represent the fourth discrete pattern. Although the financial responsibility remains in the hands of the government, the Road Administrations have a strong impact. This is consistent with the "management by objectives" philosophy that these countries have adopted.

Typically, the Central Government generally defines the total annual roadway rehabilitation and maintenance budget. In addition to the initial budget allocation, the central government may also determine the distribution of those funds by governmental jurisdiction, road system and, in some cases, by major category of road improvement type, although the involvement of the central road authority varies by country.

Decisions are made using a combination of technical analysis to achieve efficiency in fund allocation, and political, social, technical and economic considerations to achieve funding equity and balance among competing interests and political jurisdictions. This combination of technical and political considerations appears to exist in some fashion in all of the countries participating in this study. As was true with the degree of central government involvement in the allocation process, however, the variations among countries in the relative mix of technical and political considerations are broad.

Under the political level(s) the managing responsibilities of road administrations differ between countries. Some countries use "management by objectives", "directed autonomy", or "zero based budgeting" philosophies in carrying out their responsibilities; other countries are more directly tied to the Ministry of Transport which permits only "limited autonomy" to their road administrations.

There also exists variations to these two main types -- directed vs. limited autonomy -- of administrative styles. In Italy, for instance, there is an autonomous body (ANAS) that has the responsibility for managing national roads and motorway networks (toll roads as well as freeways), and deciding how to use resources allocated to it annually, but the agencies managing the other networks are not autonomous and have much less freedom than ANAS in deciding about their use of resources.

The road funding allocation decisions, which are expressed as multi-year plans, are often based and developed using benefit-cost analyses as an important planning tool. This is a good omen; the analytical procedures to be proposed later on this report are based on the same principles as the benefit-cost analysis. The difference lies in the more comprehensive approach to road resource allocation and in the clear acknowledgement of the importance of the budget constraint and other relevant criteria.

Within some of the participating countries, resource allocation decisions are made unilaterally by the Ministry of Finance. In many cases, however, allocations are made in consultation with the Ministry of Transport. The consultation process can assist the Ministry of Finance in determining the appropriate total level of funding to be made available for road and bridge improvements. This determination must consider total maintenance and rehabilitation requirements to support the desired level of overall system condition and performance for the country's road and bridge systems. Involvement of the Ministry of Transport provides the technical advantage of providing continuous information to the Ministry of Finance regarding the national and regional economic development and performance implications of transport investments and its importance to other national objectives.

III.2.2. Country by country review

In this section the road budget allocation/distribution practices are briefly reviewed country by country. The reader is reminded of the fact that the administrative structures in the participating countries are different, and, therefore, the observed practices reflect different contexts of decision-making. Despite general similarities, each of the countries has its own, particular scheme for resource allocation/distribution for its transport system.

In **Canada**, the responsibility for national roads is solely entrusted to the Provincial Ministries of Transportation. Responsibilities for road networks on lower levels is entrusted to the road departments on county, township, and city/town levels. Provincial subsidies is an important source for road funding on these lower administrative levels. Each level of government is responsible for determining its own budget; however, this must be done in accordance with needs studies updated through a uniform system of inventorying.

In **Finland**, the basis of road allocation for the Finnish Road Administration (FinnRA) is Management by Objectives (MBO). This requires a series of objective negotiations between the central administration (directors) and the regional units (road districts). The objectives are agreed between FinnRA and the Ministry of Transport. The road budget is allocated to basic maintenance and investments through negotiations between FinnRA and the Ministry of Transport. Criteria for allocation come from the agreed objectives and the list of investment projects. The road budget for new construction or other improvement investments is agreed by the Ministry of Transport on the basis of the detailed project list submitted by the FinnRA. There are no detailed criteria for this decision making, but emphasis is given to four general criteria:

(1) Highway capacity on major routes between the most important economic production centres in the country;
(2) Highway capacity of the regional transport system;
(3) Urban capacity and safety problems, particularly on major highways; and
(4) Cost/benefit analysis and first year rates of return on investment.

The Central Administration of FinnRA distributes the road maintenance budget through product-based performance contract negociations with the districts. All fund distributions are done by the road districts.

In **France**, the yearly budget for road maintenance and toll motorways is fixed by the Prime Minister, after consultation with the Minister of Finance and the Minister of Transports. This budget is managed by the "Directeur des Routes" (and partly by the "Directeur de la Sécurité et de la Circulation Routière"). The main part is distributed to the "Directeurs Départementaux de l'Equipement" (DDE, about 100 in number) on the basis of formulae depending on length, heavy traffic and climate. The DDE are given objectives and are then free to use the funds.

The French motorway network is primarily funded through tolls and managed by seven semi-public companies. The State wide budget for (i) new construction, (ii) improvements to the existing network (e.g. adding lanes), and (iii) rehabilitation and periodic maintenance is determined in negotiations between the Ministries of Finance and Transport. Thereafter the Ministry of Transport decides the distribution of the total budget between the Motorway Companies on the basis of technical criteria. The government also decides the priorities for new construction and major improvements to the existing network.

Rehabilitation and periodic maintenance - and operations, of course - are the responsibility of the Motorway Companies, given the budget. The companies generally use "pavement management systems" and base the choice of actions on pavement condition, existing and forecast, to guide efficient use of budgeted monies.

The local authorities, about 100 "departments" and 36000 communities, are free to set their own road budget and manage it.

Administratively there are also "regions" (23) in France. They have no road assets of their own, but they use a part of their budget to help either the State or local authorities to implement projects -- modernisation rather than maintenance -- in accordance with the region's preferences.

In **Germany**, the federal, state, county, and city road departments have their own budgets and priorities. Priorities can be reestablished and funds reallocated accordingly. The Federal budget is distributed among the Federal states (Laender) by formula, considering the length of the Federal road network in each state. Percentages are recalculated every five years. The overall goal is a uniform level of road condition and performance.

In **Great Britain**, the Department of Transport obtains funds from Her Majesty's Treasury for all expenditures on National roads and through grants for 50 per cent of expenditures on local roads. The other 50 per cent of expenditures on local roads comes from locally allocated revenues. The Department of Transport divides the road budget between its nine regional offices for National roads. This division is influenced by the status of plan preparations and priority of particular programmes. The Department also divides the grants available to local highway authorities on the basis of formulae and programme priority.

In **Italy**, road budget allocation is made by an annual financial law. The road budget is divided using different methodologies by the Autonomous State Road Administration (ANAS). Consideration is given to:

-- Traffic demand;
-- Pavement condition;
-- Per cent of highways with four or more lanes;
-- Elevation above sea level and snow incidence;
-- Number of freezing days per year; and
-- Geological factors.

In **Japan**, road works are classified into three categories: Government General, Toll Road System, and Regional. The Ministry of Construction decides the allocation and distribution of funds for national expenditure between national roads, toll roads, prefectural roads, and municipal roads. Priorities reflect compromises driven both by technical criteria (demand and condition) and by local governments' desires. Regional road works are independent; the budget allocation and distribution as well as priorities are determined by local governments.

In the **Netherlands**, an Infrastructure Fund has been set up for the allocation of funds for the construction and maintenance of the main road network, main waterway network and rail network. The fund is replenished from an additional charge levied on motor vehicles; at least ten per cent of the proceeds of the petrol tax and contributions from other taxes at the State level.

The provinces, municipalities and polder boards are responsible for their own road planning and for the distribution of the contributions from the central government plus own tax income to road construction and maintenance.

In **Norway**, the Parliament allocates funds to the national roads as well as special programmes to improve bearing capacity and safety on county roads. For special programmes, counties are required to participate in the funding. County, city, and local councils appropriate funding to meet match requirements or other programme needs. The Parliament also allocates funds on a project basis for national roads.

Norway uses the following criteria in allocation for national roads. For operation and maintenance funds, the cost to maintain an optimum standard is used. For new investment allocations, project ranking using benefit-cost analysis is applied. In addition, funds are appropriated for certain special programmes to address needs by geographic area of the country. Toll-road collections offer an additional source of funds, but decisions about new toll facilities is also decided by the Parliament.

In **Portugal**, the national government is vested with all road construction and maintenance as a public utility function. The general government budget has, therefore, been the source of finance. The Public Works Ministry oversees the allocation process. The process considers equity of funding and new works planned within the next year resulting from a multi-year strategy.

Portuguese toll roads are entrusted to a concessionaire -- BRISA -- which is a limited liability company in which the Government holds a majority interest. Since the Government provides bond guarantees, it also determines budget allocation.

Some local roads combine local and central funding; the central funds come also from the general budget. The final distribution decisions used by the government include:

-- Physical characteristics of each administrative region's road network;
-- Pavement condition;
-- Traffic volumes; and
-- Priority of new network construction, as contained in the multi-year plan.

In **Spain**, allocations for national roads are made in the national budget by the Finance Ministry after consultations with the Public Works and Transport Ministry. The Parliament will approve the budget every year.

The national roads budget is divided into two main programmes: the new roads programme and the maintenance and operation programme. The allocation between the two is made following the planning of new infrastructure included in the multiyear road plan and the needs for maintenance (both routine maintenance and rehabilitation) and road safety (both included in the same programme) in accordance with technical criteria.

Technical criteria for allocation of maintenance funds are based on: extent of all types of road, km of motorway, km of highway, dual or single carriageways...), type of pavement, traffic, number of bridges, condition of pavements, climatic area and other factors.

In **Sweden**, the central government and Parliament decide the funds for construction of national roads, regional transport systems, and for maintenance and operation. The Road Management Division then distributes the money on the basis of project profitability analysis and maintenance requirements. The construction programmes are prepared every third year for national and regional transport systems. The Road Management Division is responsible for the preparation of these programmes. The programmes are based on projects proposed by the Regional Administrative Boards and the Municipal and Public Authorities. After 1994, these programmes will also include maintenance and operation.

The Road Management Division distributes construction funds to the seven regions and 24 counties. Sixty per cent of the funds are allocated based on "efficiency"; the remaining 40 per cent are allocated on the basis of "equity". Maintenance funds are suballocated with consideration given to the relative physical condition of roads throughout the country.

In **Switzerland**, federal roads are supported by the Swiss Federal Highway Office (SFHO), using funds dedicated from the fuel tax for roads and traffic. Federal grants are matched at 85/15 by State governments. Distribution is based on considerations of multi-year programming, budget, predicted fuel tax allocation, financial situation of the Confederation, state of the project and construction plants. Maintenance allocations include estimates of yearly costs and the maintenance cycle of the different parts of the roads and bridges. Urban and rural roads belong to municipalities and cities. Their funds are derived from personal taxes.

In **Turkey**, the Planning Department of the General Directorate of Highways (KGM) is responsible for identifying and proposing capital investments and preparing budget estimates. This department provides technical and economic studies for investment projects and also divides the budget between motorways, state roads, and provincial roads.

In the **United States**, each unit of government has its own budget and makes decisions about allocating funds to projects. Criteria vary, but include some blend of technical consideration and political desire. The Federal Government requires each recipient to follow prescribed processes for planning, financial management, environmental assessment, and other considerations. Out of these processes, statewide improvement programmes are developed and ranked by importance at the State.

Federal funds are authorised by the U.S. Congress and provided mostly by legislated formula to the States. Funds can usually be transferred among funded programmes. States have the authority to suballocate Federal funds, but are not required to do so. "Loan" programmes may be established among States or subjurisdictions within States, where Federal or State funds can be transferred and applied to maximise their effectiveness.

III.3. FUND DISTRIBUTION METHODS

III.3.1. Principal approaches

Once national budget allocations are made, the specific allocation for a nation's road transport system must be implemented through a fund distribution method. The programme and budget methods by which funds are allocated and distributed vary by country. In some of the participating countries, resources are allocated as a single budgetary item, with distribution by jurisdiction, road system, or improvement type delegated to regional or local road administrations. In other countries, road funds are distributed or suballocated by the central authority as two or more independent budget items. These independent budget items typically include, as a minimum, a component for road maintenance/ rehabilitation and a separate component for new construction.

Other distributions may be made in order to achieve specific national or regional objectives, including such elements as environmental enhancement, historic preservation, and safety. In some cases, particularly for transport enhancements to minimise social or environmental disruption, these objectives are only indirectly transport related. The share of total road and bridge maintenance and rehabilitation funds that are attributable to environmental and non transport functions is increasing in most western European countries and in the United States. The share attributable to network development and expansion is generally declining in more developed countries.

Further distributions or suballocations may be made for local roads to achieve geographic and political equity in funding distribution. Distribution in two or more directed programme categories appears to be prevalent throughout many European countries and the United States to achieve regional balance.

The initial overall determination of budgetary allocation performed by the Ministry of Finance may be considered systemic in nature. It requires objective and subjective evaluation of alternate investment strategies against a prescribed set of national or regional goals. In some cases, initial distribution of funds by highway system and jurisdiction to achieve equity also involves measurement against these same or similar objectives. In a few cases, little rigorous evaluation appears to be required.

Systematic measurement and evaluation requires the development of standardised data and analytical procedures to ensure that comparisons are accurately made throughout the nation's regions or provinces. The types of data required for this initial allocation are general in nature. They consist of measures of system usage and extent, land area, population, and other objective measures of areal dimension, as well as standard network measures that can be applied nationwide. These latter kind of road system data and their collection are discussed in Chapter VI.

In most western European countries, the Minister of Finance assumes a major role in the decision-making, either in terms of direct determination of funding and distribution methods or else in an advisory capacity to the Parliament or other elected officials. In most countries, the overall budget determination is based on a systematic approach that relies extensively on engineering and economic assessments to determine budgetary requirements. These requirements are defined within a strategic planning matrix arrived at through professional judgment, active consultation with districts within the country, or a combination of the two methods. This approach may be based on one of several types of financial and programme management conceptual designs, such as:

-- Management by objectives (MBO);

-- Zero based budgeting (ZBB);
-- Programme, planning, and budgeting systems (PPBS);

or some other programme management technique of arriving at funding allocations and distributions within a structured framework. These programme management styles, developed by public administration and business administration graduate study programmes, are widely applied internationally as a means of allocating limited funds for a variety of public programmes. They all require some degree of technical assessment and comparison against a set of prescribed objectives. The essential difference between these comprehensive resource allocation strategies and the strategies typically used today is that standard resource allocation is a marginal process. Past year allocations are used as a baseline for comparison against possible budget options and evaluations are made on the basis of marginal changes in allocation and distribution. Under the more comprehensive method, budgets are "built up" on the basis of how well an allocation level or means of distribution achieves a prescribed goal or objective.

As a general conclusion to this section, it may be observed that annual road and bridge funding in many developed countries has stabilised in recent years, and actually declined in some instances. The response to this scarcity in funding has been mixed. In some cases, fund efficiency has become a higher priority, with rigorous benefit-cost analyses taking a greater role in fund distribution. In other cases, fund equity has become a greater consideration, as political subjurisdictions seek to maximise their share of available funds at the expense of competing jurisdictions. Therefore, the Expert Group's broad analytical approach to the task of resource allocation and distribution is a timely response to the needs of the policy makers and managers.

III.3.2. Methods of fund distribution by governmental unit

There appears to be a correlation between method of distribution and country size and homogeneity. In smaller countries, where regional variations are negligible, fund distribution is usually accomplished on a "needs" basis, using nationally established criteria for determining needs and distribution formulae. These evaluations are typically made by the central road authority. In these cases, efficiency and effectiveness of resource allocation/distribution appear to be the most significant considerations (See Box IV.3, reading of this Box is preferably done in conjunction with Chapter IV).

In larger countries with varied geography, topography, and economic dissimilarities, efficiency is put forth as the primary determinant in fund allocation, but equity appears to be a much more significant consideration. Fund allocation in these countries is often related to objective measures of system extent and usage, notably mileage and vehicular travel. In these countries, allocation and distribution is designed to ensure that all areas receive a share of available funds, regardless of need.

A combination of allocation strategies appears to be desirable to ensure both system efficiency and equity. Such a combined system could allocate funds through road programmes based on functional or administrative classifications keyed to national or regional mobility and economic development parameters. Objective economic measures of rates of return could be used to focus investment on the most economically efficient projects while an equity based measure could be used to address local projects, usually lower volume facilities, that would not be addressed using purely economic criteria.

The variation in distribution methods also appears to depend on the overall degree of centralisation or decentralisation of governmental authority and the political framework used to govern the country.

For smaller countries, or countries with few political jurisdictions and subjurisdictions, fund suballocation is used sparingly. In these cases, local governments are required to petition the central government for funding on the basis of technical analysis. The central governmental authority then establishes grant criteria and seeks to achieve equity and political balance through grantsmanship.

In larger, more decentralised countries, virtually all of the road rehabilitation funds are apportioned to subjurisdictions, along with the responsibility for road repair and maintenance. Among the participating countries, road funds are allocated for at least two major road categories, nationally most important road network (the 'Interstate System', 'E-Roads', 'Main Roads',etc. depending on the country, as reviewed in Chapter II) and other roads. The procedures used for this road category distribution are usually established in law and national policy, and based on objective measures of system extent and usage characteristics.

III.3.3. Methods of distribution by type of road improvement

In all participating countries, distribution by type of road improvement is a rigorous engineering and/or economic analysis, requiring the use of sophisticated computer programmes that relate investment to system performance impacts. In most cases, distribution analysis is sufficiently sophisticated to relate investment to changes in measurable engineering parameters such as pavement and bridge condition, safety, or levels of service.

In fewer cases, analysis is more refined, and is sufficient to relate investment to changes in highway user costs, including vehicle operating costs, travel time, fuel consumption, emissions, and safety. Several countries have efforts underway to relate investment to broader economic or other measures, such as national productivity, capital consumption, and/or social welfare. But these efforts are not widespread.

The quality, consistency, and application of complex road and bridge data banks and analytical systems to support the development of rehabilitation and maintenance budgets vary widely among participating countries. For instance, all participating countries consider bearing capacity in calculating pavement backlog requirements and in determining budget requirements and allocation. Further, site-specific pavement information is generally available among this study's participants, but often for surface conditions only. This information may include measures of roughness, deflection, rideability, and/or surface cracking. This information can be used to establish bearing capacities to support the development of pavement management programmes.

On the other hand, drainage adequacy and subbase condition is seldom available, and these are major factors that help determine the particular type of pavement rehabilitation strategy required for accurate life-cycle pavement cost estimation. In addition, future travel forecasts, particularly by vehicle category and subcategory, appear to be absent for many countries.

Safety information, including system related information on curves and grades, geometrics, and sight distance, and vehicle based information on accident rates, are data items typically not available or not used for resource allocation purposes. In some cases, reductions in fatalities and injury due to accidents are advanced as objectives for resource allocation. But there appears to be little support for determining the relationship of investment allocations to achieving these goals.

Capacity deficiencies do not appear to be a major consideration in either determining budgetary goals or in allocating funds in general, or to rehabilitation and maintenance, or in particular. This may reflect a sense among participating countries that adequate capacity exists to accommodate the foreseeable growth in highway demand, or it may be a reflection of the budget allocation practices whereby capacity additions, and rehabilitation and maintenance are decided on different grounds. This latter interpretation seems to be borne out from the data. At least in some countries, new capacity is considered separately and subjected to different evaluation criteria. But, in others, all rehabilitation and maintenance requirements are subjected to similar analysis requirements, typically based on rate of return or some other form of economic analysis, as new investments. It is not clear whether sufficient data are available to compare alternative investment strategies, which include both new investment and rehabilitation, with the same degree of accuracy or adequacy. The desirability of "level playing field" was spelled out in Chapter I, and diagrammatically expressed in Figure I.3.

III.4. CONCLUSIONS

It is advantageous for resource allocation and distribution decisions to be made using a consistent, reproducible, and standardised evaluation methodology. This methodology may be thought of as a "nested" technique, where allocation and distributions are made using common, but increasingly more detailed, data systems and analytical procedures that are linked in conceptual design.

The Road and Bridge Management System, described in Chapter I, referred to in Chapter II, and conceptually elaborated in the next Chapters, presents an attractive model to begin this standardisation and search consistency.

Any analytical design should focus on rigorous analytical forms in order to minimise the variability inherent in the use of equity to achieve regional balance in fund allocation/distribution. Although equity will continue to be used as a means of achieving regional and political balance, the use of systematic methods for allocating resources to transport will increasingly enable countries to evaluate transport alternatives on their own merits.

This move toward consistency requires the development of standard techniques and data systems, within the context of a fully integrated road and bridge management system. The system should be capable of accommodating the types of allocation and fund distribution currently required, including:

(1) Development of budgetary totals based on relating expenditures to changes in overall system performance;

(2) Development of regional distributions through the use of economic analysis that equitably compares the overall value of investment by jurisdiction; and

(3) Development of functional distribution tools to calculate and compare changes in road user costs associated with various investment strategies.

In addition, integrated system performance should be undertaken to support related economic analysis, including computations to relate capital and maintenance investment strategies to macroeconomic performance, input-output by major industry groups (see Box V.2), and economic development impact analysis.

CHAPTER IV

ANALYTICAL APPROACH TO OPTIMISATION

IV.1. THE THEORETICAL FRAMEWORK

The engineering-economic approach for optimising road management systems should be flexible enough to be applied in the diverse institutional settings found in OECD countries and discussed in previous chapters. This Chapter presents such a conceptual framework as well as guidelines for the development of an analytical procedure that will begin to address this question. The process of generating these guidelines necessarily involves a variety of micro-economic concepts and options for their application.

When the situation is viewed as a whole it is apparent that road maintenance managers are caught between two conflicting objectives:

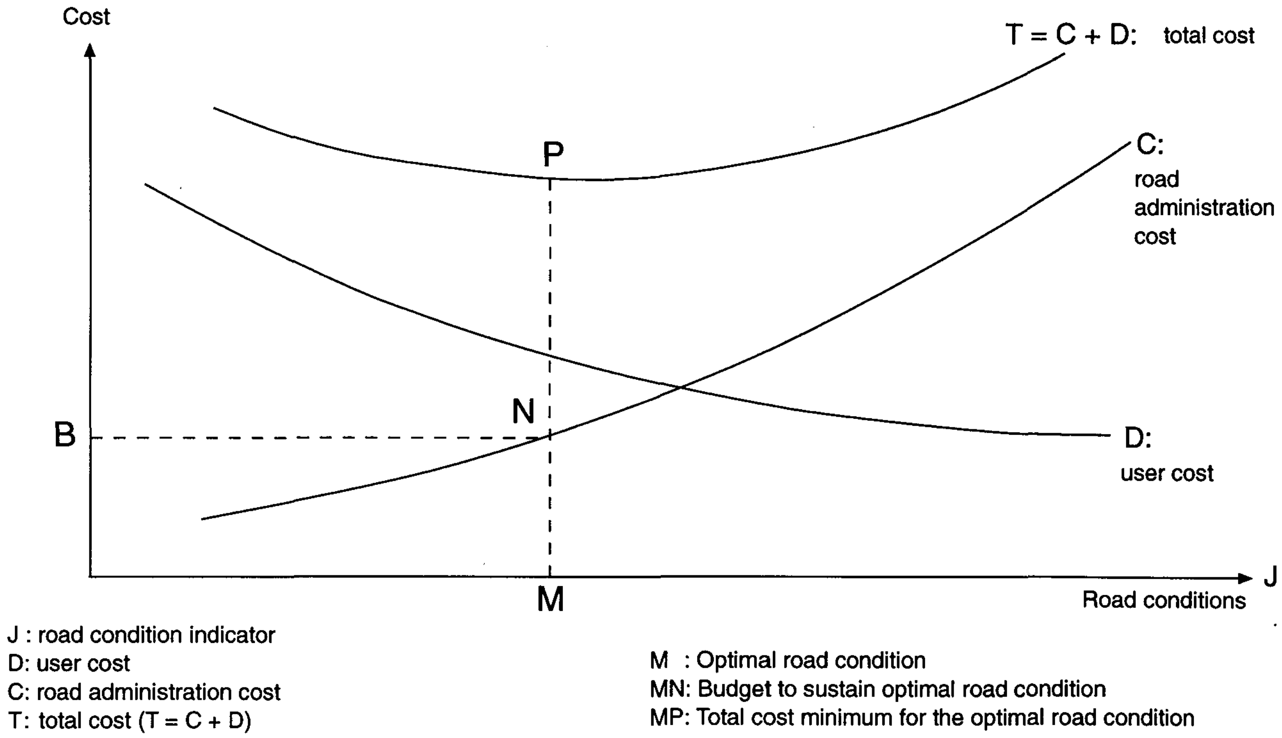
-- improving road user service, and
-- reducing the cost of providing that service.

The aim is to find the minimum possible total cost to road users and to the society as a whole (see Figure IV.1). If a graph is plotted with a road condition quality indicator on the X-axis, the curve which shows road user costs decrease and that which shows road administration costs rise. The total cost curve, the sum of these two types of costs has a minimum value i.e. the theoretical economic optimum which however does not necessarily reflect the optimum road conditions determined on the basis of the required road standards.

In Figure IV.1 the optimal road condition would be at M and the associated total cost for bringing or keeping the road in this standard would be at P; the agency costs being MN and the user costs NP. Alternatively, Figure IV.1 can refer to a subnetwork and indicate the network wide optimal road standard and the budget associated with the standard. It is important to appreciate this result which at the same time determines the best road condition standard and the associated agency cost (Or, the agency budget for an area or subnetwork and its aggregate optimal condition).

The idea presented in the graph masks a fairly common reality for road professionals. Decision-makers are often faced with financial constraints; and engineers are often faced with both a budget constraint and road standard constraints to achieve an optimum road condition. To address this reality, it is important that an analytical procedure enable the appropriate decision-makers to find the "second best optimum" in the light of these constraints. The graph illustrates this concept and the effect of standards and budget constraints on allocation and distribution of funds (See Box IV.1).

Figure IV.1. **Engineering-economic approach to optimising road rehabilitation and maintenance**



The proposed analytical procedure must also be able to account for present and future costs because the object of analysis is a set of actions whose lifetime is longer than one year. Furthermore rational road management calls for the development of multi-year road programmes, consisting of different actions to which the road condition is closely linked[1]. These actions range from yearly routine maintenance to reconstruction of the road. For instance, the costs of routine maintenance of a given road will be less than that of reconstruction but, if that road is deteriorated, the road cannot be brought to desired standard by routine maintenance alone. Also, the user costs will be much higher on a deteriorated road than on a road requiring only routine maintenance. These costs normally occur in different years and need to be related to a common comparative reference basis.

Later sections in this chapter will show how the theoretical framework is applied in practice and which simplifications may be necessary. Concrete aspects of decision processes will be tackled when dealing with the successive stages of the decision-making process and when dealing, conceptually, with the benefits of road rehabilitation and the associated external costs.

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1 Road condition is described by a set of parameters: roughness, rutting, distress, structural strength, etc. These parameters affect user costs and depend upon agency actions: reconstruction, overlay, etc., and their costs to attain a specific state of road condition.

Box IV.1. **Effects of budget and road constraints to optimising road rehabilitation and maintenance**

An often-used constraint in determining road budgets is a road condition standard. This standard may be expressed as the maximum allowable rut depth in asphalt concrete pavements, as the maximum pavement roughness value, or other quantifiable road condition states. Standards are often used to provide a uniform level of service on a given route, rather than on a single road segment. Thus, the standards may have meaningful operational value. As will be discussed later in this Box, the management must be very cautious in applying both standards and a budget constraint at the same time.

Let us assume that the standard is set at J_2. It is seen from Figure IV.2 that the total costs would be J_2P_2 of which the agency cost share, the agency budget, is J_2B_2. It is also seen that the standard is not "optimal"; the user costs are lowered because of a higher quality road, but the road agency costs are higher. The user cost decrease is less than the increase in the road agency costs, which presumably must also be paid by the users. In short, the standard J_2 is too high.

If, on the other hand, the agency has a budget constraint, say B_1, then the best the agency can do is to deliver a road condition at J_1. The consequence of this constraint is that for the society the costs are going to be J_1P_1 which is more than the minimum social cost MP. In this case the users pay more out of their pockets than what is saved in the agency budget. In short, the agency budget is too small.

There is a third idea which can be illustrated by means of Figure IV.2: as a rule it is not possible to have road condition standards and a budget constraint at the same time. For example, to set the road condition standard at J_2 and budget constraint at B_1 is simply not feasible, because B_1 monies are not enough to attain road condition at J_2; the latter requires a budget of B_2.

