HIGHWAY ENGINEERING

THIRD EDITION

MARTIN ROGERS AND BERNARD ENRIGHT

with website

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HIGHWAY ENGINEERING

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Third Edition

Martin Rogers and Bernard Enright
College of Engineering & Built Environment,
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Preface

Highway Engineering is intended primarily as a text for undergraduate students of civil engineering while also touching on topics that may be of interest to surveyors and transport planners. First and foremost, however, it must provide an essential text for those wishing to work in the area, covering all the necessary basic foundation material needed for practitioners in highway engineering at the entry level to industry. In order to maximise its effectiveness, however, it must also address the requirements of additional categories of student: those wishing to familiarise themselves with the area but intending to pursue another speciality after graduation and graduate students requiring necessary theoretical detail in certain crucial areas.

The aim of the text is to cover the basic theory and practice in sufficient depth to promote basic understanding while also ensuring extensive coverage of all topics deemed essential to students and trainee practitioners. The text seeks to place the topic in context by introducing the economic, political, social and administrative dimensions of the subject. In line with its main task, it covers central topics such as geometric, junction and pavement design while ensuring an adequate grasp of theoretical concepts such as traffic analysis and economic appraisal.

The book makes frequent reference to the Department for Transport's *Design Manual for Roads and Bridges* and moves in a logical sequence from the planning and economic justification for a highway through the geometric design and traffic analysis of highway links and intersections to the design and maintenance of both flexible and rigid pavements. To date, texts have concentrated either on highway planning/analysis or on the pavement design and maintenance aspects of highway engineering. As a result, they tend to be advanced in nature rather than introductory texts for the student entering the field of study for the first time. This text aims to be the first UK textbook that meaningfully addresses both traffic planning/analysis and pavement design/maintenance areas within one basic introductory format. It can thus form a platform from which the student can move into more detailed treatments of the different areas of highway engineering dealt with more comprehensively within the more focused textbooks.

Chapter 1 defines highway planning and details the different forms of decision frameworks utilised within this preparatory process, along with the importance of public participation. Chapter 2 explains the basic concepts on the basis of traffic demand modelling and outlines the four-stage transport modelling process. The third edition has expanded this chapter to include a number of numerical examples detailing how the four different stages of the classical transportation model work.

Chapter 3 details the main appraisal procedures, both monetary and non-monetary, required to be implemented in order to assess a highway proposal. Chapter 4 introduces the basic concepts of traffic analysis and details various theoretical models used to determine queue lengths. Chapter 5 outlines how the capacity of a highway link can be determined. The third edition has expanded this chapter to include details of the 2010 *Highway Capacity Manual*, published since the second edition of the book. Chapter 6 covers the analysis of flows and capacities at the three major types of intersection: priority intersections, signalised junctions and roundabouts. The concepts of design speed, sight distances, geometric alignment (horizontal and vertical) and geometric design are addressed in Chapter 7. Chapter 8 deals with highway pavement materials and loading for the design of both rigid and flexible pavements, while Chapter 9 explains the basics of structural design for highway pavement thicknesses. Chapter 10 takes in the highway maintenance and overlay design methods required as the pavement nears the end of its useful life. Significant revisions have been made to Chapters 8, 9 and 10 arising from the new codes in place for highway pavement design and maintenance. Chapter 11 gives details of the technical documents which highway engineers are required to produce in order to guide a development project through the planning system in the United Kingdom and Ireland. Chapter 12, a new addition, deals comprehensively with sustainable transport planning, including the design and assessment of pedestrian footpaths, cycle lanes and bus lanes within an urban context.

In overall terms, the text sets out procedures and techniques needed for the planning, design and construction of a highway installation while setting them in their economic and political context.

Every effort has been made to ensure the inclusion of information from the most up-to-date sources possible, particularly with reference to the most recent updates of the *Design Manual for Roads and Bridges* and the *Highway Capacity Manual*. However, the regularity with which amendments are introduced is such that by the time this text reaches the bookshelves, certain aspects may have been changed. It is hoped, however, that the basic approaches underlying the text will be seen to remain fully valid and relevant.

For the third edition I have a co-author Dr. Bernard Enright who has been an invaluable colleague and co-worker on the text. This edition would not have been completed without his contribution.

Martin Rogers

Sources

Chapter 1

The Transportation Planning Process

1.1 Why are highways so important?

Highways are vitally important to a country's economic development. The construction of a high-quality road network directly increases a nation's economic output by reducing journey times and costs, making a region more attractive economically. The actual construction process will have the added effect of stimulating the construction market.

1.2 The administration of highway schemes

The administration of highway projects differs from one country to another, depending on social, political and economic factors. The design, construction and maintenance of major national primary routes such as motorways or dual carriageways are generally the responsibility of a designated government department or an agency of it, with funding, in the main, coming from central government. Those of secondary importance, feeding into the national routes, together with local roads, tend to be the responsibility of local authorities. Central government or an agency of it will usually take responsibility for the development of national standards.

Highways England is an executive organisation charged within England with responsibility for the maintenance and improvement of the motorway/trunk road network. (In Ireland, Transport Infrastructure Ireland, formerly the National Roads Authority, has a similar function.) It operates on behalf of the relevant government minister who still retains responsibility for overall policy, determines the framework within which the agency is permitted to operate and establishes its goals and objectives and the time frame within which these should take place.

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In the United States, the US Federal Highway Administration has responsibility at the federal level for formulating national transportation policy and for funding major projects that are subsequently constructed, operated and maintained at the state level. It is one of nine primary organisational units within the US Department of Transportation (USDOT). The Secretary of Transportation, a member of the President's cabinet, is the USDOT's principal.

Each state government has a department of transportation, which occupies a pivotal position in the development of road projects. Each has responsibility for the planning, design, construction, maintenance and operation of its federally funded highway system. In most states, its highway agency has the responsibility for developing routes within the state-designated system. These involve roads of both primary and secondary statewide importance. The state department also allocates funds to local government. At the city/county level, the local government in question sets design standards for local roadways and has the responsibility for maintaining and operating them.

1.3 Sources of funding

Obtaining adequate sources of funding for highway projects has been an ongoing problem throughout the world. Highway construction has been funded in the main by public monies. However, increasing competition for government funds from the health and education sector has led to an increasing desire to remove the financing of major highway projects from such competition by the introduction of user or toll charges.

Within the United Kingdom, the New Roads and Street Works Act 1991 gave the Secretary of State for Transport the power to create highways using private funds, where access to the facility is limited to those who have paid a toll charge. In most cases, however, the private sector has been unwilling to take on substantial responsibility for expanding the road network within the United Kingdom. Roads tend still to be financed from the public purse, with central government being fully responsible for the capital funding of major trunk road schemes. For roads of lesser importance, each local authority receives a block grant from central government that can be utilised to support a maintenance programme at the local level or to aid in the financing of a capital works programme. These funds will supplement monies raised by the authority through local taxation. A local authority is also permitted to borrow money for highway projects but only with central government's approval.

Within the United States, fuel taxes have financed a significant proportion of the highway system, with road tolls being charged for the use of some of the more expensive highway facilities. Tolling declined between 1960 and 1990, partly because of the introduction of the Interstate and Defense Highways Act in 1956, which prohibited the charging of tolls on newly constructed sections of the interstate highway system, and because of the wide availability of federal funding at the time for such projects. Within the past 10 years, however, the use of toll charges as a method of highway funding has returned.

The question of whether public or private funding should be used to construct a highway facility is a complex political issue. Some feel that public ownership of all infrastructures is a central role of government and under no circumstances should it be constructed and operated by private interests. Others take the view that any measure that reduces taxes and encourages private enterprise should be encouraged. Both arguments have some validity, and any responsible government must strive to strike the appropriate balance between these two distinct forms of infrastructure funding.