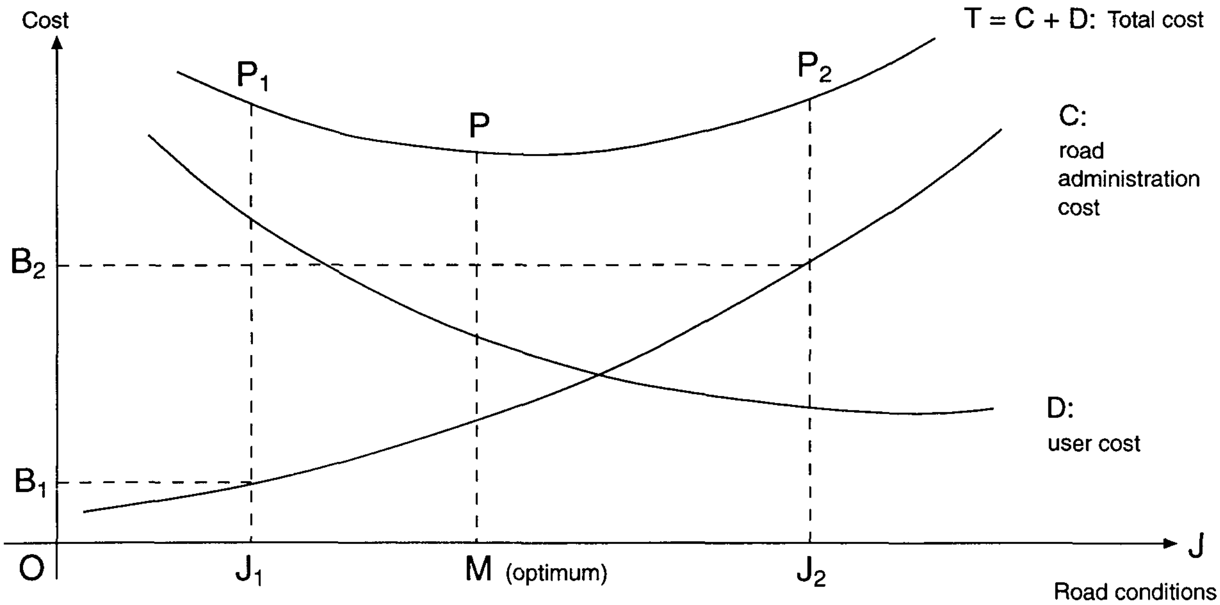
There are two cases when maintenance standards and budget constraints are both possible. These cases will have unintended consequences either on the agency or the road. In the first case the agency may have a budget of B_2 but be required to deliver a road condition of J_1. Clearly this leads to inefficiency, as B_1B_2 monies are wasted. An important by-product of the proposed framework is immediately evident: a managerial check can be exercised over the efficiency of the highway agency.

The other case is more subtle but extremely important; it is difficult -- but not impossible -- to explain it by means of Figure IV.1. It was mentioned earlier that the 'road condition' is multidimensional: the condition for roads with an asphalt pavement is characterised by distress (cracking, potholes, etc.), rut depths, roughness, and structural strength; etc. Thus, "road condition" does not mean 'rut depth' alone or 'roughness' alone, it means all the road condition parameters together. For example, the agency budget in fact is B_1 and the road standard is set at J_2; clearly an inconsistent combination as far as the graph goes. However, if "road condition" means only 'rut depth' and the standard J_2 refers to 'rut depth' only, that standard can be perhaps achieved but the other dimensions of road condition, roughness, structural strength, or distress, will deteriorate. It can also be that more than one of the road standards can be met for a few years with inexpensive 'stop gap' measures, but after a few years the road system will require extensive and expensive restoration works.

The practice described above is called **deferred maintenance**. Its harmful consequences are widely known and in order to avoid the damaging consequences it is imperative that **life cycle costs** of maintenance actions are utilised. If constraint must be used, as may be required by shortage of monies or by law, then **either** a budget **or** road standard constraints are used, but not both. The interaction of road standard and budget constraint should always be considered.

There is a yet a fourth idea which can be illustrated by means of the graph. In Figure IV.2, the costs are expressed in nominal values; an ECU saved in agency costs is equally valuable as an ECU saved in user costs. However, scarceness of funding always poses a dilemma, as discussed in section IV.6. In addition, there may be elements in user costs that have major uncertainties associated with them because they are not valued in the market. These non-market values include accidents, travelling time, and pollution to name the most important ones. It is therefore possible to weigh the user cost curve by a factor of 1/k (or the agency costs by a factor of k).

Figure IV.2. **Effects of budget and road condition constraints to optimising road rehabilitation and maintenance**



J : road condition indicator
D: user cost
C: road administration cost
T: total cost (T = C + D)

M : Optimal road condition
MN: Budget to sustain optimal road condition
MP: Total cost minimum for the optimal road condition

The importance and validity of road standard and budget constraints -- justified by non-monetary criteria and the disadvantage of taxes -- will then be demonstrated; and a solution outlined. The concept of uniform level of service will be addressed as well as the relationships between investment and maintenance policies prior to summarising the methodological rules based on the theoretical framework proposed in the Chapter.

IV.2. THE INFLUENCE OF THE FUTURE ON CURRENT DECISIONS

Figure IV.1 refers implicitly to a single year. In fact, the actions carried out in a particular year have an effect on all later years and current decisions should take this into account. For example, inadequate periodic maintenance would permit roads to deteriorate and, thus, require repairs and increase agency costs during subsequent years. In this respect it can be said that one of the objectives of periodic maintenance is the preservation of the road stock. This is quite true, but even if periodic maintenance is not neglected to the extent that it endangers the integrity of the road, any expenditure which is "saved" in this manner this year is in fact postponed until later, when the life time of the road is exhausted and it needs reconstruction at substantial cost.

It is, therefore, not possible to consider the optimisation of maintenance costs only on the basis of the current year's expenditure. The totality of current and future expenditure must be considered ("schedule of expenditure"). The "road stock preservation" objective then enters into calculations as an optimisation of "schedule of expenditure" for maintenance and that which relates to road user expenditures. The total transport cost T to be minimised is the discounted sum of expenditure C and road user expenditure D, or simply: **Minimise T = C + D.**[1]

However, expenditure which is to be made in ten years time cannot have the same weight in decision making as the same expenditure which is made next year. A valid comparison can only be made by applying an interest rate to discount expenditures on the basis of their date. Mathematical presentation of the optimisation problem is given in Box IV.2 and is necessary to its full comprehension.

IV.3. CALCULATION OF DIFFERENCES

The above calculation might appear simultaneously simple and cumbersome. However, it provides necessary theoretical support to the thought processes and calculations which will be required. It would be unrealistic to imagine the total amount of expenditure thirty years into the future. A simplification can indeed be made. The thought processes and calculations which are to be carried out will always consist of comparing two possible policies, or, less ambitiously, two possible actions for a particular year.

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1 It will be later shown that the right expression for minimisation is **T' = kC + D.**

Box IV.2. **Mathematical presentation of the concept to minimise agency and user costs subject to constraints**

Influence of the Future (cf. IV.2)

The totality of current and future expenditure must be considered ("schedule of expenditure" or "time sequence") when optimising the "road stock preservation" objective.

This is formally expressed as follows: let successive maintenance expenditure be called c_1 c_2 c_3.. c_n.. and road user expenditure be called d_1 d_2 d_3.. d_n. It is the schedule of total costs (t_i = c_i + d_i) which contains the wanted data, i.e.: t_1 t_2 t_3.. t_n.

However, expenditure which is to be made in ten years time or so cannot have the same weight in decision making as the same expenditure to be made immediately. Valid comparison can only be done by applying a discount rate to each item of expenditure on the basis of its date (see Box V.1. for a discussion about appropriate discount rates). If the discount rate is assumed to have been selected and is known as *i*, the discounting coefficient for the year *n* is $\mathbf{1/(1+i)^n}$ and the total expenditure to be minimised is: $\mathbf{T = \sum t_n / \{1/(1+i)^n\}}$.

It can also be assumed that the discounted sum of maintenance expenditure C and road user expenditure D can be calculated as follows:

$$\mathbf{C = \sum \{c_n/(1+i)^n\}}$$

$$\mathbf{D = \sum \{d_n/(1+i)^n\}}$$

Or, in short hand, **MinimiseT = C + D**. This expression will be modified later with the introduction of factor **k**.

Calculation of Differences (cf. IV.3)

Decisions always consist of choosing between two possible solutions. Thus, only differences need to be calculated. On the other hand, the differences in user expenditure are generally subjected to a change of sign and transformed into user "benefits". The objective will therefore no longer be made to minimise total expenditure, but rather to maximise the difference between benefits and costs, this difference being referred to as "net benefit". In the context of investment the discounted benefit of an operation is referred to. In the context of rehabilitation and maintenance one could talk of the net benefit of a programme, or even the net benefit of a change in the programme.

The pertinent mathematical expressions are then:

Change or difference in cost:$\mathbf{\Delta C = \sum \{\Delta c_n/(1+i)^n\}}$ ($\mathbf{\Delta C_n = C^1_n - C^2_n}$, for two projects 1 and 2)

Additional user benefit: $\Delta A = \sum \{\Delta a_n/(1+i)^n\}$, ($\Delta a_n = d^1_n - d^2_n$, for two projects 1 and 2)

Discounted net benefit[1]: $\mathbf{\Delta B = \Delta A - \Delta C}$

Marginally, each minor variation in committed funding dC leads to an additional benefit of dA. A correct choice would be to increase C as long as dA is greater than dC, or alternatively as long as dB is positive (**dB/dC > 0** or **dA/dC > 1**).

If the choice has been genuinely optimal, the value of **dB/dC = 0** at the selected point or alternatively dA will be equal to dC. Each monetary unit spent will produce a marginal benefit of the same amount. Any divergence from this absolute optimum will involve the coefficient **k** which will be discussed below.

<u>The budget constraint (the k-factor) (cf. IV.6)</u>

Whenever there is a budget constraint the maximisation problem becomes a classic operational research problem. In optimisation calculations it is necessary to apply a factor known as the dual constraint value to the constrained variable.

In economic terms this is, very simply, the constrained opportunity cost of funds.

The optimal programme without a budget constraint is one in which **dA/dC = 1**, i.e. that, marginally, an increase in funding of one monetary unit produces one monetary unit (ECU) in benefits. But if there is a budget constraint and the funding which has been fixed is judged inadequate by the decision maker it is because at the point at which the programme must be halted, **dA/dC** is greater than 1; let us say **dA/dC = k**. A new project will be of interest only if at a cost of ΔC it bears a return of $\mathbf{\Delta A = k\Delta C}$.

In order to determine whether one programme is more beneficial than another the objective function should not be the discounted net benefit $\mathbf{\Delta B = \Delta A - \Delta C}$ but a proper modification of it: $\mathbf{\Delta B' = \Delta A - \Delta C}$. This could be called a "consolidated net benefit". This is the additional benefit which the modification itself brings to the programme.

[1] Subject to what will be said below regarding the **k** factor.

Real decisions always consist of choosing between two or more possible solutions. Everything which is common to the choices disappears in the comparison process, which is only concerned with differences. One of the first results of this is that the distant future frequently disappears from calculations, as it is assumed to be the same in whichever case. Another consequence is that differences in expenditure become more easily a subject for discussion, particularly the road user expenditures which are much easier to establish than the expenditure itself.

The differences in user expenditure are generally called "user benefits", that is savings in user costs. The attempt to minimise the total expenditure is thus equivalent to maximising the difference between benefits and costs, this difference being referred to as "net benefit". In the context of rehabilitation and maintenance one could talk of the discounted net benefit of a programme, or even the discounted net benefit of a change in the programme.

Within the limits of a given maintenance policy it is generally possible to modify the total amount of funding to some extent. Marginally, each minor variation in committed funding leads to an additional minor benefit. A correct policy choice would be to increase the costs, the size of the rehabilitation and maintenance programme, until the increase in benefit is equal to the increase in cost, or alternatively as long as "net benefit" is positive (See Box IV.2).

If the choice is optimal each monetary unit spent will produce a marginal benefit of the same amount. Any divergence from this absolute optimum will involve the coefficient k which will be discussed below.

IV.4. SUCCESSIVE LEVELS OF DECISIONS - ALLOCATION AND DISTRIBUTION OF FUNDING

The above framework is presented at a sufficiently general level for it to be assumed that only one decision maker and one level of decision are involved. In reality, there are several successive levels of decision, each of which takes decisions at its respective level and assigns a total amount of funding to the level below together with objectives and instructions to implement these objectives as well as possible and in greater detail.

To simplify, decisions can be described as being of two types: allocation and distribution of funding. In this representation, one level of decision making decides the amount of funding to be devoted to network rehabilitation and maintenance. The next level, to which funds are entrusted, finds the best utilisation for them: where, when, how. The thought processes are completely different: the decision maker at the "higher" level, who is generally a politician or a high level manager, must weigh on one hand the value of public monies and on the other the services provided to citizens. He or she must then balance them in order to establish the volume of funds which will be allocated to a given sector of expenditure. The "lower" level, which is a purely technical level, has raw materials in the form of allocated funds, means of production in the form of the rehabilitation and maintenance programmes which can be considered, and has as its purpose the goal of obtaining maximum user benefits.

The basic difference is that in one case (resource allocation), establishing the amount of funding is the main purpose of decision making, whereas in the other case (resource distribution) utilising the funding -- the amount of which is a constraint -- is the main purpose. An example of how the proposed theoretical framework may be utilised in resource allocation and distribution is presented in Box IV.3.

Reality is still more complex because the person who allocates resources does not do so without having an idea of the use which will be made of them. The "distributor" too can delegate certain distribution tasks by allocating funds to subordinates.

An attempt has been made in this Chapter to make a distinction between whether the decision maker is able to modify the amount of funding which is available to him or if he should consider this as a constraint. Evidently there is a wide divergence in actual practice among OECD countries in this regard. Nonetheless, in their pure form these two decision problems are of a different nature.

Box IV.3. **Successive levels of decisions: distribution of funds between regions and road classes: an example**

The principles outlined in Section IV.1 can, and for consistency should, be followed in allocating monies to investment, rehabilitation, periodic maintenance and routine maintenance. Regarding rehabilitation and periodic maintenance a further distribution question arises which must be dealt with at the network level. Let us assume that the question concerns the apportionment of monies to different road or traffic volume classes (VC) - High, Medium, Low - and regions (R) - North and south - of the country[1]. In the most optimistic case when no budget constraint exists, it suffices to compute the minimum total cost for each region and road class separately to determine the associated budget and road maintenance objectives (dA/dC=1). This would then constitute the management's budget allocation and the objectives for technical staff as to the quality of road service they are expected to deliver to the users. Because the road condition is linked into specific actions, the management's guidelines to the technical staff also imply a specific distribution of actions to be taken but would not specify the road segments on which the remedial actions must be taken.

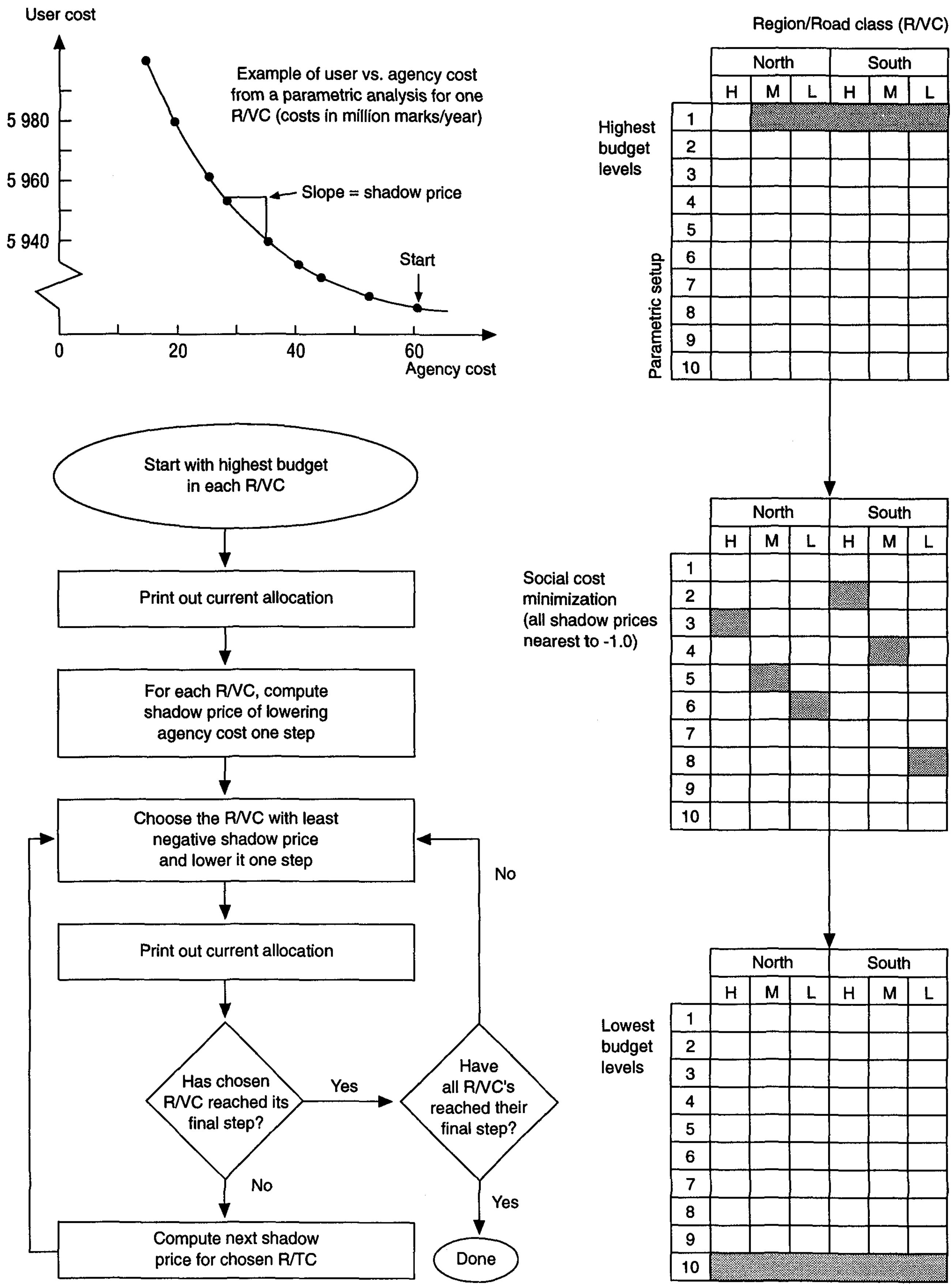
The complications arise when there is a budget constraint or standards to be achieved. A proposed allocation criterion, equalization of the shadow price, is illustrated in Figure IV.3. Again, the principles of Section IV.2 (and Box IV.2) apply. In the upper left hand corner (the change) in user costs (dA) is plotted against (the change) in agency costs (dC); the slope of the quotient dA/dC is called the shadow price as it tells how much additional benefit can be obtained for an extra ECU spent. When the shadow prices for different road classes and regions are equalized it is not economically efficient to transfer monies from any road class or region to any other. Figure IV.3 shows a concrete example and an algorithm, starting from highest budget levels and proceeding increment by increment toward lowest budget levels, how this might be accomplished. The solution in which the shadow prices for each Region-Road Volume Class are equal (and nearest to -1) would constitute the management's budget constrained allocation and road quality objectives to the technical staffs in their respective regions. It is noteworthy that these objectives are measurable and provide a basis for evaluating agency performance.

1 The specific distribution question depends on the organisation and managerial principles followed in the country. The example is given here for concreteness' sake, and must be adapted to the particular circumstances of any given country.

IV.5. EXTERNAL BENEFITS AND EXTERNAL COSTS

In the above it was considered that the benefits to be weighed against agency costs consisted solely of benefits to road users and corresponded to their "expenditure". However, other parties in addition to the managing agency and road users are affected by the level or the nature of road maintenance.

Figure IV.3. **Budget distribution between regions and road classes**



These include[1]:

-- Residents who may be affected by noise or varying degrees of local traffic difficulties;
-- Local firms whose activities may be helped or hindered beyond the mere operating costs of vehicles and, through this, regional economic development may be affected;
-- Civil engineering contractors involved in performing the works and, as a result, the employment market;
-- The larger community which incurs costs of an emotional and material nature generated by road traffic accidents;
-- The economy, and social psychology at large, which experiences the indirect effect of levying taxation.

The benefits obtained by road users are also more complex than it appears at a first glance. The most obvious gains by road users are vehicle operating costs. But economies of time are an important benefit, fairly obvious in the case of employees and commercial vehicles, but no less real for other road users. The value to be assigned to this time is therefore a problem in itself which requires the agency or decision-makers to adopt a clear position.

Let us simply bear in mind that the benefits of good maintenance include the following:

-- Monetary benefits to road users (a reduction in vehicle operating, see Figure I.2);
-- Non monetary benefits to these road users (gain in time, gain in safety);
-- Benefits to other members of society;
-- Benefits to the nearby community.

Quantifying these benefits is not a solely objective problem, and not everything can be quantified. These issues will require the decision maker to adopt positions which although reasoned, will inevitably include a subjective commitment on his part, and that in itself will constitute a decision.

The benefits which are thus taken into account and the value which is assigned to them will not necessarily be the same at all levels of decision-making. The highest levels will take into account macroeconomic or political benefits (or disbenefits) which escape the lower levels' attention and decisions.

IV.6. SCARCENESS OF FUNDING -- THE k-FACTOR

It follows from the foregoing considerations that the funds allocated to a certain level of road administration hierarchy often appear to be unrealistically low. This (often technical) level has only a partial view of the reasons which have led to the total amount given to it and is thus burdened by this day-to-day reality in optimising his work under seemingly unrealistic budget constraint.

What should the decision-maker, whose available funding is fixed as a constraint, do with a low and inadequate budget? His aim is still to achieve the largest possible quantity of benefits with the funds at his disposal. This is accomplished by applying a budget constraint (and perhaps other constraints on standards; see section IV.9) when choosing the actions and projects. In economic terms

[1] These non-quantifiable and/or external costs will be considered in Chapters V and VII in greater detail.

this is the (constrained) opportunity cost of funds. The optimal rehabilitation (maintenance) programme is one in which monetary unit increase in funding produces one monetary unit increase in benefits. If the budget, which is fixed, is judged inadequate by the (technical) decision-maker it is because at the point at which he runs out of money the benefits from a road project are still greater than its costs, by a factor **k**., which means that with one ECU more in funding it is possible to obtain **k** ECU more in benefits. This is the definition of opportunity cost: marginally, the decision maker has several possible ways of transforming one unit of road budget money into **k** units of benefits. A new opportunity, a new project, will therefore only be of interest if its (discounted) benefit is **k** times its (discounted) cost.

In order to determine whether one programme is more beneficial than another one should therefore consider not the discounted net benefit, but the modified net benefit in which the agency costs have been multiplied by a factor of **k**. One could call it "consolidated benefit" in the meaning it has in reference to private company "consolidated benefit"' statements (see Box IV.2). Experience shows that it is absolutely universal for funding to be inadequate to enable all cost effective works to be carried out. The practical consequence is that in order to seek budget constrained optimal programmes, it is necessary to apply the **k** factor to costs. What value should be given to this factor? The value of the k-factor will vary from country to country and possibly between time periods. What is important is that in each programme the value should emanate from awareness of the marginal cost-effectiveness of available funds (See also Box IV.4 for another perspective on the 'k-factor').

IV.7. MULTICRITERIA ANALYSIS

All the benefits (and costs) which may result from decisions do not necessarily appear in the figures which are used to calculate the user benefit. Numerical values cannot be assigned to some benefits, and in some cases, such as the value of time, there may be substantial uncertainty as to its value. However, it is justifiable to take such difficult-to-quantify values into account when deciding which alternative to select. In this case the numerical elements are one of the criteria for decision making, but other criteria must also play a part and the decision making process is thus of the multicriteria type. These non-quantifiable other criteria often concern the environment or economic development, or safety. The weight of such non-numerical criteria is greatest in the most important decisions, which are political in nature and involve macroeconomics, the larger environmental issues and other important factors. These criteria may express regional or psychological preferences or macroeconomic concerns.

The lower, more technical, levels of decision do not need to take account of this type of criteria -- because they are embodied in the plan or design itself -- and can normally make do with the numerical criterion which consists of the discounted sum of net benefits or, more accurately, as proposed, with the modified net benefit in which the agency costs, consisting only of monetary elements weighed by a factor of k, and then subtracted from the user benefits.

Thus, the applicability of the theoretical framework requires a clarification, which is given in a simplified form as follows (there are, of course, intermediate cases and gradations in reality):

-- "Major" decisions > political decision makers > multiple criteria > establishment of total funding and general guidelines
-- "Minor" decisions > technical decision makers > single criterion > total funding already fixed > seek to find the best use of money

Box IV.4. **The k-factor viewed as the disutility of taxation**

The **k** factor appeared in section IV.6 as a way of finding the best programme for a decision maker upon whom a budgetary constraint is imposed and who has no possibility of modifying the amount of funding that is available.

A decision maker who is free to establish the total amount of funding has a different problem. It could be anticipated that someone in this position would increase funding until the marginal benefit obtained was equal to the additional funding allocated. The subordinate decision maker, whose total funding has been fixed, would then find that **k** = 1. Why is this not the case, why does the high level decision maker not increase funding for k to equal one?

In general, the higher level decision maker does not do so because, and as will be pointed out in section IV.7, he or she must take account of criteria which have no numerical value, in particular -- at the highest political levels -- of the **disutility of additional taxation**. This term covers the following phenomena:

-- Additional taxation has negative economic consequences;
-- Additional taxation is badly received by the electorate and has negative psychological effects;
-- Additional taxation alters the overall sphere of State action, which is in itself an objective.

It is clear from experience that the State is not willing to collect additional taxes to the value of 1 ECU if citizens do not receive a considerably higher return (say, for example, 1.5 ECU for 1 ECU of taxes).

It is therefore justified for a particular value of the coefficient k to be used when establishing the sum of total funding for highway rehabilitation and maintenance. This factor has, therefore, two aspects:

-- The decision makers who decide the amount of funding allocation also implicitly establish a value for the **k** factor which may quite legitimately be greater than 1 (1.5 is probably a reasonable minimum),

-- The lower level technical decision-maker for whom the total amount of funding is fixed finds, ipso facto, a coefficient **k** which for him is merely a computational tool (a value of 2 is often encountered in reality, but different countries have different values).

The k-factor then lumps together, or sums up, criteria and factors which cannot be quantified. However, the analytical procedure proposed in Chapter IV for allocating and distributing resources for road rehabilitation and maintenance is flexible, and can accommodate different kinds of values and priorities -- as appears to be the case in the OECD countries -- and use these differences to arrive at consistent and rational recommendations.

Road rehabilitation and maintenance often fall into the second class of "minor" decisions and would benefit from the application of the proposed methodology.

IV.8. LEVEL OF SERVICE - UNIFORMITY OF ROUTES

The basis of the benefit calculations described above is to discover what road users can gain as a result of road works. These benefits increase with the number of road users affected and are approximately proportional to this number. However, other considerations which are not connected with the number of road users may play a part in decisions.

It can, for example, be a requirement for all roads of a particular administrative or functional class to comply with certain minimum specifications. For example, it may be required that all Main Roads be protected from thawing conditions; or that roads of such and such a class must be paved whatever their levels of traffic.

Similarly, it may be justified to require a route to be treated in the same way throughout its length even if some sections carry less traffic than others. It can also be decided to provide a general level of service to a particular set of roads which, although possessing a variety of traffic levels, share a common feature as regards function, type or appearance to road users.

Choices of this type, which are marked by a degree of generality, invite two types of comment about the decisions which are to be made:

-- The network level decisions by the management should be informed by comprehensive studies in which the microeconomic calculations by a management system, such as that recommended in this Report, are an important factor, but in which the desire for uniformity of service level in road network's functional classes also plays a part,

-- Lower level decisions, (yearly or multi-year programmes, distribution of funding to specific uses on specific links), should restrict themselves to minimising total user and agency costs while complying with the network level decisions which are considered as constraints or objectives.

IV.9. MAINTENANCE AND INVESTMENT

The relationship between decisions which relate to road maintenance and those which relate to investments (new construction) invites comments of a practical as well as theoretical nature.

Investment expenditure is often considered to be a noble expenditure which increases the wealth of the country. Maintenance expenditure, on the other hand, is regarded as an unavoidable but, on the whole, non-productive expenditure. Politicians are therefore often trying to increase investment expenditure as much as they can by reducing maintenance expenditure as much as possible.

The fundamental error in this cannot be over-stressed. One of the functions of maintenance is to preserve assets which have been created by a prior investment expenditure. Therefore, the benefits which good maintenance aims to bring to road users now are the same which investments aim to provide them in the future. This is ensured by the benefit-cost calculations which are used to direct maintenance programmes and based on the same principles which are used for investment programmes.

It is essential to eradicate the idea that one aspect of expenditure is noble (investments) and the other is not (maintenance and operation). It should, furthermore, be common practice for investment decisions to be accompanied with the decisions to finance maintenance and operation over its life time in a manner consistent with their use. This is necessary to ensure that the decision to invest is taken with full knowledge of its true life time cost.

In this connection, it is worth knowing that a road is one of the investments which, in percentage terms, generates the least annual expenditure. Each 100 ECU spent requires an annual expenditure of only 1 to 1.5 ECU for satisfactory maintenance. The operating costs associated with road furniture (lighting, traffic management) are higher, about eight per cent.

Awareness of these standard percentages, and those relating the GNP to total road expenditures, merit refinement and should not be taken literally to apply in every member country. They could, nonetheless, provide rough guidance which can be produced with the analytical procedures and data collection methods proposed in this report. For this reason it is essential that the Highway Agency has sophisticated management tools to help in investment, rehabilitation, periodic and routine maintenance decisions.