Within the United Kingdom, the concept of design–build–finance–operate (DBFO) is gaining credence for large-scale infrastructure projects formerly financed by government. Within this arrangement, the developer is responsible for formulating the scheme, raising the finance, constructing the facility and then operating it in its entire useful life. Such a package is well suited to a highway project where the imposition of tolls provides a clear revenue-raising opportunity during its period of operation. Such revenue will generate a return on the developer's original investment.

Increasingly, highway projects utilising this procedure do so within the private finance initiative (PFI) framework. Within the United Kingdom, PFI can involve the developer undertaking to share with the government the risk associated with the proposal before approval is given. From the government's perspective, unless the developer is willing to take on most of this risk, the PFI format may be inappropriate, and normal procedures for the awarding of major infrastructure projects may be adopted.

1.4 Highway planning

1.4.1 Introduction

The process of transportation planning entails developing a transportation plan for an urban region. It is an ongoing process that seeks to address the transport needs of the inhabitants of the area and with the aid of a process of consultation with all relevant groups strives to identify and implement an appropriate plan to meet these needs.

The process takes place at a number of levels. At an administrative/political level, a transportation policy is formulated, and politicians must decide on the general location of the transport corridors/networks to be prioritised for development, on the level of funding to be allocated to the different schemes and on the mode or modes of transport to be used within them.

Below this level, professional planners and engineers undertake a process to define in some detail the corridors/networks that comprise each of the given systems selected for development at the higher political level. This is the level at which what is commonly termed a *transportation study* takes place. It defines the links and networks and involves forecasting future population and economic growth, predicting the level of potential movement within the area and describing both the physical nature and modal mix of the system required to cope with the region's transport needs, be they road, rail, cycling or pedestrian based. The methodologies for estimating the distribution of traffic over a transport network are detailed in Chapter 2.

At the lowest planning level, each project within a given system is defined in detail in terms of its physical extent and layout. In the case of road schemes, these functions are the remit of the design engineer, usually employed by the roads authority within which the project is located. This area of highway engineering is addressed in Chapters 4–8.

The remainder of this chapter concentrates on the systems planning process – in particular, the travel data required to initiate the process, the future planning strategy assumed for the region that will dictate the nature and extent of the network derived, a general outline of the content of the transportation study itself and a description of the decision procedure that will guide the transport planners through the system process.

1.4.2 Travel data

The planning process commences with the collection of historical traffic data covering the geographical area of interest. Growth levels in past years act as a strong indicator regarding the volumes one can expect over the chosen future time, be it 15, 20 or 30 years. If these figures indicate the need for new/upgraded transportation facilities, the process then begins to consider what type of transportation scheme or suite of schemes is most appropriate, together with the scale and location of the scheme or group of schemes in question.

The demand for highway schemes stems from the requirements of people to travel from one location to another in order to perform the activities that make up their everyday lives. The level of this demand for travel depends on a number of factors:

- The location of people's work, shopping and leisure facilities relative to their homes
- The type of transport available to those making the journey
- The demographic and socio-economic characteristics of the population in question

Characteristics such as population size and structure, number of cars owned per household and income of the main economic earner within each household tend to be the demographic/socioeconomic characteristics having the most direct effect on traffic demand. These act together in a complex manner to influence the demand for highway space.

The Irish economy provides relevant evidence in this regard. Over the period 1996–2006, Ireland experienced unprecedented growth, which saw gross domestic product (GDP) double (see Table 1.1). This was accompanied by an increase in population of 17% from 3.63 to 4.24 million, with an even more dramatic increase of 47% in the numbers at work. This economic upturn resulted in a 72% increase in the total number of vehicles licensed over the 10-year period and an 88% increase in transport sector greenhouse gas emissions.

The 2006–2011 period has seen these trends reversed. While the population in Ireland has increased by 8.1% from 4.24 to 4.58 million, the total number at work has

Table 1.1 Factors influencing traffic growth within Ireland and Greater Dublin Area (GDA), 1996–2011

	1996	2002	2006	2011	Change
Ireland					
GDP (€ billion)	91.9	148.7	178.4	175.0	−2%
Population (million)	3.63	3.92	4.24	4.58	+8%
People at work (million)	1.31	1.64	1.93	1.81	−6%
Persons travelling to work (million)	1.09	1.49	1.76	1.63	−7%
Greater Dublin Area (GDA)					
Persons travelling to work (million)	0.54	0.66	0.74	0.69	−6%

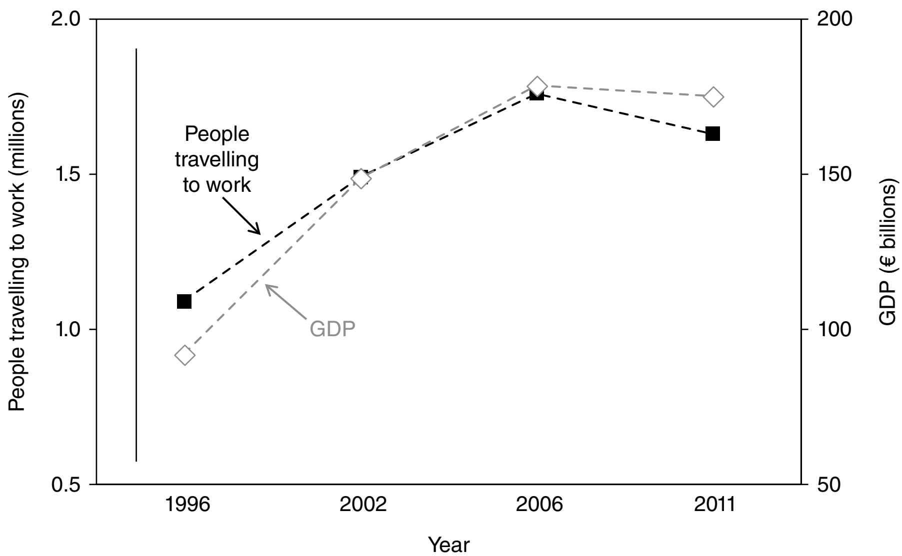

Figure 1.1 Relationship between GDP and people travelling to work in Ireland 1996–2011.

decreased by 6.4% from 1.93 to 1.81 million. This decrease is directly mirrored in the numbers travelling to work nationally which fell by 7% over the 2006–2011 period from 1.76 to 1.63 million.

This decrease in the number of persons travelling to work over the 2006–2011 period was mirrored in the Greater Dublin Area (GDA) where the figure decreased by 6% from 0.74 to 0.69 million.

As evidenced by the figures from the 1996 to 2006 period, high levels of employment growth will inevitably result in increased traffic demand as more people link up to greater employment opportunities, with the higher levels of prosperity being reflected in higher levels of car ownership. Increasing numbers of jobs, homes, shopping facilities and schools will inevitably increase the demand for traffic movement both within and between centres of population. Conversely, the 2006–2011 figures indicate that a contraction in the number of persons at work will reduce the demand for travel (see Figure 1.1).

On the assumption that a road scheme is selected to cater for this increased future demand, the design process requires that the traffic volumes for some year in the future, termed the design year, can be estimated. (The design year is generally taken to be 10–15 years after the highway has commenced operation.) The basic building block of this process is the *current level of traffic* using the section of highway at present. To this figure must be added an estimate for the *normal traffic growth*, that is, which is due to the year-on-year annual increases in the number of vehicles using the highway between now and the design year. To these two constituents of traffic volume must be added *generated traffic* – those extra trips brought about directly from the construction of the new road. Computation of these three components enables the design-year volume of traffic to be estimated for the proposed highway. Within the design process, the design volume will determine directly the width of the travelled pavement required to deal with the estimated traffic levels efficiently and effectively.