IV.10. CONCLUSIONS

The following ideas can be distilled from the above discussion:

-- The user benefits (reductions in user costs) constitute an important objective in road rehabilitation and maintenance programmes;

-- The decisions which relate to road maintenance and rehabilitation are taken at many hierarchical levels;

-- Each level passes down to the level below its instructions (objectives, constraints) and resources for action;

-- A distinction must be made between situations in which the budget has been fixed and those in which this depends on the decision in question;

-- The search for the best decisions must always involve comparison between different possibilities (variants and alternatives) and systematic consideration of the differences between them;

-- Whether or not there is a financial constraint, an ECU of funds for public use may not be directly compared to an ECU of user benefits. Comparison involves a coefficient **k** (scarceness of funds at the engineering level, disutility of taxation at the political level);

- User benefits include monetary elements, but also important elements of other types (time, safety, physical and psychical comfort, environment, etc.)

- Benefits to other citizens, or to the community, must also be considered and this may lead to the introduction of several criteria in the decision making process;

- Choices such as "minimum service", and "uniformity of level of service" may prove justified in some cases;

- Lastly, maintenance must cease to be the poor relation of investment as its purpose is to assure the value of investment over time.

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CHAPTER V

DEFINITION AND CALCULATION OF BENEFITS AND COSTS OF MAINTENANCE

V.1. INTRODUCTION

The main aim of benefit and cost calculations is to enable managers to identify the most advantageous rehabilitation and maintenance strategy, given the budget and other constraints. A corollary, subsequent aim is to enable design engineers, at the project level, to associate the most economical maintenance profile which minimises total discounted work expenditure and user costs over the life cycle of the facility subject to policies established at the network level.

Chapter I set the stage for a discussion of benefit-cost calculations. First, it showed this analysis to be useful both at the network and project levels (see Figure I.3: network, programme and project levels).

Second, Chapter I also laid down the five interacting sets of costs that comprise total transport costs: (1) 'development' (new construction), (2) 'rehabilitation and (periodic) maintenance', and (3) 'operation' (and routine maintenance) costs spent by the road agency, (4) road user costs (which are primarily vehicle operating costs but also include some accident costs and time delay costs), and (5) external costs to society (including environmental pollution, societal costs of accidents, and development and production benefits).

Thirdly, Chapter I illustrated the significance of user costs in Figure I.2. The "benefits" from roads and from their maintenance come in the form of reduced user costs.

This Chapter enumerates and explains the benefits and costs that must be accounted for over the life time of a facility in order to maintain it so as to minimise its costs to society.

In order to minimise the transport costs over the life of any facility, maintenance profiles -- a concept pictorially introduced in Figure V.1 -- must be established based on known performance of road pavements supported by condition monitoring. In most countries these profiles are based on the assumption that traffic will not experience any discernable loss of benefit up to the point where maintenance intervention takes place. This is indicated by the flatness of user costs in Figure V.1., excepting during times of maintenance or rehabilitation when users experience travel time delays. In the event of intervention as intended in the maintenance profile, the works will prevent benefits from being lost as a result of deterioration had the works not taken place. In the event of intervention later than intended -- after the road deteriorates beyond the point where traffic flow and vehicles are affected -- the purpose of the works, which themselves will now be more costly, is to restore the real benefits for road traffic to the desired level.

In order to reach good decisions, managers and design engineers must establish clearly the following criteria and information:

- The current discount rate to be applied to all quantified costs and benefits for years beyond the base year for the calculation. The rate varies from country to country, although rates between 5 per cent and 8 per cent would be typical in a Western European country. The higher the rate, the lower will be the influence of future costs and benefits, that is, a high interest rate favours low cost solutions (see Box V.1).

- Reliable and accurate values for the various quantifiable costs and benefits listed in Sections V.2-5. These values will need to reflect both national and local conditions including traffic composition, speed flow profiles and local community costs.

- Accurate records of the various factors listed in Table V.1 which will be included in the cost assessment. It is probable that specific surveys will be required to provide the information needed or at least to supplement that already available.

Using the information listed above, other relevant information, and the general framework of Chapter IV, a rehabilitation and periodic maintenance strategy can be established. This strategy will result in decision rules or policies to be adopted by design engineers in a particular rehabilitation or maintenance situation. Such a rule or policy may be given in the form of a maintenance profile shown in Figure V.1. The rule in Figure V.1 will require intervention treatments to be applied when deterioration has reached a pre-determined level; when that stage has been reached, the design engineer will seek to control costs so that the works will result in net benefits at a level not less than that identified in determining the rule.

It is important to recognise that the profile in Figure V.1 refers to the **engineering-economy** approach to rehabilitate and maintain roads. The maintenance profile for crisis management (**zero-maintenance**) approach is quite different and is shown in Figure V.2. In that management approach rehabilitation and maintenance are delayed until the road is badly deteriorated, making **both** the user costs (benefit losses) and the agency costs much larger than under engineering-economic rehabilitation and maintenance policy.

Different rehabilitation and maintenance management strategies will have a direct effect on the experienced costs and benefits. Some of these costs and benefits will be of a quantifiable and others of a non-quantifiable nature. The following paragraphs will set out the various costs of maintenance and rehabilitation split between those that are "internal" to the administration and road users and those external; some will be quantifiable and others non-quantifiable[1].

Similarly, subsequent paragraphs will consider the internal and "external" benefits of maintenance and rehabilitation whether quantifiable or non-quantifiable.

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[1] Orthodoxically, external costs accrue to non-users and internal costs to users. This division has become hazy. The pragmatic approach taken here is that distinction between external and internal costs is noted in the text, if possible, but in so far as the calculations are concerned all quantifiable costs, whether internal or external, are included. The non-quantifiable costs are elaborated and taken into account in decision-making on a case-by-case basis.

Box V.1. **Rate of Interest**

The rate of interest measures the cost of capital to an administration. Clearly, if interest rates are high, the administration, when borrowing, will pay a high price for the investment because of the requirement to repay capital and interest. Conversely, if interest rates are low, the cost to the administration will be reduced.

However, even if the administration does not to borrow in order to finance works, there will be a "social discount rate" incurred because those funds will not be available for other investment which will either not take place or do so as a result of borrowing.

There are variety of possible combinations of interest rates and possible road rehabilitation strategies. The following illustrates a possible situation: If interest rates are relatively low in the short and long term, the administration will be faced with two options; it can either build more roads of a lower quality with more frequent rehabilitation and maintenance in the future, or build fewer roads of a higher quality which will require lower and less frequent rehabilitation and maintenance in the future. The decision will be influenced, in part, by the present and forecast traffic demands on the network during the planned life of the roads.

In the context of high interest rates, the consumers seek to avoid risks, and the discounted cost of future maintenance works will be relatively low, because of the weak influence of future costs and benefits. This will favour an economic basis for rehabilitating or building roads inexpensively to last for a short life span. By doing so, and because the discounted maintenance costs will be less significant, the result is more frequent interventions on the network.

With low interest rates prevailing and solid consumer confidence, it would be expected that traffic growth would be robust, resulting in higher road user costs when maintenance works take place. For this reason the strategy of higher quality construction standards with reduced levels of maintenance would be likely to prove economically best.

When investing in long term projects such as highways, the administration will consider not only current interest rates, which will affect decisions on its capital or new works programme, but also longer term forecasts of interest rates and many other factors to determine its maintenance strategy. A comprehensive assessment is required in all cases to establish the best strategy.

V.2. QUANTIFIABLE COSTS OF MAINTENANCE

The principal costs of maintenance fall to the administration (agency) in the form of those associated with the works, including the costs of planning, design, execution and supervision. Normally, it is only possible to include quantifiable costs in a life cycle assessment, but non-quantifiable

Figure V.1. **Typical Deterioration and Maintenance Profiles**

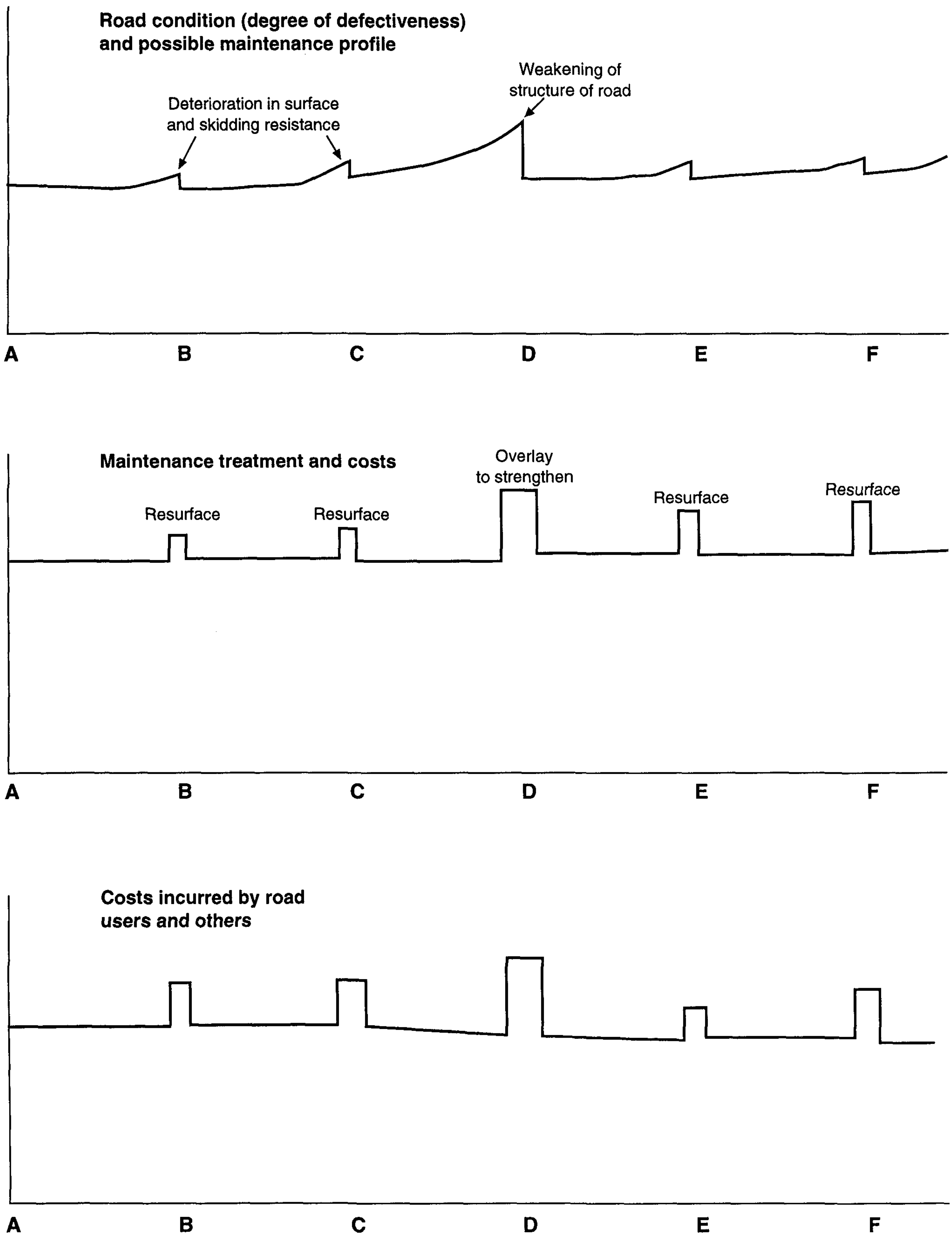

Figure V.2. **Maintenance profile based on a policy of reaction**

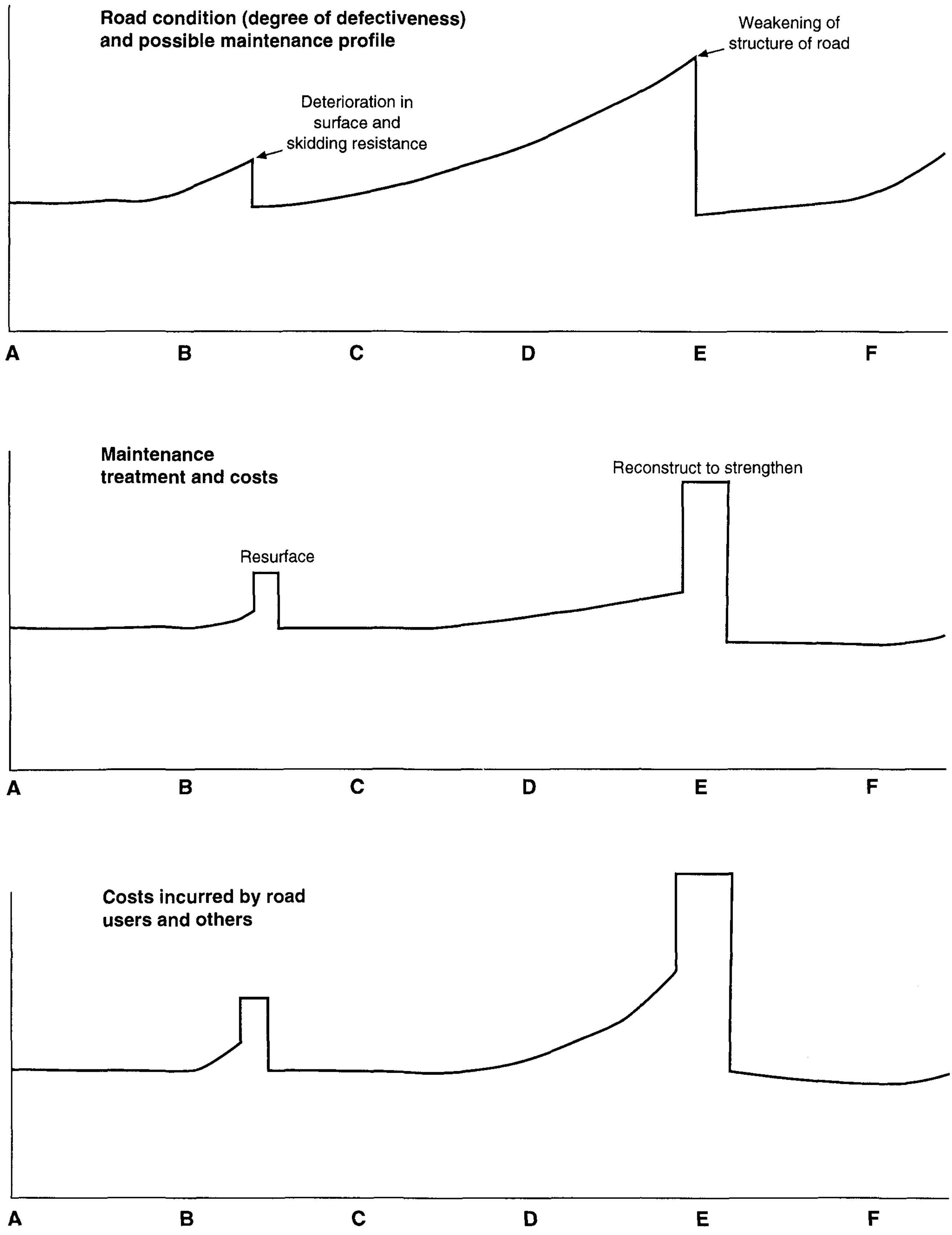

Table V.1. **Summary of quantifiable costs and benefits of maintenance**

	Chapter V References	Costs[1]	Benefits[1]
Administration			
Procedural requirements	V.2	✓	
Works	V.2	✓	
National objectives (economic prosperity)	V.4		✓
Road Users during works			
Private user	V.2	✓	
Public Transport	V.2	✓	
Road users after works			
Time	V.4		✓
Operation	V.4		✓
Maintenance	V.4		✓
Accidents	V.4		✓
Local residents			
Traffic delay	V.2	✓	
Accidents	V.2	✓	
Local Businesses			
Transport	V.2	✓	

1 In comparison to 'do nothing' alternative

costs can be considered separately where they are significant, for example, as constraints to allowable rehabilitation or maintenance strategies.

Two other sources of agency costs are worth pointing out, although they routinely are included in the direct costs of works. Both of these have a tendency to increase the road administration's costs and are done to internalise the otherwise external costs of rehabilitation and maintenance.

The first of these costs is incurred in order to avoid excessive user costs during the works. Road users will often be required to bear a cost during the maintenance works. This is normally in the form of increased cost of time, but operating costs will also increase particularly on congested roads where maintenance works will result in increased and possibly severe delay. Moreover, accident rates and their associated costs may increase when maintenance works are in place on the road. To mitigate these costs the administration needs to balance the total cost of works with those to the road user and plan the works and traffic control as a whole to ensure that combined costs are minimised.

The second source of costs is similar to the first, but is incurred because of the non-users. The presence of maintenance works on a section of road may have a variety of cost implications for those living or working in the vicinity, but not directly connected with the project. The impact will change, often significantly, depending on the nature and location of works, the local road network and the nature of the area and the community. As a result of these factors, quantifiable costs can be incurred by:

-- Local residents affected by traffic disruption in the vicinity of the works;

-- Local public transport operators affected by disruption due to the works;

-- Local businesses where delivery or collection of goods and materials can be affected by the works; and

-- The possibility of increased accidents, with their associated costs such as loss of employment, to both local residents as well as the road user.

These costs can be small or large but they are always difficult to estimate in advance. When a broad assessment indicates that they will be significant, the administration should include these costs when specifying the form of the works, planning restrictions and traffic control.

V.3. NON-QUANTIFIABLE COSTS OF MAINTENANCE

Local residents would be subject to intrusive effects of dust, noise and general disruption to movement near their homes, often despite any controls imposed within the works contract to mitigate these effects. In extreme cases clear restrictions may need to be placed on a contractor to minimise the effects particularly at critical times such as at night and weekends. Of necessity these decisions will often be made as a result of subjective assessments.

Maintenance works need to be supplied with a range of materials from quarries and batching plants, most of which will be located remote from the site requiring deliveries to be made by lorries, often using lower standard local roads. These movements are likely to result in accelerated wear and tear on these local roads and disturbance to residents and businesses along the routes. Again, planning controls may be necessary to minimise these effects.

It is possible that the adverse impact of works in the local area may act as a deterrent to the general public using road facilities while the works are in progress. This effect would be particularly difficult to assess since other influences also may contribute to such trends.

It is seen that non-quantifiable costs are most often related to the environment and their mitigation will be further considered in Chapter VII dealing with the environment and other externalities.

Table V.2. **Non quantifiable costs and benefits of maintenance**

	Chapter V References	Costs[1]	Benefits[1]
Administration			
Processing of taxes etc	V.3	✓	
Road users during works			
Environmental nuisance	V.3	✓	
Road users after works			
Reduction of post accident grief	V.5		✓
Local residents during works			
Environmental nuisance	V.3	✓	
Impact on local facilities	V.3	✓	
Employment	V.5		✓
Local residents after works			
Impact on facilities	V.5		✓
Wider Community			
Impact of deliveries to and from site	V.3	✓	
Post accident grief	V.3	✓	
Local Businesses			
Benefit of well maintained roads	V.5		✓

1 In comparison to 'do nothing' alternative.

V.4. QUANTIFIABLE BENEFITS OF MAINTENANCE

An essential objective of any national road network is to assist economic and social growth and prosperity by reducing transport costs. The benefits of providing and maintaining the road network to standards consistent with adopted policies can be assessed and quantified, although limitations in traffic modelling, valuation of time and external constraints will introduce a degree of imprecision into the assessments.

The principal benefits resulting from maintenance and rehabilitation works accrue to road users in form of reduced transport costs. A road surface, when new, will normally allow traffic to flow at a speed regulated only by traffic volume and speed limits. But when the road deteriorates to a significant extent, especially when rehabilitation will be required, the road users experience a degree of discomfort, speed reduction and other increased vehicle operating costs.

Maintenance of the road surface, as opposed to rehabilitation, normally has little effect on journey speeds, and the benefit of carrying out maintenance occurs, because deterioration has been checked and corrected so that traffic in future years will not incur costs which would have resulted from further deterioration, had the works not been carried out; the benefits identified from the original investment will be protected.

When roads deteriorate to the point where rehabilitation will be required, speeds will be progressively reduced in the interest of comfort and perceived safety. Through observation, this loss of speed, and the resulting increasing cost to the road user, can be calculated and so assist in the decision on optimum timing of the maintenance treatment. Investigations have further identified additional costs when road roughness reaches a significant level:

-- Vehicle maintenance costs increase especially due to additional wear and tear on suspension components;

-- Fuel consumption increases for vehicles travelling in a free flow situation; and

-- If road surfaces begin to lose chippings or other stone, there will be an increased incidence of vehicle damage, including to windscreens.

Additional benefits can accrue, or increased user costs can be reduced when carrying out maintenance or rehabilitation in a timely manner.

Maintenance and rehabilitation also improve the skid resistance of the road surface, other minor geometric improvements are also often done, and there will be benefits to the road user in the form of reduced accidents. Because the incidence of accidents is a rare event, these benefits can only be quantified and realised over a long time period.

Rehabilitation and maintenance works may also benefit others, besides road users, in a way which can be quantified. For example, the construction industry may increase its volume of activity, probably at higher profit levels in a growth situation and provide more employment.

V.5. NON-QUANTIFIABLE BENEFITS OF MAINTENANCE

Businesses depend on a good well-maintained road network. Not only will existing businesses benefit from good standards of road maintenance, but it is possible that other businesses may be influenced by the state of the local road network, when making a decision to expand or relocate its activities. These benefits would clearly be difficult to quantify, largely because they would be as a result of decisions, many of which would be made on the basis of commercial confidence and would not be available. However, general economic trends would be available from various sources and would give valuable information.

Maintenance works will create opportunities for employment not only locally from where the work force may be recruited, but also in the various supplies industries. These benefits are often difficult to assess because of other forces influencing the volume of work in the industry. Nonetheless, recently attempts have been made to quantify these benefits because of the local communities' interest in them. Similarly, well maintained roads bring with them other non-quantifiable social benefits, e.g. tourism.

Box V.2 develops a case study of quantifiable and non-quantifiable cost assessment and Box V.3 presents an example application of input/output analysis.

V.6. RELATION BETWEEN BENEFIT/COST AND MAINTENANCE LEVEL

Previous sections of this Chapter have described the various benefits and costs which contribute to the overall decision making process regarding when and how to maintain or rehabilitate a road. These were set out in the Table V.1.

As a concrete example how a preferred strategy -- derived through an engineering-economic management approach -- would look like, a case of periodic maintenance of a single road is shown in Figure V.1. The upper plot indicates surface condition and ride quality deteriorating slightly (to say point B), but not to the extent where it would noticeably increase road user costs. The centre plot shows a treatment (at point B, resurfacing) to restore the road condition to its original level. The centre plot also shows that, because the surface condition is prevented from deteriorating to a poor state, no significant expenditure on maintenance is incurred between the specified intervention points (B, C, D etc.). The lower plot indicates that because surface condition is always relatively good and only routine maintenance is carried out between planned interventions, the road user only incurs additional costs because of delays when the planned interventions (B, C, D, etc.) occur.

Road condition monitoring, an integral part of the Road and Bridge Management System, suggests the need for treatments at various stages. By carrying out the appropriate treatments at these stages the administration would ensure that the level of service envisaged at the time of construction would be achieved throughout the life of the road. By following this strategy a series of events would occur as shown in Figure V.1:

time	A	Road constructed;
times	B,C,E,F	Road resurfaced when minor deterioration and/or loss of skidding resistance occurs;
time	D	Road is overlaid when indicated by policy and condition data.

Box V.2. **Examples of quantifiable and non-quantifiable costs**

Examples of quantifiable and non-quantifiable costs taken into account in planning reconstruction of a section of a semi-urban motorway close to an urban conurbation:

QUANTIFIABLE

a. Administrative Requirements

Date of Scheme	....
Design Fees	$260,000
Site Supervision	$170,000

Design Fees are based on the Consultants Commission Fee Scale. In addition extra fees were paid for works considered to be beyond the norm eg publicity material etc. These amounted to $8,500.

b. Works Cost

Tender Sum	$11.30 M	Contract Final account $13.30
Total Scheme Cost	$14.70 M	Includes fees, supervision etc

c. National Objectives

The scheme was virtually 100 per cent reconstruction. The motorway had been built 20 years earlier. It had remained a local authority road with no significant maintenance until April 1989 when it became a national road.

d. Private Road User Costs

The daily road user cost for "High Growth" travel demand scenario was $70,000. The Consultant had difficulty in modelling the urban links affected because of their complex nature and felt that this was an underestimate of the effect on the urban roads.

e. Public Transport Costs

Consideration was given to the provision of park and ride sites, but this was not pursued. The only cost to the administration was in providing signs on and off the motorway to an existing park and ride site at one of the main commuter railway stations on the outskirts of the City. The cost was a few hundred dollars.

Meetings were held with the Passenger Transport Executive to keep them informed of the works programme. Traffic congestion was less than predicted; thus disruption and inconvenience to public transport was less than predicted and definitely less than originally feared by the operators.

f. Road User Costs After the Works

No details of the do nothing road user costs. The predicted cost of immediate maintenance works, if the major scheme had not gone ahead, was $640,000, to maintain a safe and adequate road surface. This would have increased significantly annually.

g. Local Residents

A survey was taken to compare the journey times on the major commuter route affected by the works. The survey showed that journey times via the motorway were not affected by the works but, in the major alternative route, journey times increased by approximately 10 per cent during the works because of the transfer of traffic. This however represented only a 3 minute increase in journey time.

There are no accident figures in relation to accidents away from the motorway.

The administration paid for minor works on the main alternative commuter routes to improve traffic flow during the works eg temporary traffic restrictions and minor radii improvements. The cost was $115,000.

h. Local Businesses

No estimate of financial impact. A pre works meeting was held with the Chamber of Trade to explain how the administration was planning to minimise delay and disruption. The Chamber expressed their concerns. However after the works letters of praise were received from the Chamber and individual shops. Therefore the impact of the roadworks was minimised.

NON-QUANTIFIABLE

a. Administration

There were no problems but the preparation work was greater, both for the agent administration, than for a typical maintenance scheme. The publicity campaign was the most significant aspect. This included:

- i. TV, Radio and Press Conferences,
- ii. Publicity leaflet distributed to commuter car parks in the City,
- iii. Mail shot to all businesses in the area,
- iv. Press advertisements,
- v. Provision of a telephone hotline -- this was updated daily when necessary. The message gave details of slip road closures etc.

The design of the traffic management proposals was more extensive than a typical scheme.

b. Road Users during the Works

Publicity campaign was aimed at persuading people to use alternative modes of transport, car share and avoid the motorway at peak hours. The scheme was programmed to take full use of the school summer holidays, when flows into the city are lighter and to be completed before the Christmas shopping season.

c. Road Users after the Works

The scheme provides a 20 year design life for road users with programmed resurface works in 10 years. The overall aspect of the motorway was improved eg new signs, white lines, safety fence etc.

An improvement to a junction layout (signing and white lines) reduced queues at peak times.

d. Local Residents during the Works

Local residents were affected by noise and dirt. The contractor also had claims for vibration damage from some residents immediately adjacent to the motorway. The main contractor was from the region, as were most of the sub-contractors, but this would not benefit the local residents.

e. Local Residents after the works

The purpose of the works was to provide a reconstructed carriageway and upgrade the motorway furniture. The administration did not take the opportunity to provide noise barriers etc. as this was not considered appropriate. This section of motorway passes through the Development Corporation area. As a separate exercise the landscape planting was enhanced on the motorway "Gateway" corridor. This will have had some incidental benefit to adjacent residents.

f. Wider Community

No planning controls were enforced with special reference to the scheme. One sub-contractor was prosecuted by the local authority for depositing waste material from the site on an illegal site (ie without planning consent).

g. Local Businesses

No significant difference to businesses between the pre and post works scenario, apart from an improvement in traffic flow into the city at peak times.

Box V.3. **Analysis of indirect impacts of road investments using input/output analysis**

APPROACH

Regional economic development can be defined as an increase in the welfare and revenues of citizens and enterprises in that region. A road investment in a certain area can lead to economic development, i.e. growth of production and revenues, if:

-- new production capacity is enhanced due to the new road,

-- decreases in transport costs improve the productivity of the companies and, in consequence, the welfare and revenues of people in the area.

These regional impacts can be analysed with the help of input/output models developed by W. Leontief. Input/output tables are based on the theory of general equilibrium which summarises and explains the dependencies and interactions between different sectors of the economy.

In addition to the direct impacts of a road investment, input/output tables make it possible to analyze the indirect effects. These indirect or multiplier effects depend on the structure of the economy and the productive sectors. Of course, the multiplier effects are rude estimates as the production structures change constantly and rapidly.

The input/output tables are based on the fact that every productive sector needs goods and services of other sectors in its production process. When its production increases, its demand for raw materials, services, machines and equipment produced by other sectors increases. This in turn increases their demand for goods and services produced by third sectors etc.

The input/output model allocates the impacts of a road investment to the different groups of the economy as follows:

-- enterprises by sector (savings in transport costs/improvement of productivity, increase in demand/sales),

-- households (employment/salaries),

-- public sector (tax revenues).