1.4.3 Highway planning strategies

When the highway planning process takes place within a large urban area and other transport options such as rail and cycling may be under consideration alongside car-based ones, the procedure can become quite complex and the workload involved in data collection can become immense. In such circumstances, before a comprehensive study can be undertaken, one of a number of broad strategy options must be chosen:

- The land-use transportation approach
- The demand management approach
- The car-centred approach
- The public transport-centred approach

Land-use transportation approach

Within this method, the management of land-use planning is seen as the solution to controlling the demand for transport. The growing trend where many commuters live in suburbs of a major conurbation or in small satellite towns while working within or near the city centre has resulted in many using their private cars to go to work. This has led to congestion on the roads and the need for both increased road space and the introduction of major public transport improvements. Land-use strategies such as the location of employment opportunities close to large residential areas and actively limiting urban sprawl, which tends to increase the dependency of commuters on the private car, are all viable land-use control mechanisms.

The demand management approach

The demand management approach entails planning for the future by managing demand more effectively on the existing road networks rather than constructing new road links. Demand management measures include the tolling of heavily trafficked sections of highways, possibly at peak times only, and carpooling, where high occupancy rates within the cars of commuters is achieved voluntarily either by the commuters themselves, in order to save money, or by employers in order to meet some target stipulated by the planning authority. Use of carpooling can be promoted by allowing private cars with multiple occupants to use bus lanes during peak-hour travel or by allowing them reduced parking charges at their destination.

The car-centred approach

The car-centred approach has been favoured by a number of large cities within the United States, most notably Los Angeles. It seeks to cater for future increases in traffic demand through the construction of bigger and better roads, be they inter-urban or intra-urban links. Such an approach usually involves prioritising the development of road linkages both within and between the major urban centres. Measures such as in-car information for drivers regarding points of congestion along their intended route and the installation of state-of-the-art traffic control technology at all junctions help maximise usage along the available road space.

The public transport-centred approach

In the public transport-centred approach, the strategy emphasises the importance of bus- and rail-based improvements as the preferred way of coping with increased transport demand. Supporters of this approach point to the environmental and social advantages of such a strategy, reducing noise and air pollution and increasing efficiency in the use of fossil fuels while also making transport available to those who cannot afford to run a car. However, the success of such a strategy depends on the ability of transport planners to induce increasing numbers of private car users to change their mode of travel during peak hours to public transport. This will minimise highway congestion as the number of peak-hour journeys increase over the years. Such a result will only be achieved if the public transport service provided is clean, comfortable, regular and affordable.

1.4.4 Transportation studies

Whatever the nature of the proposed highway system under consideration, be it a new motorway to link two cities or a network of highway improvements within an urban centre, and whatever planning strategy the decision-makers adopt (assuming that the strategy involves, to some extent, the construction of new/upgraded roadways), a study must be carried out to determine the necessity or appropriateness of the proposal. This process will tend to be divided into two subsections:

- A transportation survey to establish trip-making patterns
- The production and use of mathematical models both to predict future transport requirements and to evaluate alternative highway proposals

Transportation survey

Initially, the responsible transport planners decide on the physical boundary within which the study will take place. Most transport surveys have at their basis the land-use activities within the study area and involve making an inventory of the existing pattern of trip making, together with consideration of the socioeconomic factors that affect travel patterns. Travel patterns are determined by compiling a profile of the origin and destination (OD) of all journeys made within the study area, together with the mode of travel and the purpose of each journey. For those journeys originating within the study area, household surveys are used to obtain the OD information. These can be done with or without the interviewer's assistance. In the case of the former, termed a personal interview survey, an interviewer records the answers provided by a respondent. With the latter, termed a self-completion survey, the respondent completes a questionnaire without the assistance of an interviewer, with the usual format involving the questionnaire being delivered/mailed out to the respondent who then mails it back or has it collected when all the questions have been answered.

For those trips originating outside the study area, traversing its external *cordon* and ending within the study area, the OD information is obtained by interviewing trip makers as they pass through the *cordon* at the boundary of the study area. These are termed intercept surveys, as people are intercepted in the course of their journey and asked where their trips started and where they will finish.

A transportation survey should also gather information on the adequacy of existing infrastructure, the land-use activities within the study area and details on the socioeconomic classification of its inhabitants. Traffic volumes along the existing road network together with journey speeds, the percentage of heavy goods vehicles using it and estimates of vehicle occupancy rates are usually required. For each designated zone within the study area, office and factory floor areas and employment figures will indicate existing levels of industrial/commercial activity, while census information and recommendations on housing densities will indicate population size. Some form of personal household-based survey will be required within each zone to determine household incomes and their effect on the frequency of trips and the mode of travel used.

Production and use of mathematical models

At this point, having gathered all the necessary information, models are developed to translate the information on existing travel patterns and land-use profiles into a profile of future transport requirements for the study area. The four stages in constructing a transportation model are trip generation, trip distribution, modal split and traffic assignment. The first stage estimates the number of trips generated by each zone based on the nature and level of land-use activity within it. The second distributes these trips among all possible destinations, thus establishing a pattern of trip making between each of the zones. The mode of travel used by each trip maker to complete their journey is then determined and finally the actual route within the network taken by the trip maker in each case. Each of these four stages is described in detail in the next chapter. Together they form the process of transportation demand analysis, which plays a central role within highway engineering. It aims to describe and explain both existing and future travel behaviours in an attempt to predict demand for both car-based and other forms of transportation modes.

1.5 The decision-making process in highway and transport planning

1.5.1 Introduction

Highway and transportation planning can be described as a process of making decisions that concerns the future of a given transport system. The decisions relate to the determination of future demand; the relationships and interactions that exist between the different modes of transport; the effect of the proposed system on both existing land uses and those proposed for the future; the economic, environmental, social and political impacts of the proposed system; and the institutional structures in place to implement the proposal put forward.

Transport planning is generally regarded as a rational process, that is, a rational and orderly system for choosing between competing proposals at the planning stage of a project. It involves a combined process of information gathering and decision-making.

The five steps in the rational planning process are summarised in Table 1.2.

In the main, transport professionals and administrators subscribe to the values underlying rational planning and utilise this process in the form detailed below. The rational process is, however, a subset of the wider political decision-making system and interacts directly with it both at the goal-setting stage and at the point in the process at which the preferred option is selected. In both situations, inputs from politicians and political/community groupings representing those with a direct interest in the transport proposal under scrutiny are essential in order to maximise the level of acceptance of the proposal under scrutiny.

Table 1.2 Steps in the rational decision-making process for a transportation project

Step	Purpose
Definition of goals and objectives	To define and agree the overall purpose of the proposed transportation project
Formulation of criteria/measures of effectiveness	To establish standards of judging by which the transportation options can be assessed in relative and absolute terms
Generation of transportation alternatives	To generate as broad a range of feasible transportation options as possible
Evaluation of transportation alternatives	To evaluate the relative merit of each transportation option
Selection of preferred transportation alternative/group of alternatives	To make a final decision on the adoption of the most favourable transportation option as the chosen solution for implementation

Assuming that the rational model forms a central part of transport planning and that all options and criteria have been identified, the most important stage within this process is the evaluation/appraisal process used to select the most appropriate transport option. Broadly speaking, there are two categories of appraisal processes. The first consists of a group of methods that require the assessments to be solely in money terms. They assess purely the economic consequences of the proposal under scrutiny. The second category consists of a set of more widely based techniques that allow consideration of a wide range of decision criteria – environmental, social and political as well as economic, with assessments allowable in many forms, both monetary and non-monetary. The former group of methods are termed economic evaluations, with the latter termed multicriteria evaluations.