A highway investment is divided in two phases in the analysis: the investment or construction phase and production phase when the road is opened to traffic. The first lasts usually 2-4 years after which the multiplier effects fade away, unless the road investment and rehabilitation activities continue at the same level in the region. On the other hand, the effects of the latter, generated by the transport cost savings, are more or less permanent.

One of the major problems of input/output analysis is due to the fact that regional input/output tables usually do not exist, but the analyst has to be content with national figures. Regions with a production structure that differs considerably from the national average cannot be taken properly into account. As a consequence, the accuracy of the input/output to estimate regional effects is somewhat questionable.

EXAMPLE

Investment phase

The improvement of Lansivayla, a major motorway leading form the central business district of Helsinki to the west, costs approximately 250 million marks and will take 4 years. The indirect effects of the investment amount to 635 million marks and are about 2.5 times the original investment. The productive sectors will benefit of 40 per cent of the total or almost 300 million marks as increased sales. The households salary revenues increase 100 million as well as the revenues and profits of entrepreneurs. The public sector's tax revenues increase by 70 million marks. 8 per cent or 50 million marks of the indirect effects will benefit foreign companies as imports increase.

The sales of services increase 170 million marks. The most benefitting sectors are: transports and wholesale and retail trade. Among the industrial sectors, which gains 100 million marks as increased sales, the most benefitting sectors are metals, chemicals, oil products and food industry.

Due to the increased sales, companies are able to hire almost 3000 additional workers. These new employment opportunities will, however, last only as long as the construction activities take place or 4 years.

Production phase

When the Lansivayla improvement work is achieved, monetary transport costs (excluding time savings) will decrease by almost 17 million marks per year. These savings will stimulate the economy with more than 40 million marks every year. From this, companies benefit 20 million as increased sales, households 7 through higher salaries and entrepreneurs 9 million marks due to increased profits. Tax revenues increase by almost 4 million.

The increased demand and salaries, generated by the transport cost savings, makes possible the creation of 80 permanent employees. Most of them will be in the service sector (43) and among the industrial sectors in the food producing sector.

The resurfacing treatments specified above would cost in real terms similar amounts at stages B, C, E and F, productivity gains offsetting the eventual price increases. The increases would reflect both the need for new and better materials as well as the increased costs of working on very congested roads.

Figure V.2 shows a maintenance profile based on the "crisis management" approach. An intervention is carried out when the deterioration approaches a certain level which is considered unacceptable, because for instance, the public and/or politicians complain about too extensive development of ruts and pot-holes. The upper plot indicates that surface deterioration has reached a substantial level before intervention is effectively forced on the administration. The centre plot indicates that after point B, deterioration accelerates and increasingly costly and frequent repairs are required to keep the road serviceable until the major intervention becomes essential. The lower plot demonstrates that the deteriorating condition and routine maintenance works required impose on road users high costs, because of increased journey times, vehicle operating costs, and delays as minor and major works are carried out.

In adhering to the "crisis management" policy indicated in Figure V.2, the following events would occur:

A Road constructed;
B-C Road resurfaced as a result of substantial deterioration of surface; and
D-E Road reconstructed as a result of major structural deterioration.

The maintenance works indicated in Figure V.2 will be significantly different from those indicated in Figure V.1. At a time between B-C the cost of patching will be great and limited repairs could not ensure the integrity of the road, hence necessitating major resurfacing works. Depending on the degree of deterioration it may be necessary to carry out more extensive works than simple resurfacing, such as partial reconstruction. User costs incurred as a result of reducing speed over the deteriorating surface will increase over time.

At times between D and E, the road will be at or near the failure condition, user costs will increase exponentially and probably be at an unacceptably high level by the time the reconstruction works are carried out.

The strategy in Figure V.1 shows clearly that the effect of planned and timely preventive maintenance based on accurate condition data will ensure that the benefits expected from the investment in the new road at the time of construction will be achieved throughout the time. The strategy in Figure V.2 illustrates that as condition deteriorates, many of the benefits expected of the investment in the road will be reduced and as deterioration increases further, the loss of benefits can be very substantial especially on a major busy highway where free flow speeds would otherwise be possible.

Figures V.1 and V.2 are diagrammatic schemes seeking to illustrate the general effects of different strategies. It should be noted that the scales indicating works and user costs have not been quantified and could be widely different. On roads carrying very low levels of traffic flow, the works costs could be higher than the user costs, but on very busy roads, the user costs could be very much greater than the works costs.

V.7. APPLICATION OF COST AND BENEFIT CONCEPTS TO THE RESOURCE ALLOCATION PROCESS

In the first three chapters resource allocation and distribution was discussed from the point of view of a government or the Central Administration which both collects taxes and allocates funds to the transport sector. This Chapter has focused on the "grass roots" level where the costs are incurred and where the allocated funds are spent. The network level distribution of monies meets the project level spending of these monies at this juncture.

The operating units of the administration, which in many countries are called the Regional Organisations as opposed to the Central Administration, will be required to take account of all the quantifiable and non-quantifiable factors listed in this Chapter and summarised in Tables V.1 and V.2 when distributing money from its funds to individual projects. Each operating unit will need rules and analytical procedures, to assist in this process so as to ensure even treatment throughout the administration. (Box V.2 presents an example enumeration of quantifiable and non-quantifiable costs considered in the reconstruction of a semi-urban motorway).

For these reasons, and for the reasons below, discussions about resource allocation and distribution take place at various levels depending on the structure and requirements of the Ministry of Transport and the Central Administration. Annual allocation based purely on the then known condition of the network in each year would result in an erratic variation of funding and works on the network. Such annual variation would not be helpful to the Ministry, which will need to constantly re-adjust its income targets. Nor would it be helpful to the construction industry, which will face high risks in investment in an uncertain future and the road user, which will face varying levels of works from year to year. The Road Administration (or the Ministry of Transport as the case may be) must, therefore, develop a long term plan to assess the net benefits of its road programme over a period of several years to provide stability in funding.

Formulating such a road rehabilitation and maintenance programme requires the quantification of net benefits, with a reasoned assessment of the non-quantifiable benefits, of road rehabilitation and maintenance at the network level rather than by individual projects. This approach is necessary not only to demonstrate the value for money of the plan, but also to offer a comparison of the social and environmental benefits which comprise other forms of national expenditure such as health, law and order, defence and social security.

The rehabilitation and maintenance programme must, therefore, be competitive even though there are difficulties in making true value-for-money comparisons. An example of this difficulty is that maintenance is usually carried out as a preventive treatment before serious deterioration occurs and little information is available on the true economic cost to the road user of delaying maintenance until deterioration reaches an advanced state.

Before concluding this Chapter, it is important to point out one more cloudy aspect of resource distribution to operating units and projects. If one operating unit, because of the nature of its maintenance projects, directed a higher proportion of funds to non-quantifiable factors in a particular year, it will result in fewer funds being available for maintenance and rehabilitation treatments. This shortfall will be simply detected by future condition surveys which would indicate the need for a higher proportion of funds, as a result of assessment of quantifiable benefits, for such an operating unit in future years. In this way this particular operating unit has ensured itself a high funding level over the years, first on the basis of non-quantifiable benefits, and then on the basis of quantifiable benefits. A consistent and comprehensive procedure is therefore required to ensure (regional) equity.

It warrants restatement that the proposed three-tier hierarchy[1], network-programme-project, is a necessary feature of resource allocation and distribution. The hierarchy helps ensure fairness, to avoid mis-allocation or mis-distribution of monies, and, over time, to ensure a consistent and well-justified level of funding for maintenance and rehabilitation.

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1 In Chapter I the relationships between three hierarchical levels were explained. As noted then, the program level is an intermediate activity which ties together the network level resource allocation/distribution with the project level expenses.

CHAPTER VI

CHARACTERISATION AND MEASUREMENT OF HIGHWAY CONDITION

VI.1. ROAD AND TRAFFIC INFORMATION SYSTEM

A road administration necessarily collects huge amounts of data. The mission of the data collection personnel in a Road Administration is *to enable management to strengthen the decision-making process and increase productivity.* Figure VI.1 shows how this mission relates to the management system, such as that articulated in this report.

As road systems have become more complex, so have the aims and methods of data collection. Historically, traffic counting systems were the first to be developed in a systematic manner; they were later extended by speed and accident studies. Soon the development of "road data banks" followed containing information on the road network and the physical characteristics of its links. With time, it became apparent that an integrated traffic monitoring system was required. Road condition, traffic management, weather, and, last but not least, weigh in motion data were included in the Road Administration's information system. Today, the road and traffic monitoring system is an important module in the road administration's information system, as is shown in Figure VI.2 (that it is regarded as only a module is because the full information system contains also socioeconomic, cost, and other relevant information).

The key to the effectiveness of a Road Agency's information system is a location reference structure which enables the user know the time and place of each data item. For example, the road information system contains data on the network configuration (administrative and functional classification), surrounding environment, physical characteristics of the road links, road surface, pavement, structures, traffic, accidents, actions taken, and other elements considered necessary in road agency management, including updates and changes. This information is not optimally useful unless it can be located precisely in time and space.

The information system normally serves multipurpose objectives of the Road Agency, such as Central Administration's needs regarding planning and investment as well as rehabilitation strategies, or the Regional Administration's needs for organising routine maintenance activities. The greater the complexity of the multipurpose objectives, the more elaborate are the requirements on the system's information management capabilities. A wide variety of systems, including hardware and software, is available to meet specific needs. The good ones enable user-friendly input and output as well as classification and organising of information of any type that has been inventoried or monitored.

Figure VI.1. **The mission of data collection in a road administration**

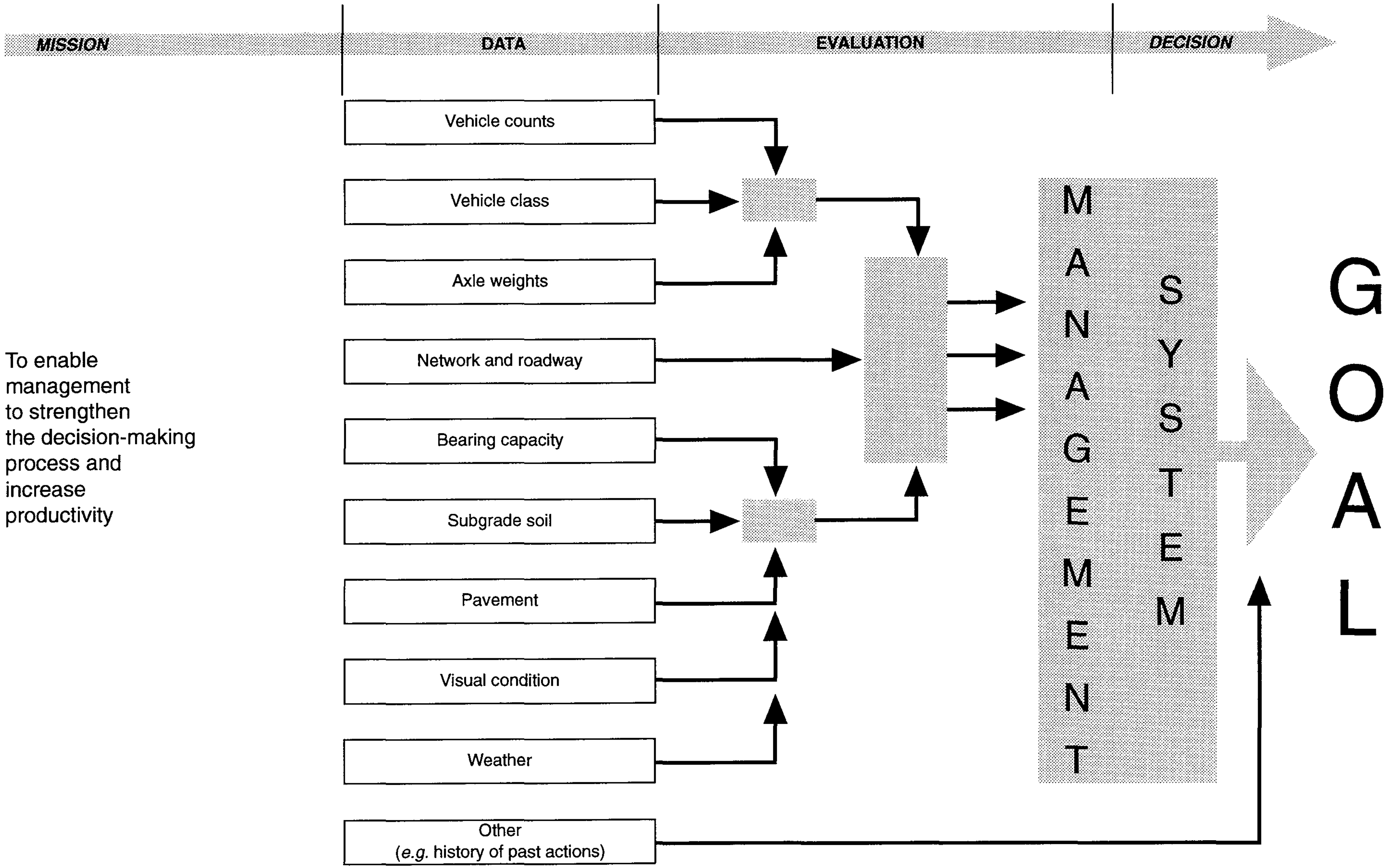
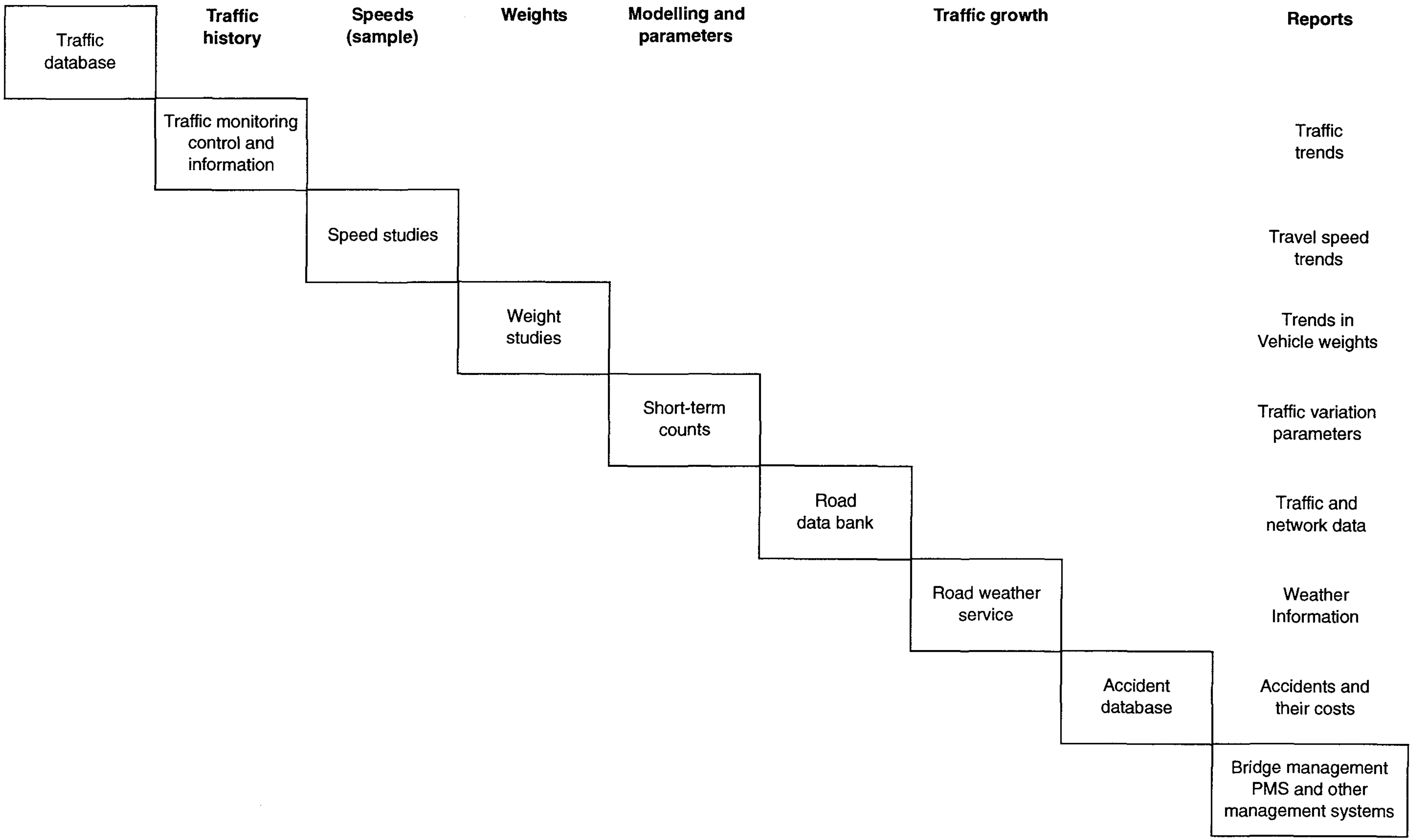


Figure VI.2. **Road and traffic monitoring system**
(a part of integrated information system)



The usefulness of any information system[1,2] depends to a large extent on the quality of the data it contains. This rests not only on the appropriateness of the monitoring procedures but also on the error-free characteristics of the data compiled; any input of information into the data base must be controlled and validated. The validation should be performed right after the monitored data has been controlled for coherence and, the second time, at the stage of physical loading of the data in the data base, especially if data input is done manually.

The information system is merely an information organiser, but a necessary one. An important function of the system is its usage together with analytical procedures and management systems, such as described in this Report so as to optimise resource allocation and distribution for road rehabilitation and maintenance.

VI.2. ROAD CONDITION MONITORING

Road condition monitoring[3] is a process of tracking time-dependent changes in the observed condition of a road and its environment (for example, progression in surface deterioration, climatic conditions, traffic patterns, maintenance activities).

Compared to, for example, traffic counting, road condition monitoring has not reached the same degree of uniformity as regards definition of variables, sophistication in statistical procedures to minimise data collection, and even acceptance as a legitimate periodic road agency activity. Therefore, there exists a degree of variance -- a searching for cost-effective "best practice" -- in current road monitoring procedures. What is described in this Chapter is merely a good prototype, not necessarily a recommendation. Moreover, road condition measurement conventions and variables which are measured depend on management practices, available measurement and information technology, and expertise of the road administration personnel. Suffices it to state that in a modern road administration, road condition measurements are made with fast, automatic multi-parameter devices, which utilise Global Positioning System (GPS) for the location of measurements.

VI.3. LEVELS OF ROAD CONDITION MONITORING

Monitoring can be classified and is often organised according to levels of accuracy and frequency, as is customary also in traffic counting. Another purpose of a monitoring structure by levels is to allow

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1 PATERSON, WILLIAM D.O. and THOMAS SCULLION (1990). *Information Systems for Road Management: Draft Guidelines on System Design and Data Issues*. World Bank Technical Paper, Report INU 77. World Bank. Washington, D.C.

2 The 1992 OECD report on *Bridge Management* proposes a similar approach to bridge data collection and management and presents a detailed review of developments so far, issues and future perspectives.

3 The reader is also referred to the OECD/World Bank report on DC1 *Road Monitoring for Maintenance Management* (Volume 1) published in 1990 which -- albeit centred on developing country issues and visual inspection -- develops a systematic framework for road damage recording.

for the assessment of road conditions in a wide variety of circumstances and to serve many different needs of the administration.

Figure VI.3 presents a diagram describing five levels of monitoring structured according to frequency, amount of data collected, network size, use, degree of automation, data base support, and capability of providing input for policy and planning decisions. Although five levels have been defined, they can be separated into three groups: the first is level I, the second group comprises levels II and III, and the third is made up of levels IV and V.

The first group of road condition monitoring is designed for a preliminary study aimed at scoping the requirements for the planning of network (or region) wide maintenance works and/or for establishing statistical criteria, the location of permanent monitoring stations, and the equipment needs for continuous monitoring schemes. The infrequent, often 'one time only' survey may be followed by similar sample surveys to add new variables to be monitored or check the effectiveness of new maintenance initiatives, or inspect the quality of road maintenance at (regional) network level.

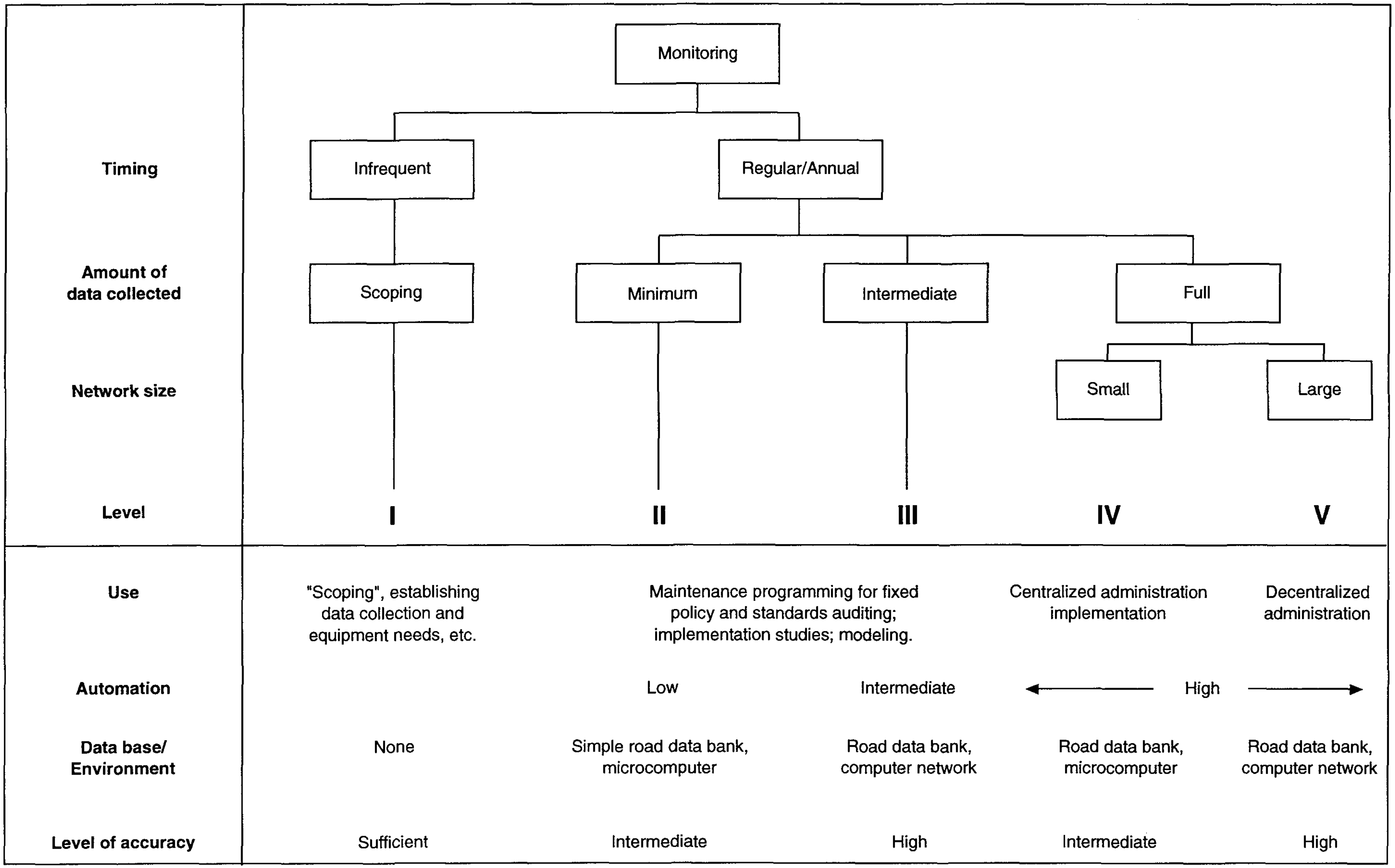
The second group, levels II and III, is the main data collection activity for road conditions. It is used when maintenance/rehabilitation policies are determined using an optimisation model and when the policies based on road surface condition are applied, requiring a certain amount of data to be collected. Detailed data are gathered normally on a sample of road links or groups of links, while the condition of others is forecast using deterioration models. Often only roughness and rutting are measured (because high efficiency, high speed equipment can be used). Measured distress condition and bearing capacity (deflection) data are averaged, typically in 100 m to 5000 m block lengths. These same data are used for auditing network condition, monitoring adherence to maintenance quality standards, for project implementation studies (in which case more detailed data may be collected or supplemented from other sources), and for estimating the deterioration and optimisation models and validating them. On average, this type of data gathering is done in two or three year intervals rotating the links or groups of links being sampled.

The third group of monitoring serves data collection for the design and implementation techniques of maintenance/rehabilitation works. For maximum coverage, continuous measurements (or nearly so) are used. These are required for precise identification of defective zones and their location to design and to apportion work zones accurately. It calls for high level automation of monitoring equipment to accommodate the relatively large amount of data collected on a relatively short period (one year) regular repetitive basis.

There can be a sixth level, or a fourth group, of road condition monitoring which is done at permanent locations (often coinciding with the permanent traffic counting stations) and which serves research and development studies. At these locations detailed data are recorded on a great variety of variables, including not only road conditions but also weather, axle loads, maintenance/rehabilitation activities, costs, etc.

There is an underlying ranking in monitoring levels allowing for 'downward compatibility'. The different levels are arranged to permit their staged and gradual implementation as to the number of items investigated, depending on network size, data collection technology, and institutional capacity. The 'downward compatibility' of monitoring levels will ensure that the different decision-making levels utilise the same data. As will be articulated in Chapter VIII, this is an important attribute of the road information system.

Figure VI.3. **Levels of monitoring road condition**



The levels of monitoring outlined above presume that a comprehensive inventory of the road system and traffic was undertaken when the information system was set up. For the purposes of rehabilitation and maintenance such inventory consists of data assembling prior to maintenance management (i.e. concerning past history), data that can be considered "permanent", such as:

- past cumulative traffic data,
- initial facility geometry,
- initial structure and characteristics of subgrade soils,
- past maintenance actions.

In summary, road condition monitoring is based on two approaches: statistical sampling on test sections belonging to road links or groups of links, and full length (continuous) measurements. Both slow, labour-intensive methods with manual data handling and semi- or fully automated measuring equipment with enhanced electronic data processing are used, depending on the circumstances and sophistication of the agency.

VI.4. CHARACTERISATION OF ROAD CONDITION

The information obtained from road condition surveys serves multiple objectives. The most important questions needing answers are:

- What are the conditions or trends at a particular location of a network, or where are the locations with a certain condition?

- On an aggregate basis and on average, what is the road condition as it appears to users?

To answer these questions two major types of data need to be collected: data on traffic conditions and data on pavement conditions.

Data related to traffic and climate exogenous to surface and road structure are dealt with here very briefly. The most important factors are (see also Figure VI.1):

traffic: gross load
axle and wheel configuration
frequency of load applications
speed

climate: rainfall
daily variation of temperature
frost heave
freeze-thaw and wet-dry cycles

In collecting traffic data, relationships between average daily volumes (considering vehicle type classification) and associated axle load distributions should be well established. This is essential for predicting future cumulative loads on road sections and assessing their residual lives in combination with pavement strength evaluation. These data, together with an evaluation of overloading risks and climatic conditions, are required to properly design rehabilitation or periodic maintenance measures for the purpose of extending service lives of pavements.

For road condition and for road management systems the level and amount of data required will have to be cut down for practical reasons to a necessary, but sufficient amount in order to make the network and project maintenance management operational. This depends on the methodology adopted. The methodology can assume that the concern of rehabilitation/maintenance is either on the functional condition of pavements (stressing surface characteristics conditions) or on the structural conditions of pavements (strength, bearing capacity and residual life oriented), or both. Because this report is concerned with both rehabilitation and periodic maintenance the interest is on both surface characteristics and the structure.

Research conducted for determining the important factors to characterise pavement condition suggests that they can be classified into three groups: surface, pavement and structure. Roughness (unevenness), rutting, and distress[1] appear to be the most important surface and pavement characteristics. Roughness has been shown to have a strong relation to car and truck operating costs and also encompasses many of the road condition attributes captured by rutting and distress. However, distress and rutting have their own causal factors and, often require different engineering interventions, so that they should be kept separate from roughness. As for pavement strength, structural number or residual life (bearing capacity) can be derived from test results.

A further consideration in quantifying surface, pavement and structural conditions is that the dimensions adopted should relate on the one hand to causal factors and, on the other, to engineering decisions to intervene with maintenance works. The features and dimensions used to quantify surface distress conditions and pavement structural conditions should help determine when the pavement has reached a condition which requires periodic maintenance or rehabilitation and what action should be taken.

In sum, then, besides geometry characteristics, the road endogenous factors are related to surface, pavement and structure, for example:

surface	roughness
and	rutting (including material loss due to studded tyres in some countries)
pavement	distress
structure	strength
	rutting (deformation)
	depth to water table

Finally, it is noted that rideability assessment can also be obtained from pavement condition monitoring by measuring road roughness. Roughness can also be related to traffic level-of-service (speed) and vehicle operating costs.

1 A study by Hajek and Haas -- HAJEK J.J. and RALPH HAAS (1987). *Factor Analysis of Pavement Distress for Surface Condition Predictions.* A Paper presented at the Annual Meeting of the Transportation Research Board. Washington, D.C.-- identified five factors of pavement distress, four of these described different kinds of cracking.

VI.5. MEASUREMENT OF ROAD CONDITION

There are combinations of procedures and measuring equipment that can be used to collect data on road and traffic conditions. It is not the scope of this report to make an exhaustive and detailed analysis of this topic, instead, only the principal features of the procedures and equipment are indicated.

Monitoring of a network will generally be performed in a staged manner. The hierarchy chosen is that discussed in Section VI.3 "Levels of Monitoring". Scoping, at Level I, is preferably done using fast monitoring methods, although that depends on the accuracy imposed. Monitoring at levels II to V will focus in detail on functional and structural road conditions.

However, the hierarchy of the levels is by no means orthodox. While those set out above are in agreement with the analytical procedures encouraged in this report, the primacy of one level over the other is a matter of debate and will depend on whether the issues at stake are on maintaining surface characteristics to a standard, which respond to performance (economic) criteria, or whether the aim is at preserving structural integrity (which extend the residual life of the road). Although these issues are coupled, the priorities will be dictated by whatever methodology is adopted.

Monitoring is often performed in an order which successively scans the characteristics related to:

-- the surface,
-- the pavement (layers), and
-- the structure (down to the soil).

Surface monitoring concerns the impacts of vehicle interaction. Pavement monitoring is concerned with mechanical fatigue and environmental distress of layers. Structural controls are linked to bearing capacity and, therefore, to service life.

VI.5.1. Surface conditions

When beginning to establish systematic road condition monitoring, there is general consensus that the first priority is to obtain rapidly a complete assessment of the road network surface condition. How this is done depends on the sophistication of the Road Administration.

The first time monitoring is undertaken, it is commonly done by a visual inspection survey combined with an evaluation of riding comfort. This effort usually is the reconnaissance aimed at estimating the overall relative distribution of network condition states and serves as a precursor for more advanced assessment. The drawback of this is its subjective character; the visual evaluation and rating will rest entirely on the expertise and judgment of highway engineers.

In subjective rating the following categories are normally used:

Good: Substantially free of defects and requiring only routine maintenance,
Fair: Significant defects; requiring periodic maintenance,
Poor: Extensive defects; requiring reconstruction or strengthening.

Complete coverage of the network can also be made through an automatic continuous measurement of pavement roughness (unevenness). Roughness is the most appropriate and sensitive parameter to be measured, particularly in view of condition trends. Although a high level of accuracy, in contrast with other highway characteristics, is required to measure roughness, technology has developed a range of reliable high speed equipment. Roughness (caused by longitudinal deformation of road profiles) is a product of both construction quality and a combination of distresses, it can be considered as the final signature of distress. It is also the aspect of road surface condition that mostly influences vehicle operating costs.

Another surface characteristic parameter that can be continuously monitored is skid resistance. Its measurement is based on a road friction test (for which a standard exists) which can produce either a transverse friction coefficient or a longitudinal one. Both are useful indicators for locating zones which are an accident hazard due to skidding. A new generation of monitoring equipment currently under development evaluates the surface textures from which skid resistance is inferred. Surface texture also has the potential for measuring surface drainage conditions and for being associated with some components of vehicle operating costs (tyre wear and fuel consumption).

When objective measurements are used, surfaces are no longer subjectively classified as 'good', 'fair', and 'poor', instead ranges of roughness (and skid resistance) values are used to classify the surface condition.

VI.5.2. Pavement distress

The distress patterns of pavements generally involve cracking (narrow and wide), materials losses (ravelling, disintegration, potholing) and deformation (rutting, plastic deformation in flexible pavements; settling, depressions and slab stepping and pumping in rigid pavements). Monitoring these features requires the ability to recognise the types and patterns of defects and quantify their severity and extent. Excepting the well configured case of rutting, for which automatic methods of measurement have been developed, all other distress conditions still rely on labour intensive visual inspection.

In visual inspection, catalogues are used to recognise the types of distress. They are quantified by averaging the extent of the area occupied by the distress over an arbitrary section of the road surface. A classification into three to four groups is normally used to quantify distress. In visual condition assessment, tentative explanation is provided for the probable cause of deterioration.

Research and development are under way to improve distress measurement by means of pattern recognition through electronic imaging of surface distress.

VI.5.3. Structural capacity

The objective of monitoring the structure is to provide information for strengthening pavements through overlaying or other rehabilitation measures[1]. Data are collected on either strength or bearing capacity of the road structure, or both.

For strength, a semi-destructive static fixed point test is available using the dynamic cone penetrometer. The data collected will contribute to evaluating the structural number of the layers and subgrade. The structural number is often calculated from the design data and adjusted for traffic and environment.

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1 OECD, Road Transport Research (1993). *Road Strengthening in Central and Eastern European Countries*. OECD, Paris.

Non-destructive methods have been developed to derive bearing capacity (remaining life) or structural number from deflection data. Four general classes of equipment are routinely used to collect deflection data:

-- Static Beam Deflection Equipment (Benkelman beam),
-- Automated Deflection Equipment (Deflectograph, Curviameter),
-- Steady State Dynamic Deflection Equipment (Harmonic Induce Load),
-- Impulse Deflection Equipment (Falling Weight Deflectometer).

Adopted rehabilitation designs must be field calibrated for local conditions and materials by the help of one of these methods.

Due to the low yield rate of measurement provided by these types of equipment there is a tendency to confine this mode of evaluation to the poorest condition class of roads for which annual or semi-annual roughness and distress condition data exist. Given that bearing capacity wears away slowly, its measurement fits perfectly to a rotating programme for road links and data are collected every four to five years, the intermediate years being estimated through a model. Structure evaluation is always done when designing road strengthening, in which context some additional local information is collected, such as:

-- drainage conditions (water table level and moisture content),
-- material properties (laboratory analysis of samples).

VI.5.4. State of engineering structures

The condition of engineering structures, bridges, tunnels and viaducts is evaluated on the basis of regular and thorough visual inspections. Periodically and when necessary special instruments are used to evaluate particular components of complex structures such as a piled foundations of bridges. This evaluation allows the structural condition of the engineering structure to be ascertained, superficial decay to be detected, deterioration to safety components (bridge parapet, guard rails, etc.) to be identified and protective coatings on metal surfaces to be assessed.

Some countries have at their disposal an operational system (for instance SCORPION) using gamma and X-rays, thermal mapping, georadar and other technologies enabling a thorough but non-destructive inspection of engineering structures. Important engineering structures, such as bridges, have their own special purpose management systems. Increasingly these systems have become a part of the same system used for roads. To be sure, the principles put forward in this report for resource allocation and distribution on roads can, and should, be also used for bridges[1].

VI.6. ROAD CONDITION MEASURING DEVICES

The quality and condition of the pavement are considered by the road user and road manager to be the most important parameter to assess the quality of the road changes with time and traffic, it is desirable to have quick, reliable and automatic systems of collecting and storing data. In the past few

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1 See the aforementioned OECD Bridge Management report.

years, measuring devices have become automatised, the validation and some analyses of data are carried out by computers onboard the vehicle. Even relatively old measuring equipment are now modernised and computerised. This virtually eliminates data reduction and transcription errors and allows data collection on a large scale, at network level. Several multi-parameter devices are available on the market, such as the Canadian ARAN (Automatic Road Analyzer), the Swedish RST (Road Surface Tester), or the French SIRANO (Système d'Inspection des Routes et Autoroutes par Analyses Numériques et Optiques).

CHAPTER VII

ENVIRONMENT AND OTHER EXTERNALITIES

VII.1. ENVIRONMENTAL CHALLENGE

During the life cycle of a road or a network the responsibilities and life styles of people, their travel demands, and communities as a whole will change. The road network has to be adapted to these new circumstances. Unfortunately, such changes are highly case specific. The elaboration of a checklist of the major prevailing environmental issues, or the enumeration of pro-active options, is therefore an immensely tedious undertaking. That different interest groups perceive the issues and options in different ways, only makes such an undertaking more complex. However, although no generally applicable agreement can be reached on goals and objectives, even problem definition, nor the monetary values of intangible benefits, an agreement is possible on the course of action needed. This provides a window for contributing to the mitigation of complex environmental problems.

In the last decade awareness of the value of the environment has increased in the industrialized world. Environmental considerations in planning, design and construction of new roads have expanded. The costs of new roads to fulfill expectations of the public are today remarkably higher than just a decade ago. Equally remarkably, there exists widespread willingness by the politicians, officials and the general public to pay for these costs. The higher costs for the construction of tunnels or aesthetically pleasing viaducts, for park renovation, for sophisticated control systems and other environmental mitigation measures also increase the costs of rehabilitation and maintenance of these structures.

Environmentally sensitive construction and maintenance of roads are desirable because they provide tangible benefits: cleaner air and more pleasing appearance of the environment; protection of neighbourhoods; increased quality of life; and higher value of land and homes. Access without visible nuisance of the roads is a highly valued commodity. Another instance of this value capture is in urban centres where aesthetically pleasing environmental spaces have created thriving business conditions.

Environmental assessment (EA) is already required, starting in advance planning phases for new road constructions in all OECD countries. But no impact assessment is mandatory for rehabilitation and maintenance. Apparently the thinking is that the road is there, it carries traffic; these are facts. Often, however, rehabilitation or maintenance of a road takes place in new circumstances and it is adapted to take on "new obligations".

Investment in the environment in the context of road works is already substantial; presently 5-15 per cent of the road costs are environment related expenditures. This figure attests in a concrete way to the importance and necessity of caring for the road and traffic environment. Road rehabilitation presents an opportunity to enhance the value of the environment. Rehabilitation and maintenance are now experiencing a change in concept and content: their purpose is to preserve the value of the investment **and** to improve the environment[1]. It is therefore vitally important to promote training of personnel in environmental assessment and monitoring to detect opportunities for positive approaches to environmental management and to encourage methods that include affected interests in planning studies when rehabilitating or maintaining roads.

VII.2. INFLUENCE OF ENVIRONMENTAL REQUIREMENTS

Road maintenance and rehabilitation, traditionally viewed as a mundane topic for second rate engineers, are carried out today in changed circumstances and operate with a changed concept. They have a key position in preserving the value of road assets, providing improved service to road users and renewing environmental quality. The environmental requirements directly or indirectly influence all phases of maintenance and/or rehabilitation works, from planning to execution, and account for the most important component of the non-quantifiable costs and benefits.

There are two overarching aims to maintain the road network:

-- To preserve the value of investments and to provide road infrastructure and service to road users in the most economical way, and

-- To adapt the road to new circumstances responding to the requirements of the public as regards traffic flow and congestion, protection of the environment, traffic safety, and service to the community.

In line with these two orientations actions are influenced by environmental legislation and public requirements for environmental improvements, recovery and rejuvenation, i.e.:

-- In planning, environmental criteria are given more weight - even if formal multicriteria analyses are not used. In design, much emphasis is placed on achieving balanced and environmentally pleasing solutions -- using noise barriers, landscaping measures, aesthetically pleasing structures, etc. -- even if this means increased costs; this ensures the environmental values that are preferred by the public;

-- In traffic management, much consideration is given to less noisy or less polluting alternatives;

-- In periodic maintenance of road surfacings, shoulders and rest areas, the entire road space is included as part of the scope of work;

[1] WORLD BANK (1994). *Environmental Handbook for Roads.* Technical Report for Training. The World Bank. Washington, D.C.

-- In carrying out the construction work proper, specific environmental requirements have to be followed. Construction equipment can only be operated during restricted time periods and must conform to strict noise and pollution standards; pollution due to construction materials has to be controlled and the environmental impacts of quarries, borrow pits and material treatment areas must be taken into account already when evaluating alternative road work solutions; finally, in traffic diversions attention must be paid to safety, noise and other impacts;

-- In the planning and implementation phases, the affected interests must be considered and the public at large will be consulted;

-- In traffic operation and work implementation, the impacts of roads, traffic and road works are monitored to attend to any problems that may have gone undetected.

VII.3. MODES OF IMPACTS; THEIR MEASUREMENT AND MITIGATION

One of the difficulties in measuring impact is the largely subjective nature of the environmental effects of much road work. The consequences of interactions between road work and the environment has to do with user and community 'feelings' and 'satisfaction' -- difficult variables to quantify.

Table VII.1 contains an overview of the often non-quantifiable impacts, at least in cost terms, impacts of maintenance and rehabilitation works by type of impact and by type of works. Needless to say the table is suggestive of what should be considered and some items may require an in depth study when others can be omitted. In the table the significance of the relationship is assayed, and an attempt is made to attach a positive or negative sign to the impact. It is emphasized that the impact depends on **how** the action was planned, designed and executed. In some cases if a "+" sign is possible, so is also a "-" sign; the former signifying a thoughtful, well executed action, the latter a poorly conceived and executed action. Some examples of possible mitigation measures follow to augment the table.

If one were to think of the interaction between the road system and the environment as an exchange of matter and energy, one might be able to define a rational indicator for assessing impacts. On either side of the equation, the exchange could be of natural or man made origin, its effects being permanent (eg., wastes recycled during construction or de-icing agents contaminating water sources) or temporary with the possibility of environmental recovery. Quantifying these effects and modeling in order to predict outcomes might then be possible. This could lead to accomplishing the goal of preserving the environment from the adverse effects of road work.

New approaches to analysing the environmental impacts of road works are less applicable to older roads, bridges and transport system elements. Existing infrastructure continues to be one of the causes of fragmentation of the natural environment. Since planning cannot be done to eliminate deleterious effects, they might be mitigated by measures such as constructing suitable verges, providing tunnels and bridges to enable wild animals to cross roads, and lowering speeds and noise levels. Where the effects of fragmentation cannot be mitigated it may be possible to take compensatory measures, replacing lost habitats or enhancing marginal habitats through appropriate forms of environmental improvement.

Other sources of environmental impact, and approaches to them, include the following:

Table VII.1. **Impacts of maintenance and rehabilitation works**

	Human and Social Environment					**Physical and Natural Environment**			
	Visual Landscape	**Noise**	**Safety**	**Land Use**	**Culture Heritage**	**Soil Erosion**	**Water**	**Air**	**Flora Fauna**
PAVED ROADS									
-- Periodic maintenance	+/-	+	+/-	+	+/-	+/0	0	+/-	0
-- Rehabilitation									
- Local	+/-	0	+	0	+/-	0	0	+/-	+/-
- Corridor	+/-	+	+	+/-	+/-	+	+/-	+/-	+/-
GRAVEL ROADS									
-- Periodic maintenance	+/-	+	+/-	+	+/-	+	0	0/-	0
-- Rehabilitation									
- Local	+/-	+	+	0	+/-	+	0	0/-	0
- Corridor	+/-	+	+	+/-	+/-	+	0	-	0
ALL ROADS									
-- Routine maintenance									
- surface related	+	+	+	0	0	+	0	0	0
- drainage	0	0	0	0	0	+	+	0	0
- road side	+/-	+	+	0	+/-	+/0	+/-	0	+/-
- signs/markings	+/-	0	+	0	+/-	0	0	0	0
- ice/snow control	0	0	+	0	0	0	-	0	-

+ : positive impact most of the time
- : negative impact most of the time
0 : no significant impact
+/- : variable impact, depending on the context, planning, design and execution

Air pollution

In planning: Minimise traffic congestion by flow management. A comprehensive evaluation of transport policies to curb auto use may be desirable in selected circumstances. Introduction of imputed prices for health effects in choosing between alternatives may also be beneficial (In Sweden the value of the health effect of air pollution for one person a year is 15,000 SEK).

In execution: Use fuel efficient construction equipment having catalytic converters; minimise traffic congestion by efficient traffic control of work zones; consider other transport policies; minimise (or restrict) the use of air polluting materials and methods, e.g. bridge paints should be water soluble.

Noise pollution

In planning: Evaluate the use of open graded asphalt and speed limits, possibly in combination; weigh the possibility of erecting noise barriers or acoustic screens during rehabilitation works; monitor noise levels in the surrounding areas. Introduce imputed prices when comparing alternatives (in Sweden the value of a person disturbed by noise during a year is 8,000 SEK. In Switzerland the budget for the rehabilitation of existing highways by installing noise screens is 70 M. Sfr).

In execution: Use noise insulated construction machines; apply speed limits and speed-bumps thoughtfully; noise emissions at night may require special steps.

Water pollution

In planning: Special care must be taken regarding (risk of) ground water pollution, erosion (rural areas) and floods; new sewage or drainage systems have to be planned, if they were not built originally. Water pollution impacts can be severe, unless protective steps are taken both in planning and execution.

In execution: Polluted waste water (for example from water jetting of old leaded paint from a steel bridge) has to be treated before disposal, because of its toxicity or because of sanitary requirements.

Soil and waste

In execution: Removed materials have to be divided into different classes for controlled deposition; some materials can be recycled and reused as construction material (e.g. asphalt concrete, concrete, fly ash).

Safety

In planning: Safety of travellers and workers on the work site has high priority. The use of traffic and works separating walls or signals is one effective way to increase safety; transition between different work phases requires good planning.

In execution: The layout of the work zone is important for access to and from the work zone, and for traffic itself and its signing and control. The workers have to be trained in measures to ensure traffic safety. The supervision of the execution of traffic safety measures at the work site is important.

Landscape and visual impacts

In planning: Landscape is a subjective "concept" that cannot be priced -- but it is highly valued. Because the road exists, planning may not be able to make a great deal of difference in upgrading the alignment or a better fit of the road into the existing topography. However, small measures sometimes offer substantial possibilities. For example, a concrete retaining wall can be covered with rocks, plants, or designs using local materials; noise screens can be used to hide the road and to cover it from direct sight; advertising can be regulated along the road, in cities lighting can be used to produce certain effects; signs and signals can be redesigned or re-placed to improve a road's visual image; use of appropriate local vegetation can create unique views; etc.

Land use

In planning: Traditional rehabilitation works have limited or no impact on land use; their application as a positive measure to affect land use is also limited. If, however, an innovative concept of rehabilitation is adopted, it can be used to increase quality of life in neighbourhoods -- i.e. in man made environment in general -- by increasing or decreasing accessibility or road capacity as may be desired; wetlands can be recreated or rejuvenated for natural habitat of flora and fauna; etc.

Flora and fauna

In planning: Care has to be taken that the status quo does not deteriorate; natural environment can be protected in several ways: protectional vegetation, animal fences and over/under-passes, creation of natural habitat by means of wetlands and water channels, instituting traffic restrictions, etc.

In execution: The greatest positive and negative impact on flora and fauna takes place during the execution of works. Correct timing of works (e.g. avoiding nesting periods) judicious use and re-use of materials and machines, and selection of appropriate work methods, can protect significantly flora and fauna and the natural environment. Studies have shown that execution of works may have the greatest environmental impact.

VII.4. INFLUENCE OF THE COSTS

Earlier in this report, the costs were divided into two parts: quantifiable and non-quantifiable. Often costs are also divided into internal and external costs, those affecting users and the owner of the road, and those affecting the non-users, respectively. However, the division in internal and external costs is arbitrary and the major distinction is between costs that have a market value (quantifiable costs) and "costs" for which no market exists (non-quantifiable costs).

Internal costs

Most internal costs, costs to users and to the agency, can be quantified, and they are by far the most common costs involved in rehabilitation works. As implied above, the converse is also true: all costs that can be quantified can be internalised and included in benefit/cost analyses, for instance. This was the reason for dividing costs and benefits into two kinds in Chapter V: quantifiable and non-quantifiable.

External costs

These are costs which the society -- users and non-users alike -- has to pay, but which are not included in the budgets -- unless special planning efforts to mitigate or compensate environmental harm are undertaken -- nor in user costs, and/or which cannot otherwise be quantified and internalized. Again, as discussed in Chapter V, most of the external costs are related to the environment. These external, but non-quantifiable costs have great importance and must be included in the decision-making process either as constraints -- which the plan or design transforms into a cost -- or benefit. This is a practical way of using multicriteria analysis in the framework of the engineering-economy analysis proposed in this report.

Multi-criteria analysis

The following nations use multi-criteria analysis for environmental assessment and comparison of road rehabilitation alternatives: Canada, Finland, Germany, Italy, Portugal, Spain, Sweden, Switzerland and USA. Sweden is taking an extreme position and is in the process of introducing money prices for all negative environmental impacts to be used in evaluating new investments. This is not wholly without drawbacks, because environmental costs are circumstance specific and averages will hide the issues. Even accounting for all the direct costs caused by new environmental legal obligations is very difficult. Multicriteria analysis will preserve the original dimensions of the issues and plan, design, or execute the works in a manner that either eliminates or limits negative consequences, and achieves desirable benefits.

VII.5. PRICING OF UNDESIRABLE IMPACTS: CO_2 TAXATION, AS AN EXAMPLE

Pricing of undesirable impacts is becoming increasingly popular. An effluent type of taxes have a venerable background and respond to microeconomics theory where charging is used to modify behavioural choices so as to maximise public welfare. However, the adoption of effluent taxes has been slow, because of the great complexity and political externalities of such taxes[1]. Several countries have adopted CO_2 taxes to curb increases in local (hydrocarbons and carbon monoxide) and global (greenhouse effect) pollution. Table VII.2 shows the present situation in several OECD Member countries with regard to CO_2 taxes. Given the novelty of the effluent taxes, their effectiveness should be monitored and evaluated and not taken for granted.

VII.6. DISCUSSION

Even in the context of new construction a quantitative consideration of the environment is difficult. Environmental costs of new construction is the most common theme discussed in public hearings. Take the example from Switzerland where a section of a national highway, 24km long, currently under construction, had an initial cost estimate of USD 165 million in 1967. Because the road traverses an ecologically difficult zone on a lake shore, changes in alignment and adaptations to different environmental obligations pushed the final cost estimate to USD 735 million! In this instance the external costs were internalised in the project plan, its design and construction.

1 DORNBUSCH R. and POTERBA J. (1991). *Global Warming: Economic Policy Responses*. The MIT Press. Cambridge., for extensive discussion.

Table VII.2. **CO_2 taxation**

Nation	Taxation in use	Applied formula
Finland	no, but	unleaded - 8% of the petrol tax
Germany	no, but	unleaded - 10% of the petrol tax
Italy	no	
Japan	no	
Norway	yes	diesel appr. 6 ¢/1 fuel appr. 20 ¢/1
Portugal	no	
Spain	no	
Sweden	yes	air fuel 9.7 ¢/kg petrol 7.2 ¢/kg unleaded 3.3 ¢/kg diesel 8.9 ¢/kg
Switzerland	no, but	unleaded - 8 ¢/kg of the petrol tax
USA	no, but	in some States: - "gas guzzler tax" at initial purchase $ 400-600 - tax on the mileage to pay at the annual inspection (Cal)

For rehabilitation and maintenance the situation is much more difficult. The status quo is the road in use and the traditionally quantifiable costs of rehabilitation or maintenance works may be small and have negligible impacts. However, this conclusion can be incorrect[1]. Also, attempts to construct a scalar valued index for environmental quality -- such as a benefit/cost ratio, or a "present environmental index"[2] -- will hide the issues rather than bring them out so that they can be meaningfully addressed.

After environmental factors gained in importance and began to influence the choice and execution of maintenance and rehabilitation actions, the costs increased. The legal requirements for less polluting work methods, materials and waste treatments in all work sites, pushed in the same direction. The before-and-after difference is no longer small. However, the differences in the perceived weights of the various circumstance-specific factors make it impossible to develop average environmental

[1] Therefore, the Netherlands, for example, from 1993 onward at least 3 million guilders will be made available annually for the next 10 years to implement mitigation or compensation measures for rehabilitations of existing roads.

[2] Similar to the subjective "present serviceability index" used in evaluating pavement quality.

costs -- i.e. average mitigation actions, in fact -- for maintenance and rehabilitation. Environmental impacts can, and should, be considered, and their costs calculated when possible, specific to each road section and action.

Positive environmental attitudes and proposals for mitigation or compensation actions as well as public consultation and participation throughout the project and programme planning stages help the road administration to accomplish its mission, rather than become mired in adversary proceedings where road improvements are blocked. When done this way, the external non-quantifiable "costs" are automatically internalised and quantified and brought in to have a role in the decision-making process.

Public participation is long recognised as an important element in all transport planning. It has gained new impetus for instance in the United States since the passage of the ISTEA (Intermodal Surface Transportation Efficiency Act, 1991) legislation which reinforces community based planning processes.

This changed approach for road rehabilitation and maintenance programmes will be more costly. However, by applying this approach it is possible to improve roads and the service they provide, and to integrate them better in the environment making them more acceptable in regard to community concerns. Actions and measures conceived in this way gain political and public acceptance. The public is willing to pay for the higher costs of the more extensive environmental rehabilitation, and, at the same time, the existing road itself can be maintained and rehabilitated.

Rehabilitation and maintenance must, then, be viewed as a chance to adapt the road to new conditions in a way which increases the values of both man-made neighbourhoods and natural habitat, in addition to being essential for preserving the economic value of the road asset and providing service to users. In carrying out the rehabilitation and maintenance works in an environmentally sensitive way, using recycled or non-polluting materials whenever possible, a positive service to the environment and to quality of life is done.

CHAPTER VIII

BEST PRACTICES

VIII.1. INTRODUCTION

There are three institutional components -- organisation, financing and management -- that characterise road administrations. In Chapter II Road Administration organisations in OECD countries were classified; in this Chapter they are brought into a wider context reviewing the relevant literature on road agency organisations. This is followed by a brief appraisal of financing mechanisms, especially of the designated Road Fund. After these background reviews, the managerial and technical problems of resource allocation -- the focus of the present OECD Scientific Expert Group -- are examined. Finally, this Chapter proposes guidelines for 'best practices' -- guidelines which are based on sound principles, and are flexible enough to be instituted in widely different institutional frameworks existing in OECD countries.

The answers to the survey of the Group clearly show that resource allocation and distribution is a political, economic, environmental, administrative, and technical problem. All these issues are interrelated. For example, political factors influence regional autonomy, regional balance and desirable directions of economic development; market forces affect economic growth; environmental factors and administrative boundaries and responsibilities, often of historical origin, together with the political and economic factors all motivate the functional classification of the road network. This functional classification in turn supports the technical work which underlies network development and development of priorities by road administrations for new investment, rehabilitation and maintenance.

Up-to-date functional classification becomes even more important when road administrations are faced with limited resources or when an integrated, multimodal transport system is being developed from an existing system. Proper system rationalisation can support the development of priority programmes for road and bridge improvements that maximise the effectiveness of available resources, and will help in establishing an "integrated" road system that is complementary to other modal systems.

VIII.2. ORGANISATION AND ADMINISTRATION

Structures for organisation and administration vary from country to country. They seem to be dependent on the size, population, and historical heritage of the country. Relevant from the point of view of allocation and distribution of resources to roads is the fact that in each country it is the government -- Federal, State, or Municipal, and in some cases these together -- which has jurisdiction over the road network and also allocates resources. Intergovernmental transfers of funds, or delegation of authority to distribute road funds between different functional classes or regions of country, are normally based on required planning processes. These planning processes must take into consideration demographic, economic, environmental, and social factors and be consistent with long range financial and other plans often embodied in functional classification and expectations about land use.

Thus, in countries having a Federal organisation, planning processes are prescribed for receiving Federal road funds that are allocated by the Federal government, based either on a fixed percentage, on a formula, or the planning process itself. States that make up the federation also require planning processes as a precondition for using State or local funds; and, there are restrictions on which roads or facilities, or to what activities, the intergovernmental transfers may be made.

In countries without a Federal structure the processes are similar. The national government allocates resources on roads based on a combination of technical recommendations made by a professional staff and politics. The national road agency in turn distributes these between the regions of the country and between functional classes using planning processes and managerial techniques, *management by objectives* being the most common one, based on both politics and the use of the relevant technical information.

In areas where roads have two or more interested jurisdictions, for example main roads in cities which serve both the city and the nation, planning and political processes are prescribed for allocation of funds and selection of projects.

VIII.2.1. Road agency objectives

The effectiveness of various policies, planning requirements, funding incentives, and technical assistance to achieve these objectives has been studied (1), mostly only in the U.S.. Studies and evaluations of the effectiveness of transport agencies are almost non-existent, in spite of the chronic lack of road funds. Equally scanty has been the study of organisational structures. Most road agencies have a typical line organisation. It is not known if this is the most effective and appropriate organisation to deliver the road programme, nor is it known if the agency structure evolves depending, for example, on the size of the country, population, information technologies, road construction and maintenance technology, or other factors.

Typically a state road agency has a centralised line organisation and decision-making structure. The regional organisations, also organised along functional lines, are the executing units of the programmes, made by the central planning and programming staff. Decision-making that takes place at the regional level deals with straight forward work planning (e.g. design of rehabilitation actions, maintenance routines, snow plough routes, etc.) and less with programme planning.

A study of these issues brings with it a number of other, more technical questions which have an important bearing on the resource distribution in a road agency. Among these are the following: should decision-making be centralised or decentralised; what is the role of the regional offices in managing a road agency; how important are economies of scale and scope in managing and organising a road agency; what is the optimal number of regions into which a country or State should be divided; are there trade-offs in building a few projects fast vs. having several under construction at the same time; and, how might privatisation affect the organisation and its structure.