Evaluation of transport proposals requires various procedures to be followed. These are ultimately intended to clarify the decisions relating to their approval. It is a vital part of the planning process, be it the choice between different location options for a proposed highway or the prioritisation of different transport alternatives listed within a state, regional or federal strategy. As part of the process by which a government approves a highway scheme, in addition to the carrying out of traffic studies to evaluate the future traffic flows that the proposed highway will have to cater for, two further assessments are of particular importance to the overall approval process for a given project proposal:

- A monetary-based economic evaluation, generally termed a cost–benefit analysis (CBA)
- A multicriteria-based environmental evaluation, generally termed an environmental impact assessment (EIA)

Layered on top of the evaluation process is the need for public participation within the decision process. Although a potentially time-consuming procedure, it has the advantages of giving the planners an understanding of the public's concerns regarding the proposal, and it actively draws all relevant interest groups into the decision-making system. The process, if properly conducted, should serve to give the decision-makers some reassurance that all those affected by the development have been properly consulted before the construction phase proceeds.

1.5.2 Economic assessment

Within the United States, both economic and environmental evaluations form a central part of the regional transportation planning process called for by federal law when state-level transportation plans required under the Intermodal Surface Transportation Efficiency Act of 1991 are being determined or in decisions by US federal organisations regarding the funding of discretionary programmes.

CBA is the most widely used method of project appraisal throughout the world. Its origins can be traced back to a classic paper on the utility of public works by Dupuit

(1844), written originally in French. The technique was first introduced in the United States in the early part of the twentieth century with the advent of the Rivers and Harbours Act 1902, which required that any evaluation of a given development option must take explicit account of navigation benefits arising from the proposal, and these should be set against project costs, with the project only receiving financial support from the federal government in situations where benefits exceeded costs. Following this, a general primer, known as the *Green Book*, was prepared by the US Federal Interagency River Basin Committee (1950), detailing the general principles of economic analysis as they were to be applied to the formulation and evaluation of federally funded water resource projects. This formed the basis for the application of CBA to water resource proposals, where options were assessed on the basis of one criterion – their economic efficiency. In 1965, Dorfman released an extensive report applying CBA to developments outside the water resources sector. From the 1960s onwards, the technique spread beyond the United States and was utilised extensively to aid option choice in areas such as transportation.

CBA is also widely used throughout Europe. The 1960s and 1970s witnessed a rapid expansion in the use of CBA within the United Kingdom as a tool for assessing major transportation projects. These studies included the CBA for the London Birmingham Motorway by Coburn *et al.* (1960) and the economic analysis for the site of the proposed third London airport by Abelson and Flowerdew (1972). This growth was partly the result of the increased government involvement in the economy during the post-war period and partly the result of the increased size and complexity of investment decisions in a modern industrial state. The computer program COBA has been used since the early 1980s for the economic assessment of major highway schemes (DoT, 1982). It assesses the net value of a preferred scheme and can be used for determining the priority to be assigned to a specific scheme, for generating a shortlist of alignment options to be presented to local action groups for consultation purposes or for the basic economic justification of a given corridor. In Ireland, the Department of Finance requires that all highway proposals be shown to have the capability of yielding a minimum economic return on investment before approval for the scheme is granted.

Detailed information on the economic assessment of highway schemes is given in Chapter 3.

1.5.3 Environmental assessment

Any economic evaluation for a highway project must be viewed alongside its environmental and social consequences (Figure 1.2). This area of evaluation takes place within the EIA for the proposal. Within the United States, EIA was brought into federal law under the National Environmental Policy Act 1969, which required an environmental assessment to be carried out in the case of all federally funded projects likely to have a major adverse effect on the quality of the human environment. This law has since been imposed at the state level also.

Figure 1.2 Roads in environmentally sensitive locations.

Interest in EIA spread from America to Europe in the 1970s in response to the perceived deficiencies of the then existing procedures for appraising the environmental consequences of major development projects. The central importance of EIA to the proper environmental management and the prevention of pollution led to the introduction of the European Union Directive 85/337/EEC (Council of the European Communities, 1985), which required each member state to carry out an environmental assessment for certain categories of projects, including major highway schemes. Its overall purpose was to ensure that a mechanism was in place for ensuring that the environmental dimension is properly considered within a formal framework alongside the economic and technical aspects of the proposal at its planning stage.