The survey conducted as part of the Group's work has given insights on how some of these questions are currently resolved by the road agencies.

VIII.2.2. Lessons from past studies

A review of the literature reveals that there is a shortage of research on State or country road agency organisation, its operations and performance. Larson and Rao's (2) comprehensive study of the U.S. State Highway Agencies' capital programme management practices illustrates the complexity of these practices and the variance that exists between the States. Talvitie and Sikow (3) studied productivity growth in a country's road agency and Hartgen (4) compares the productivity and effectiveness of state highway agencies over time in the U.S.

Larson and Rao cite a 1984 survey of the U.S. state highway professionals (5) whose responses led to the conclusion that transport is perceived and used by state policy makers as means to ends other than those directly impacting transport, "sometimes to the discomfort of transportation professionals." Larson and Rao venture to guess that "in a more competitive environment for resources, highway capital programmes will likely require a new focus and broader ranging goals", but they maintain that there is no "right way" to manage the highway capital programme and argue for "directed autonomy" to allow creative approaches to be developed by individual States.

Hartgen develops "State profiles" to gauge a State's performance. His findings suggest that explanations based on traffic, weather, climate, taxation, etc. are not sufficient and not even relevant to describe agency performance. Finding a widening gap between States between 1984 to 1989, Hartgen proposes that road agency performance is more related to "political environment, managerial climate, and capitalization philosophy" than the above variables. More recently Humphrey, Meyer, and Walton (6) reviewed methods -- and implicitly also challenge Hartgen's methodology -- used for comparing State highway performance.

Talvitie and Sikow's studies yielded information about management and organisational structure. Their finding that road capital programme is subject to substantial economies of scale in certain ranges implies that there is an optimal number of highway regions (in Finland four or five, not the actual 13). The number of highway regions, or a reduction in them, certainly depends on "political environment, managerial climate, and capitalisation philosophy" as advised by Hartgen.

An interesting finding was the strong effect on the costs of management variables describing resource distribution. (Slow) speed of construction, (large) number of projects, (large) size of own (fixed) labour force had significant negative effect on cost efficiency and productivity. This, supports the Larson and Rao and the AASHTO finding that "project selection is influenced most heavily by legislators and boards or commissions". If, however, performance is measured exclusively in terms of getting more roads or better quality product for dollar spent, this would conflict with the interests in management accountability and improved agency performance.

The fact that resource distribution significantly affects costs and performance can be especially challenging to management. Substantial changes in the labour force, resource distribution and rehabilitation programming practices, organisation and technology are difficult to make, because of the "political environment, managerial climate and capitalisation philosophy", or because of the leverage of "legislators and boards or commissions", as carefully worded by Hartgen, and Larson and Rao. To this list should be added the profession's neglect of highway construction and information technologies' effect on organisational structure.

This short review of past studies indicates that resource allocation and distribution is important not only to road condition, as the graphs in Chapter IV show, but also to agency performance. Planning processes employed -- and, indeed, required -- for allocating and distributing resources are, therefore, as important for a well managed road system as ensuring that free competition exists in the market and that organisational reforms keep pace with technological development.

VIII.2.3. Directed autonomy

The discussion above presented key ingredients for improved management of roads referring to "political environment, managerial climate, and capitalization philosophy", "directed autonomy .. allowing creativity", and "balance between the need for direction and control on the one hand and freedom and flexibility on the other depending on the political, cultural, and demographic circumstances" (of each country).

There are several approaches to resolving the conflicts within public organisations, when trying to achieve the objectives of accountability, direction, control, flexibility, freedom and creativity. One of these is organisational reform that will enable management to manage efficiently.

As mentioned, the typical road agency organisation structure is a line organisation. This organisational structure is based on the technocratic idea that each line has its own stand-alone product output, and that within the line output (e.g. rehabilitated road), inputs (e.g. factor prices), and management (e.g. the number of projects) are not separable from each other. This is the centralised line organisation. However, this may not be the most efficient organisation structure.

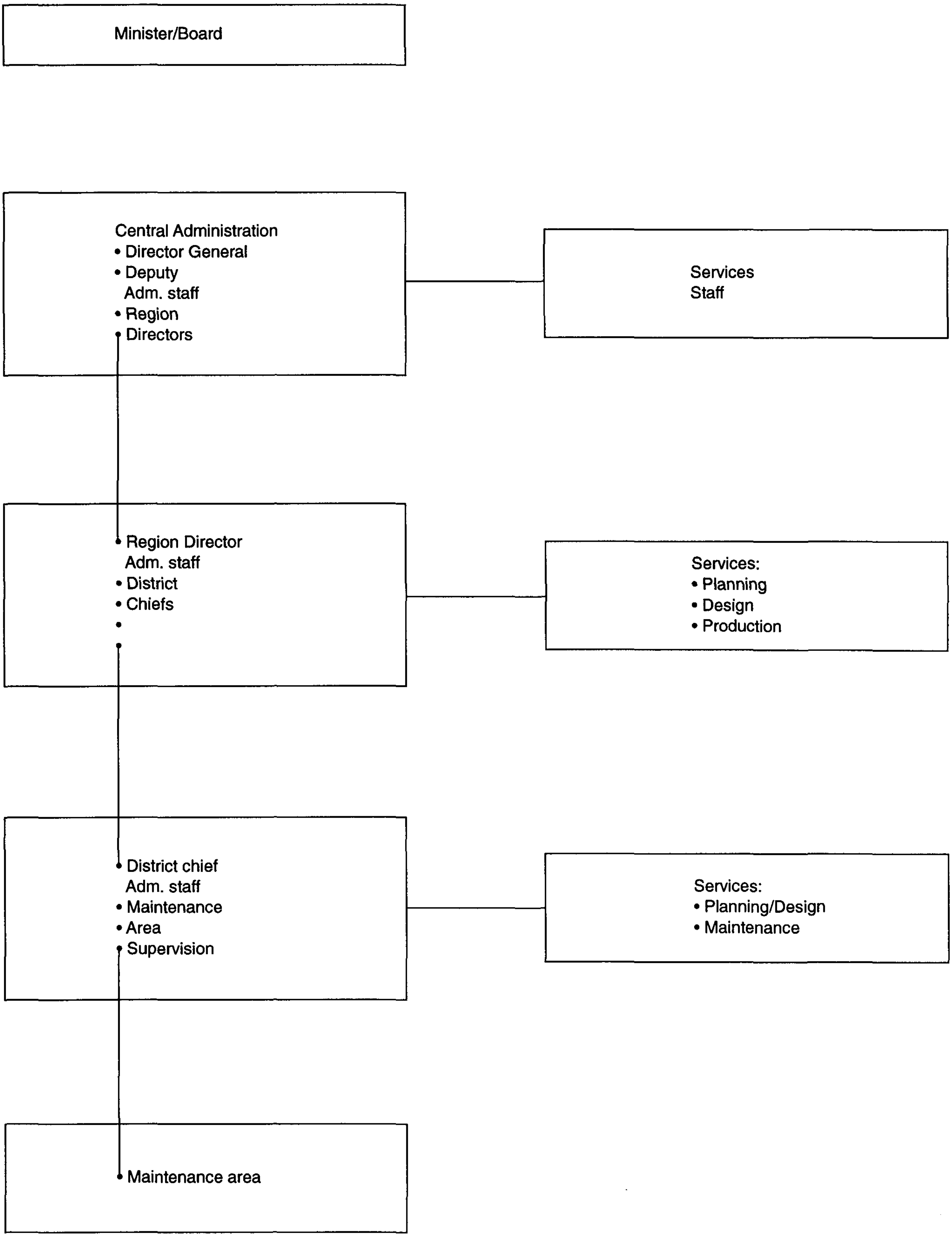
On the basis of the studies, cited above, it can be inferred that maintenance, rehabilitation and new construction are not separable either from each other or from management, but that factor inputs are. Translated into practical terms this means that the Central Administration must have a *comprehensive responsibility* regarding the distribution of monies within the country (or for recommending to the Board or the Ministry) and between the main activities of new investment, rehabilitation and maintenance. It further suggests that the Directorate of the Agency should be composed of the Chief Executive/Director General and the Region Directors and form a *general purpose management team.*

This management team will have support staff, presumably at the headquarters which, at the request of the Directorate, undertakes studies regarding resource allocation and distribution, develops policy proposals, and provides other services of national significance.

Following the results and reasoning above, the regional agency, which is responsible for executing the national programmes, must also have a *comprehensive responsibility* to manage all its outputs, given a broad distribution of monies and a statement of common policies. The region director should be accountable (to the Director General) for design, construction, rehabilitation and maintenance once the policy has been established. The region director will "own" the policy because he was a member of the team that formulated and recommended it.

The organisational structure (ref. Figure VIII.1) can be called a *fractal organisation*, because each lower level is a replica of the higher level. This organisational structure does not mean that everything is delegated. The words *general purpose* and *comprehensive responsibility* apply to management of activities which are performed at a given level; e.g. programming and executing road condition surveys, rehabilitation or maintenance of roads at the regional level, etc. Centralisation, decentralisation and

Figure VIII.1. **"Fractal" organisation for a highway agency**



delegation depend to a large extent on technology, especially information technology. Organisational structure should not stay in the way of efficiently employing information technology.

If the country is divided into numerous regions the size of the Directorate can become too big and make it unmanageable. It, therefore, is important that the number of regions is optimally small. Presumably this depends on the level of technology and information systems utilised in the country. Studies are, therefore, in order to determine how many regions and how many fractals a country should have[1].

Needless to say, the issue of organisational structure and decentralisation of authority and decision-making has political importance. An organisational reform is always a process. The conclusion reached in the productivity studies applies also to organisation: the study of the organisation to fulfil its mission is important. For resource allocation and distribution to serve the needs of the public effectively, it is important that organisational structures keep pace with changes in society and developments in technology.

VIII.2.4. Changing context of rehabilitation and maintenance

It was noted in Chapter VII that "During the life cycle of a road or a network the responsibilities and life styles of people, their travel demands, and communities as a whole will change. The road network has to be adapted to these new circumstances". The changing context of road rehabilitation and maintenance is important and profoundly affects them both. It has been noted in several places in this report that today road rehabilitation and maintenance -- and road construction as well -- operate in a new environment and with a new concept. The objective of maintenance and rehabilitation is no longer to simply keep the road in appropriate condition as a structure, the road also must change in response to other external changes in its environment.

It was proposed for this reason, that road administration organisation and managerial and analytical procedures accommodate training needs of personnel in environmental and aesthetic assessment for recognising opportunities for positive approaches to environmental improvement and to consider affected interests early in the studies that are undertaken. Rehabilitation and maintenance have experienced a change in concept and content: they are meant to preserve the value of the investment **and** to improve the environment.

VIII.3. FUNDING AND TAXATION OF ROAD USE

VIII.3.1. Introduction

The question of funding and levying taxes on road use was considered to be outside the scope of the Expert Group's activities. Nevertheless, that question is so important that it cannot be left without a short commentary.

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1 A hypothesis can also be made that a line organisation could be more efficient with low level technology and insufficient information systems, and a fractal organisation only becomes possible with the employment of more advanced technologies and information systems. More research and experimentation is needed on this matter. For example, the organisational structure existing in federally organised countries has not been investigated from the economic point of view.

In most participating countries allocation of the road funds is done from the country's general budget. Earmarking is done only in Switzerland and in (some States of) the U.S. Of course, all or a part of toll revenues are earmarked to the toll roads in Austria, France, Italy, Norway, Spain, the U.S., and elsewhere where toll roads exist. In these cases the level of toll charges is regulated. A part of the toll revenue may be dedicated to other purposes -- public transit or amelioration of automotive air pollution -- to make the tolls more acceptable to the public.

The survey of Member countries showed a strong interest in "earmarked" funding sources. These earmarked funds could come from existing gasoline and other user taxes, and tolls. This is not surprising because the level of total funding per kilometre of road length showed considerable variance among the Member countries, from USD 7 000 to 125 000 per km per year! Most countries spend between USD 15 000 and 45 000 per km annually, including investment, rehabilitation, maintenance, operations and administrative expenses.

The division of funds between different activities showed similar variance. The maximum spent for new construction was 80 per cent of the total expenditures, and the minimum was 20 per cent. Generally, the percentage devoted to new construction was 25 - 50 per cent.

The wide variance in these figures undoubtedly represents the widely different environmental conditions, past expenditure for the road network, and growth in travel demand in the country. Similarly, it reflects the sore need for improved analytical procedures to allocate monies to roads and to distribute them between functional classes and remedial activities.

VIII.3.2. Basis for road user contributions

In Chapter IV a comprehensive framework was proposed for allocation and distribution of road funds. In that framework, minimisation of total transport costs -- the agency and the user costs -- determined both the allocation and distribution of funds and the condition standard of roads. According to the survey, few, if any, of the countries used user costs to help determine the road condition standard. Instead, the road condition standards were determined by engineering and other considerations.

Figure I.2 showed that the user costs were three fourths of total transport costs when the daily demand flow is as low as 300 vehicles/day **if** an "optimal" road rehabilitation and maintenance policy is observed. The big **IF** is the "optimal" rehabilitation/maintenance policy and the agency costs it entails.

It is not known how much the present budgets are below the "optimal". The feeling is, however, that in most countries the present road allocations are well below the "optimal", but if increased road allocation is desired, it must come from the road users themselves.

The issue is not, as road users maintain, that they already bestow more to government revenues than is spent on roads. The issue is that governments do not have surpluses, but instead experience shortages of tax revenues in most countries. It also is debatable whether the road users pay too much; road transport causes external costs on environment, noise, and congestion for which there is no market at present. There also is considerable evidence of cross-subsidisation from cars to trucks, especially to the heavier trucks.

There is a need for the governments to demonstrate to road users that they would be better off, in terms of reduced user costs, if they paid more to allow road improvement programmes to be carried out (in "optimal" fashion, of course). The converse is also true; the road user groups -- the trade associations, shippers, carriers, economic development and public interest groups -- need to take their case to the government and show what the consequences of *status quo* road budget would be, and what would be gained by incremental increases in road allocations in terms of industrial development, job creation, mobility, and sustained economic performance.

These facts, the road users claiming to pay too much and the government allocating too little monies to roads, point again to the need for having better information and better analytical procedures for determining road budgets and standards. The analytical framework elaborated in Chapter IV of this report, and the Road and Bridge Management System on which it is based, can provide such information to help resolve the conflict between feelings and values.

VIII.3.3. <u>Types of road user charges</u>

The customary public finance principles of economic efficiency, administrative cost, and equity, in addition to cost recovery, apply in developing the road user charges. In order to satisfy these criteria several kinds of user charges are required and even then compromises are required:

i. Variable charges -- fuel charges -- are good because they are related to usage and very inexpensive to collect; the fuel charges relate both to road wear and to externalities, many of which correlate closely with fuel consumed.

ii. Fixed annual charges -- vehicle charges -- are appropriate to influence the composition of vehicle fleet to become less polluting.

iii. Tolls; while tolls are relatively expensive to collect, their collection technology is improving with great strides. Tolls are equitable; they have the advantage of enabling pricing of the externalities and localising the pricing[1]; that is, users of better facilities can be made to pay more. Tolls may also receive user acceptance because users perceive a link between toll and facility condition. Tolls are suitable for collecting revenues from foreign vehicles[2].

iv. Heavy vehicle charges, based on the axle loads and distance driven. As for tolls, efficient collection mechanisms have been developed. New Zealand, for example, collects axle load-distance charge using a hubodometer -- odometer attached to the hubcap -- quite inexpensively, 2-3 per cent of revenues. It has been suggested that a hubodometer is less expensive than most existing systems, weight-distance or simply gross weight charges which do not induce truckers to choose axle systems which would minimise road damage.

VIII.3.4. <u>Road fund</u>

A Road Fund is a holding of dedicated revenues collected as road user charges. Earmarking revenues in the form of a Road Fund has several advantages and disadvantages. The most apparent advantages are:

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[1] The newest toll charging mechanisms can also be used to localise fuel charges and earmarking them not only to roads in general but roads in that jurisdiction and geographical area.

[2] This is a very important feature in the European context, especially for the former Comecon countries where foreign traffic can be substantial and governmental funds to build roads are unduly limited. Tolls are, of course, a prominent feature of the so called BOT concession facilities.

i. A Road Fund makes for a stable road budget and avoids "political" diversion of road user charges.

ii. Stable road budget promotes efficient programming and may contribute toward lower contracting costs.

iii. A Road Fund makes increasing user charges more acceptable because their usage can be identified and monitored.

iv. A Road Fund facilitates cost recovery and equity; beneficiaries and those who pay can be matched.

v. A link between payments and benefits may promote more efficient management of funds and increase sense of accountability because the programmes can be easily monitored.

The most common disadvantages are:

i. A Road Fund entails a cost in terms of loss of budgetary freedom, especially in unforeseen fiscal difficulties.

ii. A Road Fund cannot be supported theoretically; it could lead to distortions between different sectors of the economy; in particular, it could lead to overspending in the road sector.

iii. Road Funds have not been successful in ensuring adequate monies for maintenance; there has been a tendency to use road fund monies for new construction.

iv. Other disappointing experiences with some earmarking experiments.

Lessons from earmarked road fund experiments, and the identified "cons", propose that the following factors are important if a dedicated road fund is contemplated:

i. The planning process and the types of expenditures and functional classes for which road fund can be used must be clearly specified.

ii. The yearly level of expenditure, the road sector allocation and its distribution between the major activities -- new construction, rehabilitation, and maintenance, should be determined by reliable, periodically updated data and appropriate analytical procedures -- the Road and Bridge Management System and the Analytical Procedure described in Chapter I -- not by the availability of monies.

iii. Proper political control of road management, in addition to auditing and accounting safeguards, which covers both the money usage and the performance of the road administration, should be exercised.

iv. The Road Fund authorisation should be periodic, e.g. four years at a time to maintain "checks and balances".

Funding and road user charges are important issues. Road user costs dominate the transport costs, already at demand levels of 5000 veh/day, the agency costs are only 10 per cent of the total costs, **if** the "optimal" maintenance policy is followed.

Consequently economic returns of maintenance and rehabilitation are high, often 30-60 per cent. At demand levels of 2500 veh/day, annual road user costs on a road in poor condition are USD 25 000/km higher than on a good road. This is 2-3 times higher than the costs of maintaining the road in good condition.

These descriptive facts are significant and point toward the critical importance of road user charges in planning and determining multi-year road programmes. Equally important is the inclusion of user groups to participate in possible raising and earmarking of the user fees.

VIII.4. MODELS FOR BEST PRACTICES

VIII.4.1. Three kinds of models

The above brief survey of current governmental practices, administrative arrangements, relevant literature, and comments on funding practices, demonstrates that, regardless of organisation structure, resource allocation and distribution decisions of road funds are done at three levels -- network, programme, and project -- and that this is important for good and accepted practices. The problem lies however in how to provide and process the information to best support this practice; that is, using the analytical framework proposed in Chapter I. At present the allocation/distribution decisions may be more based on intuition than facts in many, and perhaps most, countries.

Before describing the desired -- and necessary -- information and analytical needs and outputs at each level, the basic structure of the road resource allocation/distribution problem is once again reviewed. In Chapter II it was found that regardless of a country's governmental or administrative organisation there always exists a hierarchical decision-making situation: at the highest level the decision-maker is confronted with the need to allocate resources at the network level between programmes and subnetworks[1]. After the network-programme level allocation a project level multi-year plan is formulated and, finally, each individual project designed for implementation. These three levels are a way to simplify the complex decision-making problem and permit development of models which serve the decision-makers and support the kinds of decisions to be taken at each level.

VIII.4.2. The network level

The focus of the network level model is on policy and intelligence: the long run road condition to be provided, total (desired and actual) spending by region of the country, trade-offs between new investment and routine maintenance, scrutiny that the policy followed is consistent with other transport policies, etc. Operationally, the model stresses broad categories of actions and spending, distribution of monies between functional classes of roads, and relation of spending to "optimal" road condition sought and preservation of the road asset. The network model can also show the present level of road user charges and their relation to the budget. The network level intelligence also serves the Ministry's

[1] In some countries the resources are allocated first between programmes -- development, rehabilitation, routine maintenance -- and then between subnetworks -- defined either functionally or administratively; in other countries the allocation of resources is done in the reverse order, first between functional or administrative classes and then between programmes. The order in which the allocation is done is related both to the evolution of governmental structures and to the sources of funds available for different programmes or subnetworks.

and the Road Administration's needs to inform the public about their policies, and provides an informed basis for public debate about these policies.

Figure VIII.2 once again portrays this optimisation problem in resource allocation and distribution[1]. The objective is to minimise the total of agency and user costs. This optimisation determines both the optimal road condition -- expressed in several dimensions (evenness, distress, bearing capacity, rut depth) -- and the optimal budget. It is shown in the figure that both a budget constraint and standard constraint(s) are possible, but that both constraints will cost money in the long run -- and often also in the short run. As is seen from the figure, the consequences of non-optimal budgets and standards to users can be quantified. The method then allows examination of policies in which road users are given an opportunity to pay more to improve the road condition. (See also the earlier discussion on some implications of the Road Fund set up for this purpose).

In summary, at network level the long term goal, the optimal road condition distribution and associated budget, is sought; at this level budgets for various subnetworks -- by functional or administrative class, by region, by traffic volume -- are determined and a distribution for remedial actions is suggested. This is done by the Ministry and the Road Administration managers, and their model -- 'the network level model' -- is tailored to meet their demands and omit unnecessary technical details.

VIII.4.3. <u>The programme level</u>

Figure VIII.3 (and Figure I.3) illustrate schematically the function of the programme level between the network and project levels. The programme level focuses on locally and regionally important information: what projects will be implemented, when, what action will be undertaken, how long is the project anticipated to last, what is the approximate budget, what other ameliorative works are contemplated? The programme level output, a multi-year schedule of projects, consistent with the network level prescriptions is, thus, important both to the agency and to the immediately affected interest groups and serves as a major information tool. It provides quantitative information about how the programme makes a contribution toward implementing the road policy.

The multi-year programme is done in interaction with project-specific decisions, but is separate from them. It conforms to the budget and action distribution, "optimised" at the network level in the central administration, and seeks to achieve the goal in a most economical manner subject to technical and local constraints. These local constraints include interdependencies between links, environmental constraints (e.g. utilise existing asphalt plants or provide rationale for their location, because these plants and quarries normally require an environmental permit), local needs -- economic and social -- with respect to road conditions, local pinpoint knowledge about factor prices, etc.

The programme procedures are different from the network and project level models, but compatible and are designed to meet the needs of the technical and policy staff and also serve local information needs. Because the future cannot be predicted accurately -- owing to technology development, changes in peoples values, and changes in economic "climate" -- the *planning process* implied by Figure VIII.3 is repeated periodically, say every 3-5 years, to check that the long term optimum and the multi-year programme stay contemporary.

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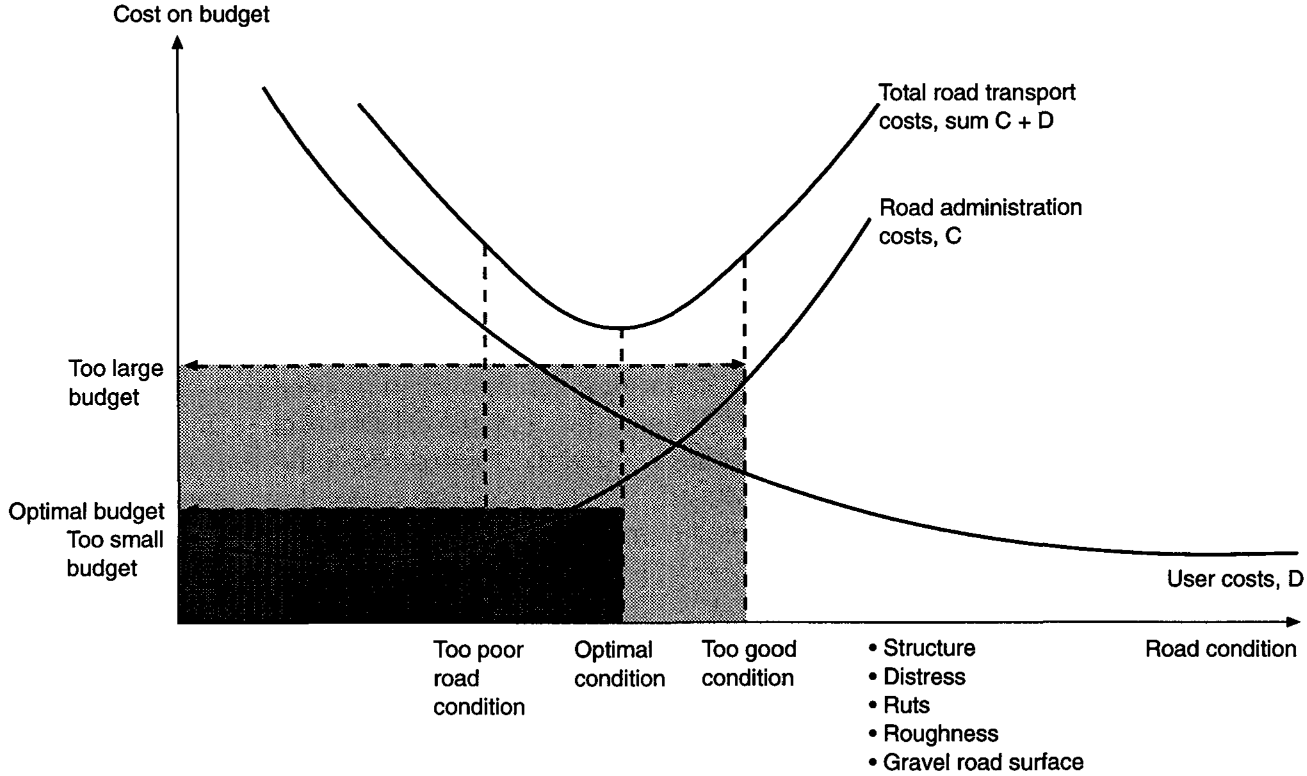
1 This figure applies both to network and project levels; in the former case it represents a group of links, e.g. Main Roads, and in the latter case the specific road being rehabilitated.

Figure VIII.2. **Optimisation of road condition and road budget**



VIII.4.4. <u>The project level</u>

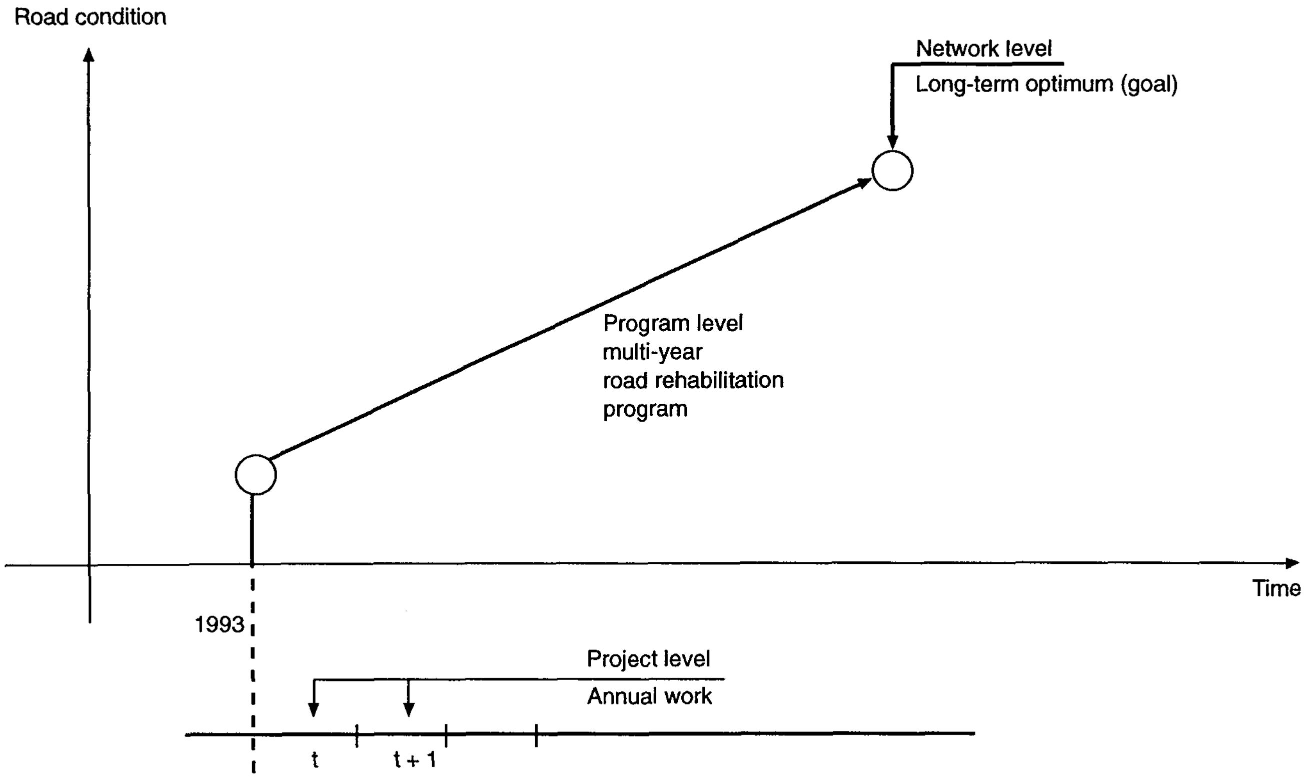
The project level is the annual work programme, derived from the multi-year plan. It is basically an engineering document. The project level adds intensive local knowledge about the "engineering history" of the road links to road management decisions. It is concerned with how exactly the project will be executed, e.g. the design, timing, and contracting. It may contain modules or expert systems on pavement mix design, use of levelling courses, optimisation of engineering works, etc.

The project level also deals with all associated details of the action; designs to ameliorate environmental impacts, traffic management questions, nuisances during construction, etc.

VIII.5. INFORMATION NEEDS FOR BEST PRACTICES

Best practices in road resource allocation and distribution, and in road user charges which are tied to them -- even if in no other way than travel demand -- can only be based on good data and good analytical procedures. All levels of governments -- federal, state, and local -- involved in road keeping share common needs in developing road improvement programmes and evaluating their impacts. The

Figure VIII.3. **Multi-year planning process in rehabilitation and maintenance**



major difference is in the level of detail and breadth. Project specific analyses require intensive data support and national studies require extensive data support.

Typically a Road Agency requires the following information[1] in order to develop the analytical procedures and parameters required in resource allocation.

Physical information

i. Road link inventory (location, geometry, furniture, land use; etc.)
ii. Pavement structure (type, strength, depth, drainage, sub soil, surface; possibly other info)
iii. Pavement condition (roughness, distress, rutting, texture, deflection; etc.)
iv. Structures (foundation, superstructure, material, restrictions; etc.)
v. Structures condition (inspection system)

Operating information

vi. Traffic volume (AADT and seasonal traffic variations, vehicle composition, axle loadings, truck size and weight; etc.)
vii. Operating characteristics (road geometry, traffic control, adjacent development; etc.)

[1] The items in parentheses are for example, only. A more complete list for road data can be found in Paterson and Scullion, 1990; see also HPMS).

viii. System operation (speed, degree of congestion and duration, daily variations in operating characteristics)

ix. Safety (fatalities, injuries, property damage, other accident details)

Implementation

x. Implementation information (programmed action, action taken, total cost, unit cost, time, quality assurance)

xi. Other implementation information (info on routine maintenance, unusual events, contract type; etc.)

System usage

xii. Passenger travel surveys (origin-destination studies, other travel demand and system usage studies, user cost components)

xiii. Truck and goods movement surveys (origin-destination, type of commodity, route, type of load -FTL,LTL, etc., operating costs)

xiv. Vehicle statistics (vehicle characteristics for fuel, emissions, age distribution, vehicle capital and operating costs, emission factors; etc.)

Socioeconomic information

xv. Socioeconomic and land use information needed in travel demand, economic impact studies

Environmental information

xvi. Pollutant concentrations and pollutant sources, environmentally sensitive areas, other environmental information on which the road or traffic have influence

This incomplete list gives an idea of the overwhelming complexity of the information systems needed in road management. While this complexity may seem daunting, it is nonetheless imperative that reliable data collection systems be in place to address the areas above and support the overall informal system.

It is appropriate to conclude this section by reiterating guidelines for developing data systems.

-- integrate data, eliminate duplication, and minimise the burden placed on all participants (of users and suppliers)
  - ♦ determine exactly what is needed beforehand
  - ♦ tailor the data system for its intended use
  - ♦ use sampling whenever possible

-- meet the data needs of data suppliers as well as end users
  - ♦ make success important to both parties

-- eliminate the need for special data collection efforts
  - ♦ modify existing data systems rather than conducting special studies or developing new systems

-- ensure data consistency and accuracy
  - ♦ check data accuracy continuously
  - ♦ provide feedback to data suppliers
  - ♦ audit data quality randomly
  - ♦ publish data compilations and results of audits

Relation of general information needs to the specific data needs of the RBMS

This section shows that the general information needs of a Road administration sketched above also serve well the Road and Bridge Management System and would require no large changes in the current best practices in data collection.

The network level: On the national (Federal/State) level, funds are allocated to roads, and often jointly to all transport facilities, by the responsible (general purpose) governments. Once allocated, road agencies at these levels distribute the funds between regions, functional classes of road networks, and activities -- new investment, rehabilitation, maintenance -- based on elaborate planning processes and analytical procedures which encompass political, economic, social, environmental, and technical factors. The network level model focuses on those considerations which the political and managerial decision-makers consider important.

The aggregate distribution of road funds at the network level is done without a specific object, road, bridge or action in mind. The distribution concerns regions (states, provinces, municipalities), functional road class, and activity - normally new investment, rehabilitation, maintenance[1]; in some cases only investment and maintenance. This distribution may entail restrictions on uses of money; for example Federal monies may only be used on Federal roads.

In order to distribute monies between regions, functional classes, and activities, a road agency should have expertise, data, software and hardware, and analytical procedures to:

i. Estimate aggregate travel demands and loadings by heavy vehicles on the road network,
ii. Establish the physical condition of the road network with a degree of precision and detail appropriate at this level,
iii. Suggest a distribution of remedial actions and associated budgets to achieve a specified objective or objectives (e.g. minimisation of total (weighted) transport costs),
iv. Evaluate consequences of implementation delays due to budget constraints on road condition and future budgets,
v. Calculate the costs and benefits of the remedial actions in sufficient detail,
vi. Relate the distribution of monies to other factors (environment, economy, taxation, social concerns and equity, etc.) seen relevant to the road programme,

The programme level: The second level prioritises improvements and determines the remedial actions and priorities in an overall road improvement programme. The road improvement programme is usually proposed by the regional (district, local) agency and approved by the national (Federal, State) administration. In some cases the approval simply means observation of stipulated guidelines which

[1] These activities are further divided into specific actions: adding lanes, building a road segment, bridge deck improvement, type of rehabilitation action, and type of routine maintenance actions. What is important to note here that no specific link or object is identified.

may specify factors, objectives, co-operation of affected local officials, public participation, environmental criteria, and consistency with other modes of transport.

In order to formulate a strategic road improvement programme the regional road agency should have expertise, data, software and hardware, and analytical procedures to:

i. Assign estimated travel demands and loadings by heavy vehicles on the road links,
ii. Establish physical condition of the road links in necessary detail,
iii. Choose the road links and propose the remedial actions to be undertaken on these links consistent with the budget,
iv. Prioritise suggested improvements consistent with the programme objectives and budgets established at the network level,
v. Incorporate the remedial actions and priorities into an overall road multi year improvement programme,

The project level: At this level the project is designed by the regional (local) road agency or by a consultant, and in some cases by a contractor, suitable in detail for execution by the contractor or the road agency's own work force. The project level model is a pure engineering tool but which accepts information from the network level.

In order to choose the performance specifications and other details of particular remedial action -- widening the road link, building shoulders, reconstructing the structural pavement courses, layer thickness, particulars of the asphalt mix, etc. -- consistent with the road improvement programme the regional road agency should have expertise, data, software and hardware, and analytical procedures to:

i. Know the travel demands and loadings by heavy vehicles on the road link to design the remedial action,
ii. Know the original design and present physical condition of the road link, and the history of prior remedial actions,
iii. Know the environmental factors pertaining to the road link which influence the design of the remedial action,
iv. Calculate the costs of the chosen design,
v. Know the procedures for executing the design to confirm with warranted quality,

It is recommended that the OECD RTR Programme launch a comprehensive study to agree on common definitions of desired data and describe procedures for collecting and maintaining that data in a GIS (Geographic Information System) environment. Technologies offer inviting opportunities, not imaginable before.

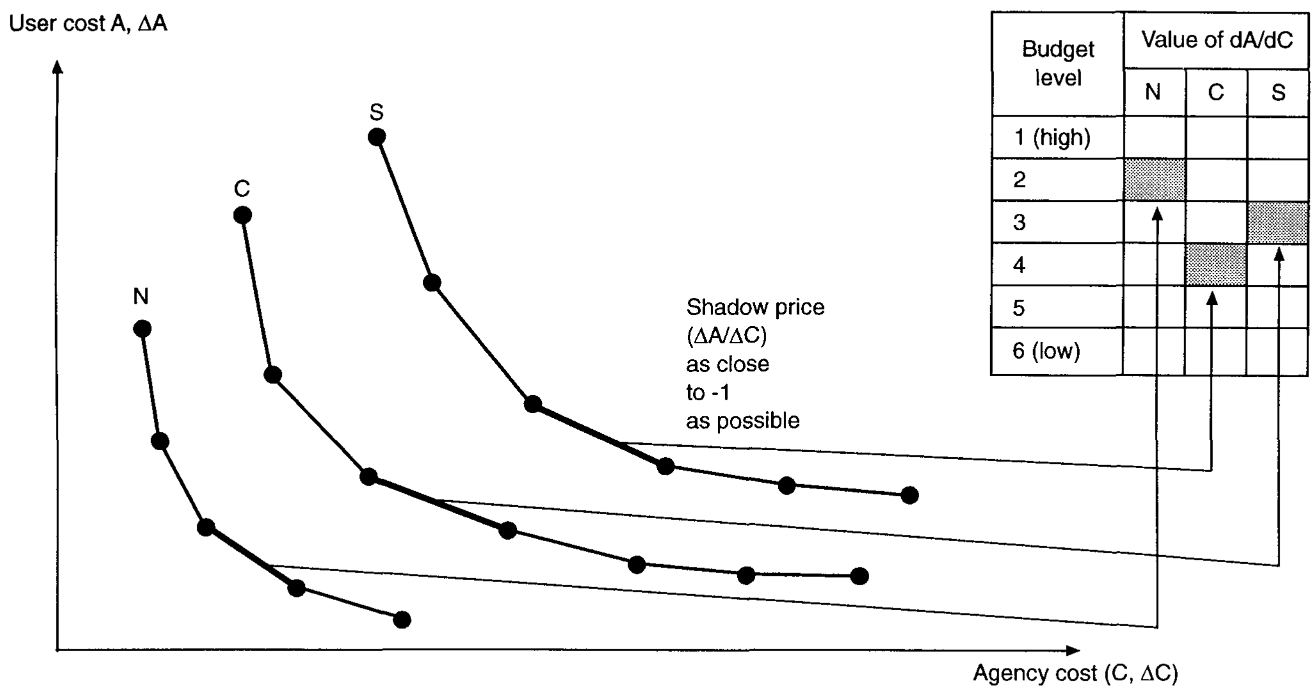
VIII.6. TRADE-OFFS WITH OTHER PROGRAMMES, DISTRIBUTION OF MONIES BETWEEN PROGRAMMES, THE BUDGET CONSTRAINT

As mentioned earlier, the principles of determining optimal budgets and standards should also be followed in allocating monies to investment, rehabilitation and routine maintenance, and in dividing the monies between functional classes of roads, and between regions of the country. The simple reason is that all these issues are interrelated and should be recognised as such. This requires a comprehensive

Road and Bridge Management System and associated analytical procedures imbedded in Figures VIII.2 and VIII.3.

In this section of the Chapter a practical method for distributing scarce resources between competing interests is proposed. The principle for doing this is the one explained in Chapter IV, and again shown in Figure VIII.4, and it must take place at the network, that is, Central Administration level. Here it is assumed that the allocation question concerns the apportionment of monies between regions -- North, Central, South -- and traffic volume classes. An analogous procedure can be applied for other distribution questions.

Figure VIII.4. **Budget distribution between regions - an illustration**



Optimal total budget = constrained regional budget levels (shadow price closest to -1).

In the most optimistic and in reality idealistic case, when no budget constraint exists, it suffices to determine the minimum total cost point for each programme separately and record the associated budget. When there is a budget constraint or standards to be achieved, as is normally the case, the procedure is more difficult but systematic. The proposed allocation criterion, equalisation of the shadow price, is illustrated in the upper left hand corner figure. Again, the principles of Section IV.6 are applied. The change in user costs (dA) is plotted against the change in agency costs (dC); the slope of the quotient dA/dC is called the shadow price as it tells how much additional benefit can be obtained for an extra ECU spent. When the shadow prices for different programmes are equalised it is not economically efficient to transfer monies from a programme to another.

This is accomplished by varying the **k-factor** (same value being used for each Region) until a solution is found whose agency cost equals the budget constraint. In practice it is often more illustrative to proceed in the manner shown in Figure VIII.4. Starting from an unconstrained budget allocation, budgets are reduced stepwise for each Region's sub-network (in this example, 3 regions). Using an algorithm, changes in user and agency costs are calculated and sub-network budgets having the shadow price values closest to -1 are chosen as the constrained optima.

Again, it is emphasised that the solution obtained is a engineering-economic solution. It is subject to many uncertainties involved in calculating user costs[1] and assumes equal (marginal) utility of money among all user groups. Therefore, there may be strong social and political reasons why the engineering-economic solution will not be observed. These reasons range from the desire to have uniform standard on a route, in itself an engineering consideration, to issues of regional policy, to equity between different user groups. These matters must be decided through a democratic process which each country has implemented in its own fashion, but what can be provided is the approximate economic costs of following a given policy.

Often this deviation from optimal policy manifests itself in a tendency to give greater apportionment to low volume roads than would be optimal in engineering sense, or to pursue road investments in a region where there is but little economic activity. However, there can be strong social reasons why low volume roads need be kept in better form than would be economically efficient.

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[1] For example, graph VIII.4 implies that all users have a user cost curve as shown. That of course is not true, there is a wide variance in costs between users. The hypothetical model is a statistical model which hides variances. However, the model is a useful construct and true in average.

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CHAPTER IX

CONCLUSIONS

Regardless of the specific administrative and organizational structure of a country, the survey conducted as part of this Report shows that there is consistency in how road funds are allocated and distributed. For "best practice" to accomplish this allocation and distribution, countries have developed - or should develop - an integrated Road and Bridge Management System.

In outline, the management system should be capable of assessing the physical and operating conditions of the current road network with the accuracy and detail desired by the road administration. By using estimates of travel demands -- disaggregated geographically and functionally -- the management system should provide forecasts about future investment requirements, both in capital and rehabilitation outlays as well as routine maintenance to achieve varying levels of system performance. It should also provide input to allocation of costs among road users to help gain adequate and equitable funding of the road network over the long run.

For 'best practices' in resource allocation and distribution decisions, a unified analytical framework is proposed - minimization of user and agency costs. However, a clear distinction is made between network, program and project level systems. The first serves policy applications by the Central Administration and the latter two project prioritization, selection and design, normally applied by the regional executing agency. It is important that all these application purposes are based on the same data.

During the course of its work, the Scientific Expert Group developed a consensus on 'Ten Commandments' which governments and road administrations should follow in developing a method for resource allocation and distribution for road maintenance and rehabilitation programme and for the process that this method might find worthwhile to follow. These 'commandments' are:

I. *Maintenance is an opportunity for enhancing the environment as well as safeguarding the road network asset.*

II. *Road and bridge maintenance should be pursued for the sake of the users. Therefore, public participation is an essential part of developing the road maintenance programme.*

III. *Roads and bridge assets should be maintained in an economical way.*

IV. *An analytical framework is important for delivering an economical and environmentally sound product. In the Report such a framework is termed Road and Bridge Management System (RBMS).*

V. *User costs must treated as important costs and included in the analytical framework, in the RBMS.*

VI. *Budget constraint on the administration's expenditures is an important feature of the analytical procedures. Competitive maintenance and rehabilitation programmes are one important means to address these constraints.*

VII. *The entire road budget and trade-offs between alternative uses must be considered when allocating and distributing resources.*

VIII. *The analytical framework and the management systems used in allocating and distributing resources must be compatible with the road administration's organization and management style.*

IX. *The methods used at network, programme, and project levels must be different but interlocking and utilize the same data base.*

X. *Data systems which support the road and bridge management systems must be timely and reliable.*

ANNEX A

ROAD LENGTHS AND TRAFFIC VOLUMES

Table A.1. **Road length (1,000km) by functional road class** (1989/1990/1991)

	Motorway	**Main roads I**	**Main roads II**	**Collector roads**	**Local roads**	**Urban roads**	**Privat./ other r.**
Canada	1.63	20.7	-[1]	20.81	77.23	36.75	no data
Finland	0.25	7.46	4.04	22.67	42.46	no data	59.2[2]
France	8.04	28.26	not relev.	354.0	526.0	-[3]	no data
Germany	10.96	42.10	-[1]	84.9	88.3	410	no data
Grt-Britain	3.10	12.36	-[1]	35.6	309.0	-[4]	no data
Italy	(no	data	available)				
Japan	5	21	26	131	940	-[5]	no data
Netherlands	2.09	1.96	3.04	48.36	-[4]	48.80	13.38
Norway	(no	data	available)				
Portugal	0.68	2.30	2.22	4.87	10.20	no data	no data
Spain	5.43	15.26	15.26	64.47[6]	-[6]	no data	no data
Sweden	0.94	13.17	11.66	not relev.	72.09	35.7[2]	72.9[2]
Switzerland	1.5	18.3	18.3	-[7]	51.2	-[7]	no data
Turkey	0.39	31.26	31.26	no data	no data	no data	324.7
United States	85	219	219	1,301	4,355	no data	no data

1. Figures for Main roads II included in Main roads I.
2. Only roads with state-subsidies.
3. Figure is included in local roads
4. Figures are included in Collector roads.
5. Figure is included in the other categories.
6. Figures for Local roads included in Collector roads.
7. Figures for Collector roads and Urban roads included in Local roads.

Table A.2. **Road length (1,000 km) by administrative road class** (1989/1990/1991)

	Federal	State	Country	City	Rural community	Other
Canada	not relev.	21.70	20.81	36.75	77.23	no data
Finland	not relev.	77.08	no data	12	no data	59.2
France	not relev.	36.30	354.0	526.0	625.0	no data
Germany	53.1	84.9	88.3	410	-[1]	no data
Grt-Britain	not relev.	15.39[2]	294.0	50.65	-[3]	-[3]
Italy	6.2[4]	46	110	440	192	no data
Japan	not relev.	21	155	940	-[1]	no data
Netherlands	4.05	7.08	29.82	49.22	14.85	12.96
Norway	not relev.	26.27	27.00	35.87	no data	no data
Portugal	no data	20.27	no data	no data	no data	no data
Spain	20.69	71.06	64.66	-[5]	no data	no data
Sweden	not relev.	97.9	not relev.	35.7	not relev.	72.9[6]
Switzerland	1.5	18.3	no data	8	43.2	no data
Turkey	not relev.	not relev.	not relev.	not relev.	not relev.	not relev.
United States	269	1,285	353	1,141	no data	no data

1. Figures for Rural community included in City.
2. Figures stand for Motorways and trunk roads.
3. Figures included in Country.
4. Figures for Federal stand for "Motorways".
5. Figures for City included in figures for Country.
6. Figures for Other stand for Private.

Table A.3. **Traffic loads (million vehicle km travelled) by functional road class** (1989/1990/1991)

	Motorway	Main roads I	Main roads II	Collector roads	Local roads	Urban roads	Privat./ other r.
Canada	47,100	-[1]	-[1]	25,900	-[2]	-[2]	no data
Finland	1,994	11,938	3,777	7,597	4,136	no data	1,175[3]
Germany	140,100	102,700	-[4]	80,800	45,800	139,500	no data
Grt-Britain	61,000	69,400	-[4]	127,000	154,200	-[5]	-[5]
Italy	51,750	(Other	roads	275,250)			
Japan	(Totally	628,581 not	specified	on road	classes)		no data
Netherlands	34,570	7,040	10,050	17,990	-[6]	no data	no data
Norway	(no	data	available)				
Portugal	18,468	8,630	7,470	6,374	no data	no data	no data
Spain	31,148	43,246	35,888	-[7]	-[7]	no data	no data
Sweden	7,090	20,100	4,960	not relev.	12,855	16,000	1,700
Switzerland	(Totally	42,759 not	specified	on road	classes)		
Turkey	no data	26,056	no data	no data	no data	no data	no data
United States	939,580	793,401	629,903	543,591	no data	no data	no data

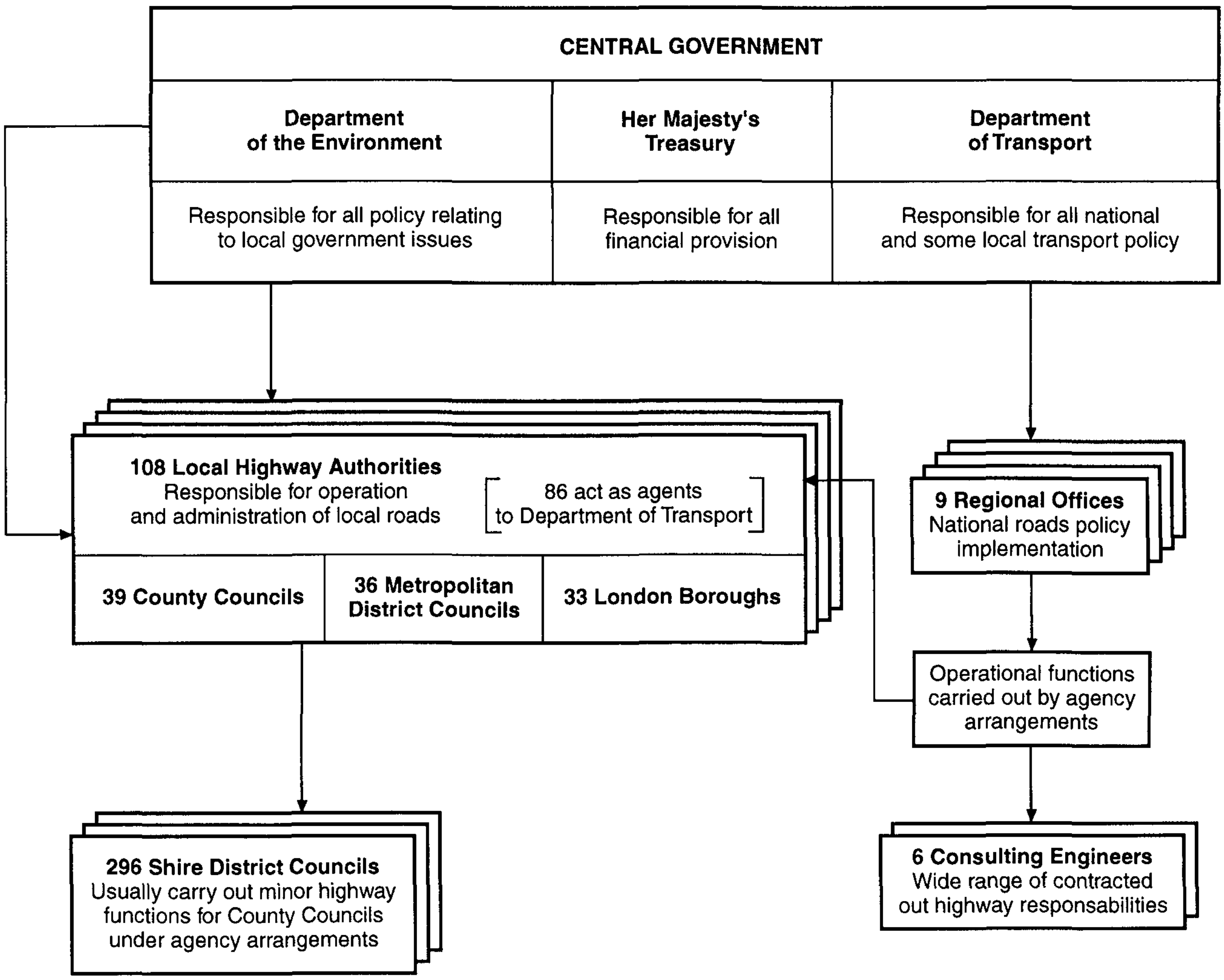
1. Figures for Main roads I and II included in Motorways.
2. Figures for Local and Urban roads included in Collector roads.
3. Only roads with state-subsidies.
4. Figures for Main roads II included in Main roads I.
5. Figures for Urban roads and Private/other roads included in Local roads.
6. Figures for Local roads included in Collector roads.
7. Figures for Collector roads and Local roads included in figures for Main roads II.

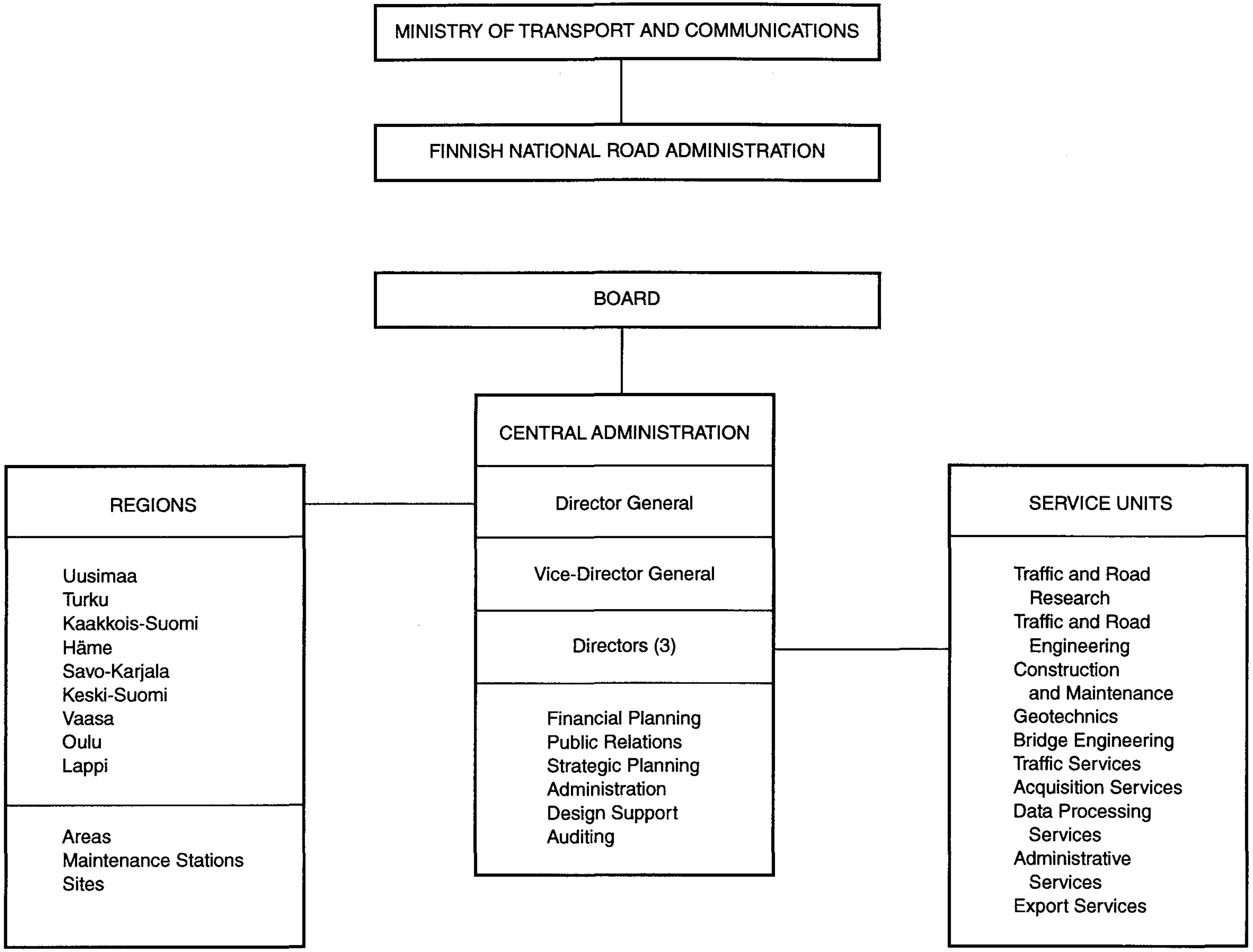
ANNEX B

ORGANISATION OF ROAD ADMINISTRATIONS

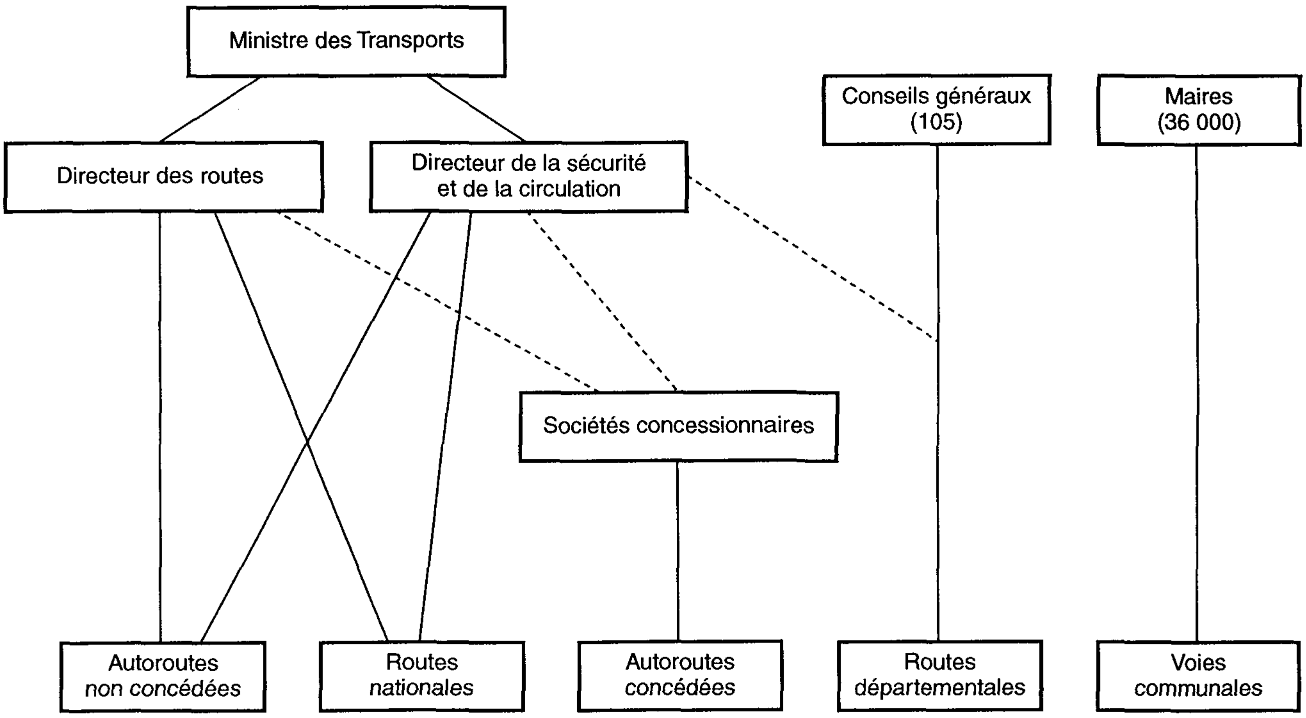
England
Finland
France
Germany
Japan
Netherlands
Norway
Spain
Sweden
Switzerland