Within the United Kingdom, the environmental assessment for a highway proposal requires 12 basic impacts to be assessed, including air, water and noise quality, landscape, ecology and land-use effects, and impacts on culture and local communities, together with the disruption the scheme will cause during its construction. The relative importance of the impacts will vary from one project to another. The details of how the different types of impacts are measured and the format within which they are presented are given in Chapter 3.

1.5.4 Public consultation

For major trunk road schemes, public hearings are held in order to give interested parties an opportunity to take part in the process of determining both the basic need for the highway and its optimum location.

For federally funded highways in the United States, at least one public hearing will be required if the proposal is seen to:

- Have significant environmental, social and economic effects
- Require substantial way leaves/rights of way or
- Have a significantly adverse effect on property adjoining the proposed highway

Within the hearing format, the state highway agency representative puts forward the need for the proposed roadway and outlines its environmental, social and economic impacts together with the measures put forward by them to mitigate, as far as possible, these effects. The agency is also required to take submissions from the public and consult with them at various stages throughout the project planning process.

Within the United Kingdom, the planning process also requires public consultation. Once the need for the scheme has been established, the consultation process centres on selecting the preferred route from the alternatives under scrutiny. In situations where only one feasible route can be identified, public consultation will still be undertaken in order to assess the proposal relative to the *do-minimum* option. As part of the public participation process, a consultation document explaining the scheme in layman's terms and giving a broad outline of its cost and environmental/social consequences is distributed to all those with a legitimate interest in the proposal. A prepaid questionnaire is usually included within the consultation document, which addresses the public's preferences regarding the relative merit of the alternative alignments under examination. In addition, an exhibition is held at all local council offices and public libraries at which the proposal is on public display for the information of those living in the vicinity of the proposal. Transport planners are obliged to take account of the public consultation process when finalising the chosen route for the proposed motorway. At this stage, if objections to this route still persist, a public enquiry is usually required before final approval is obtained from the secretary of state.

In Ireland, two public consultations are built into the project management guidelines for a major highway project. The first takes place before any alternatives are identified and aims to involve the public at a preliminary stage in the scheme, seeking their involvement and general understanding. The second public consultation involves presentation of the route selection study and the recommended route, together with its likely impacts. The views and reactions of the public are recorded and any queries responded to. The route selection report is then reviewed in order to reflect any legitimate concerns of the public. Here also, the responsible government minister may determine that a public enquiry is necessary before deciding whether or not to grant approval for the proposed scheme.

1.6 Summary

Highway engineering involves the application of scientific principles to the planning, design, maintenance and operation of a highway project or system of projects. The aim of this book is to give students an understanding of the analysis and design techniques that are fundamental to the topic. To aid this, numerical examples are provided throughout the book. This chapter has briefly introduced the context within which highway projects are undertaken and details the frameworks, both institutional and procedural, within which the planning, design, construction and management of highway systems take place. The remainder of the chapters deals specifically with the basic technical details relating to the planning, design, construction and maintenance of schemes within a highway network.

Chapter 2 deals in detail with the classic four-stage model used to determine the volume of flow on each link of a new or upgraded highway network. The process of scheme appraisal is dealt with in Chapter 3, outlining in detail methodologies for both economic and environmental assessments and illustrating the format within which both these evaluations can be analysed. Chapters 4 and 5 outline the basics of highway traffic analysis and demonstrate how the twin factors of predicted traffic volume and level of service to be provided by the proposed roadway determines the physical size and number of lanes provided. Chapter 6 details the basic design procedures for the three different types of highway intersections – priority junctions, roundabouts and signalised intersections. The fundamental principles of geometric design, including the determination of both vertical and horizontal alignments, are given in Chapter 7. Chapter 8 summarises the basic materials that comprise road pavements, both flexible and rigid, and outlines their structural properties, with Chapter 9 addressing details of their design and Chapter 10 dealing with their maintenance. Chapter 11 outlines two areas where highway engineers interact directly with the development planning process. Chapter 12 defines the concept of sustainability in the context of highway and transportation engineering, addresses the importance of sustainability to good urban design and details a number of tools for measuring the success of delivery of different transport modes.