Roads Administration in England

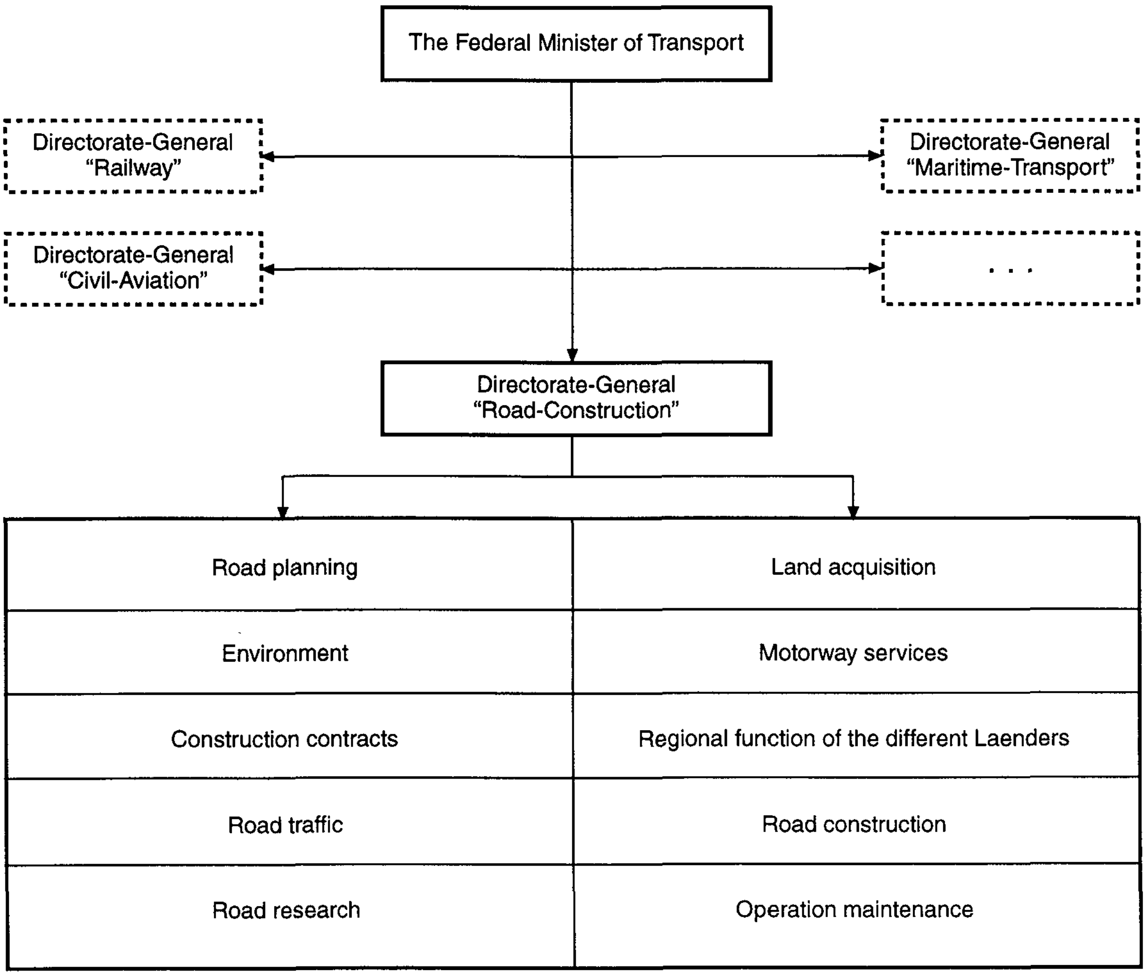



MINISTRY OF TRANSPORT AND COMMUNICATIONS
FINNISH NATIONAL ROAD ADMINISTRATION
BOARD
CENTRAL ADMINISTRATION
Director General
Vice-Director General
Directors (3)
Financial Planning
Public Relations
Strategic Planning
Administration
Design Support
Auditing
REGIONS
Uusimaa
Turku
Kaakkois-Suomi
Häme
Savo-Karjala
Keski-Suomi
Vaasa
Oulu
Lappi
Areas
Maintenance Stations
Sites
SERVICE UNITS
Traffic and Road Research
Traffic and Road Engineering
Construction and Maintenance
Geotechnics
Bridge Engineering
Traffic Services
Acquisition Services
Data Processing Services
Administrative Services
Export Services

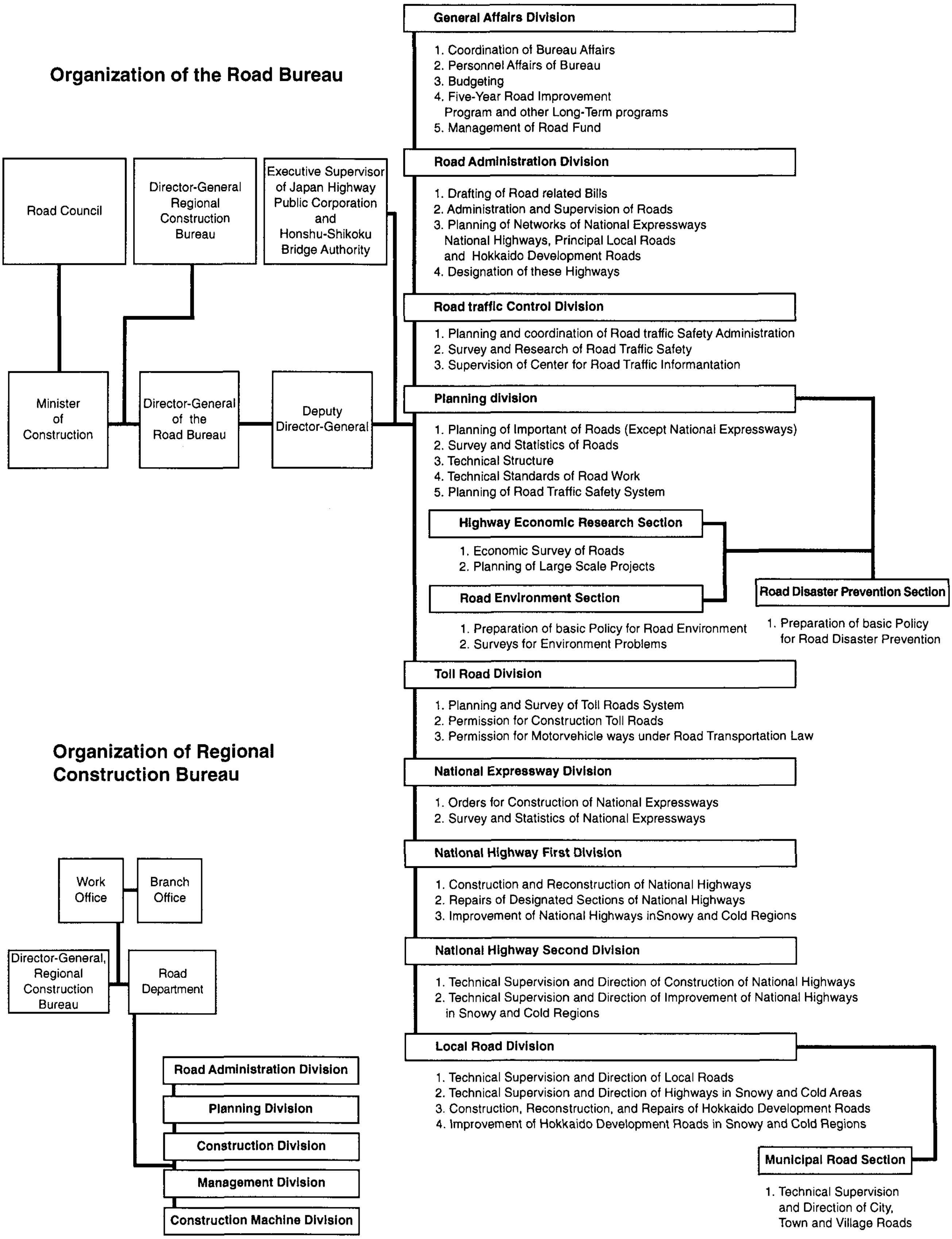
Organigramme de l'administration routière de la France



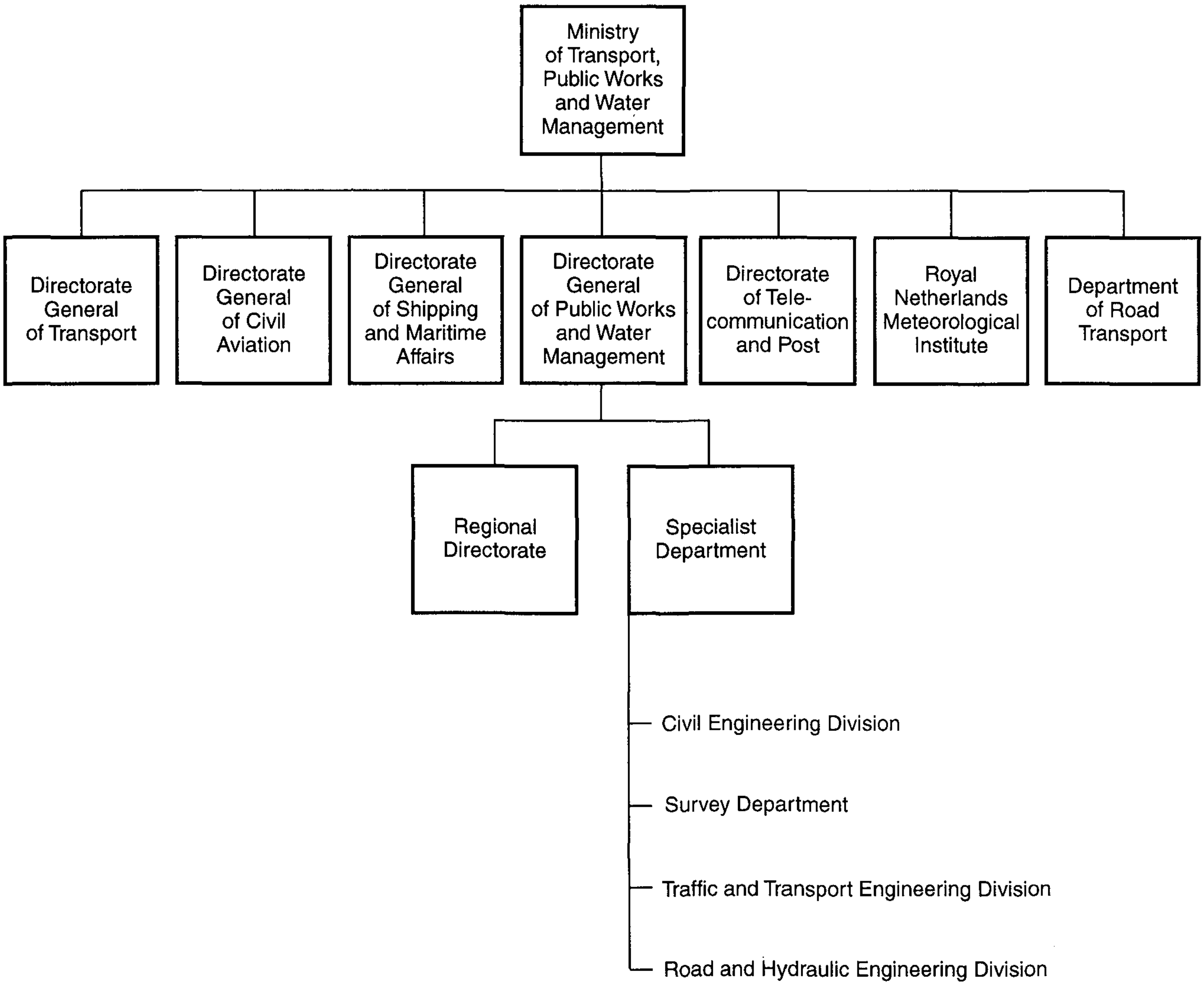
Organisation Chart of the Federal Ministry of Transport
(Germany)



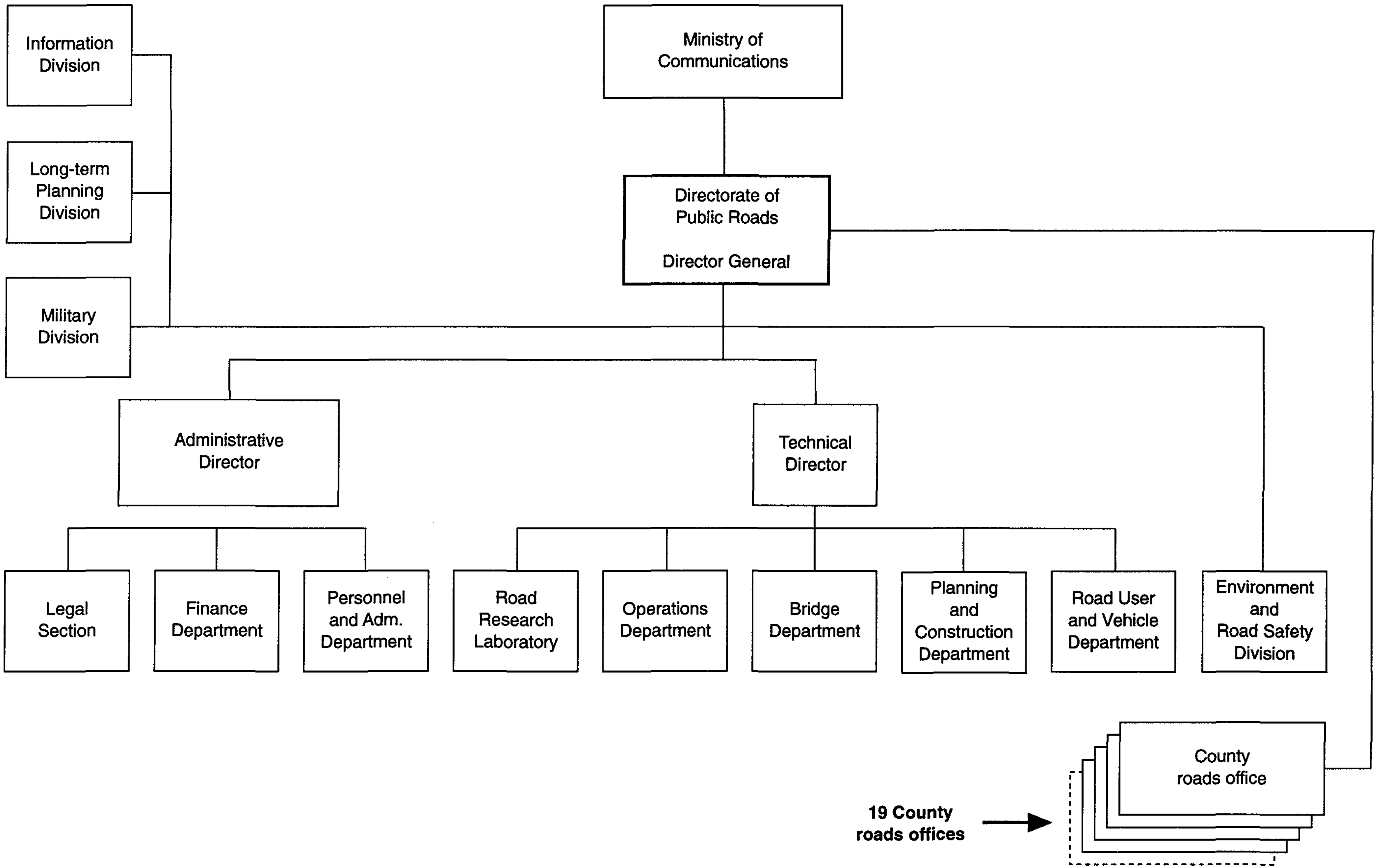
Organisation of the Road Bureau (Japan)



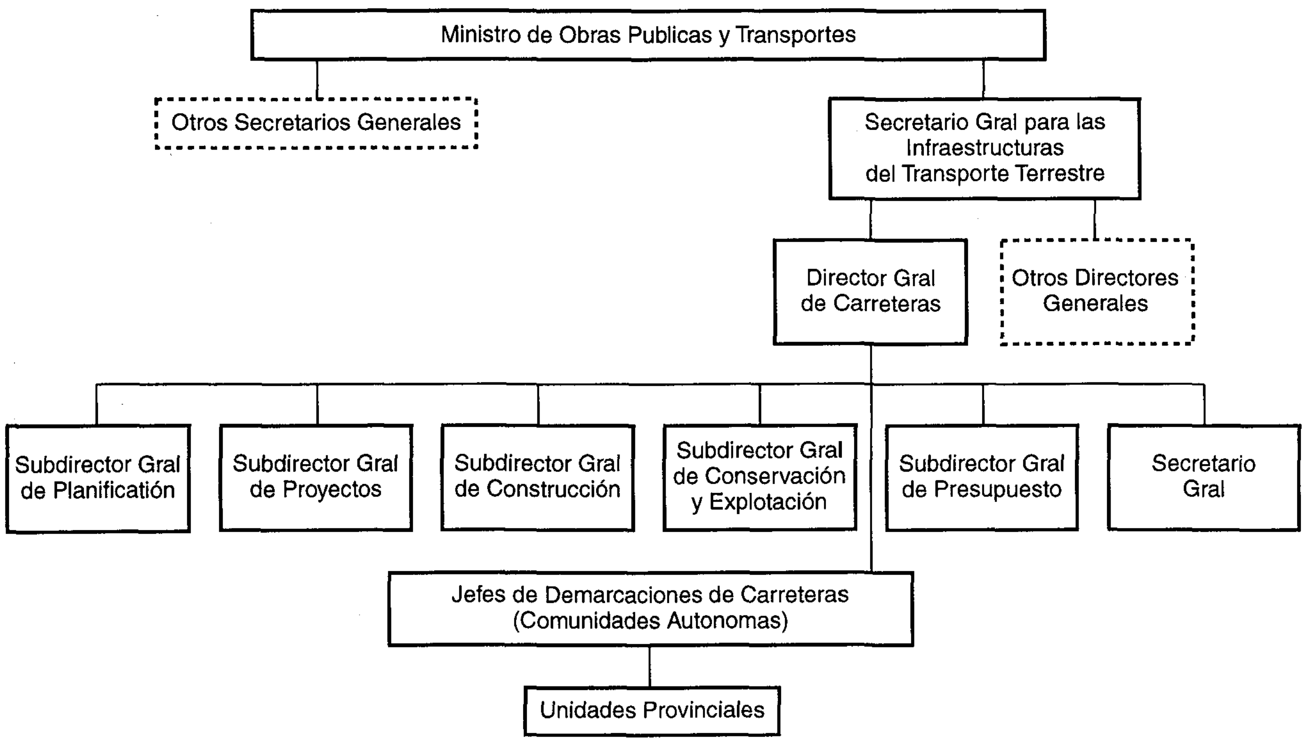
Administration of the Main Road Network in the Netherlands



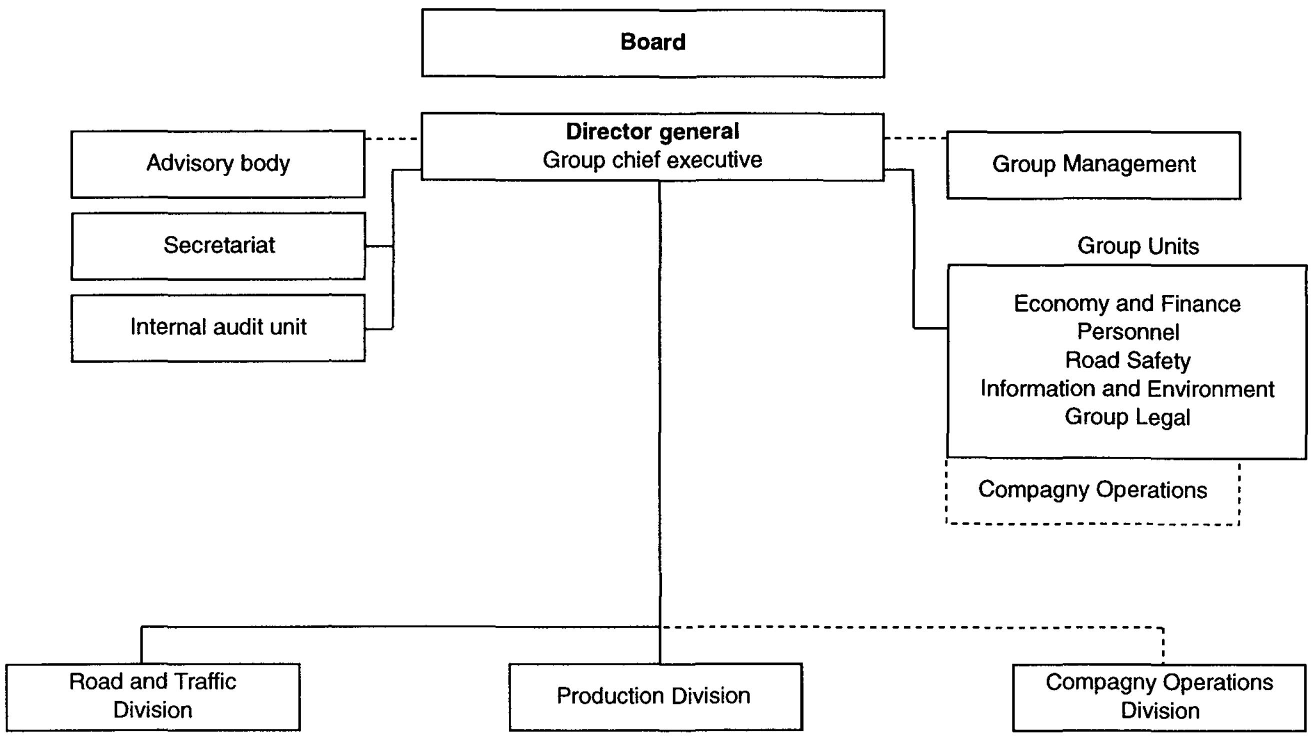
Norvegian Public Road Administration – Organisation



Road administration in Spain

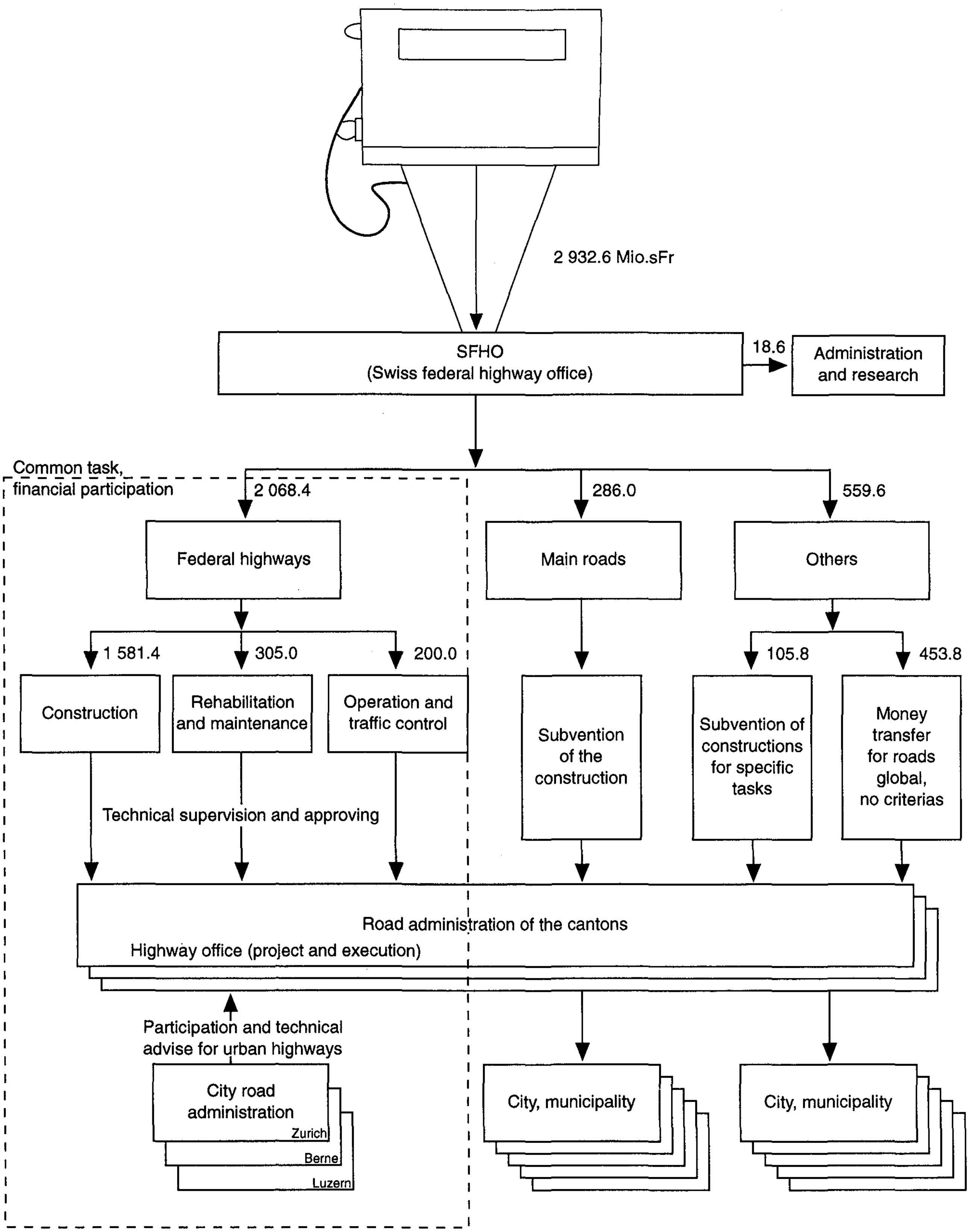


Swedish National Road Administration



Organisation of the road administration (Switzerland)

Finance distribution is based on the budget 1993; in Mio.sFr. (swiss francs)



ANNEX C

LIST OF EXPERTS

Chairman: Mr. Antti TALVITIE

Mr. Harry B. CALDWELL	United States
Mr. Francisco CRIADO	Spain
Mr. Hanspeter DOBLER	Switzerland
Mr. Wolfgang EMDE	Germany
Mr. Melvyn. GAILLAC	France
Mr. Luc-Amaury GEORGE	France
Mr. J.M. GOPPEL	Netherlands
Mr. Michel B. GORSKI	Belgium
Mr. Katsuji HASHIBA	OECD
Mr. Burkhard HORN	OECD
Mr. Arne JOHANSSON	Sweden
Mr. Don KOBI	Canada
Mr. José MACIEIRA	Portugal
Mr. Hisayoshi MORISUGI	Japan
Mr. John OLIVER	United Kingdom
Mr. François PRUDHOMME	France
Mr. Enrico SAMMARTINO	Italy
Mr. Antti TALVITIE	World Bank/Finland
Mr. Raimo TAPIO	Finland
Mr. Tor-Sverre THOMASSEN	Norway
Mr. Jacques THÉDIÉ	France
Mr. Dinçer YIGIT	Turkey

The report was edited by a Co-ordination Group; Messrs. H.B. Caldwell, H. Dobler, M. Gaillac, M.B. Gorski, A. Johansson, J. Oliver, A. Talvitie, R. Tapio, J. Thédié, in co-operation with Messrs B. Horn and K. Hashiba of the OECD Secretariat.