Planning Sustainable Infrastructure

Unit 2:
Transport Systems – 2
The Land-use/Transport System

Contents

Introduction

In the first unit on the topic of transport you were introduced to the transport technologies and developed an understanding of the technical skills and thinking of engineers who work with the technologies. Technologies by themselves though are only the building blocks. For the vehicles and infrastructure to meet the transport need it is important to recognise that the technology needs to work as a transport system. Further more the transport system itelf needs to work as part of a much larger system. Transport in an urban context is part of the overall city form which is made up of the transport system and the urban form. The transport system and the urban form interact and together with transport policies provide the system in which people and businesses can respond to their transport needs.

In this second unit, you will be introduced to systems thinking and systems analysis at two levels. On a first level we will look at the way transport agencies such as RailCorp manage the vehicles and infrastructure under their control as part of the transport system. From a government and agency perspective these technologies are considered as assets. The agency is typically responsible for aquiring, operating and maintaining the assets through out their life and then replacing the asset at the end of its life. The technologies exist for one purpose and that is to play their part in the delivery of the transport service. Asset management principles are used by these agencies to aquire and look after these assets. The management of these technologies (or assets) mostly becomes the responsibility of engineers who are involved from conception to disposal. Current best practice is to apply what is known as a systems engineering approach whereby the technologies are thought of as a complete engineering system, not a collection of discrete technologies. We will look in this unit at some of those principles.

At the second level you will be introduced to the processes and methods engineers use in the "land use/transport/environmental" system at the regional and sub-regional scales. Although the same generic methodology of "systems analysis" underpins this level, the "system" under consideration is much more complex than the system of transport technologies managed as assets within a single agency.

It is important to point out that "transport" by necessity involves a synthesis of interacting sub-systems: land use; transport; and the environment (meaning the social, economic, health and physical environments). Furthermore, transport provides an excellent example where technological systems (all forms of transport technology and their operational characteristics) interface with socio-economic systems (land use) and there is therefore the additional behavioural dimension to the system that requires understanding and analysis.

The agents (or actors) involved in transport in the real world are numerous, and responsibilities for transport are fragmented, as we will see in Unit 3. Briefly, by way of an example, let us consider roads. The ownership is primary government responsibility but today there are private companies that build, own and operate roads (toll roads, bridges and tunnels). Both sectors can be engaged in planning, using government public servants or private sector consultants. To build a road requires development consent (from the government planning body) and must conform to environmental policies and regulations (undertaking an EIS). Traffic management is the responsibility of the main road authority or local government, and parking policies are usually promalgated by local government. In the use of the roads, most of the traffic is privately owned, maintained and operated cars, motorcycles and bicycles. Private firms haul freight around in trucks and vans. The buses are operated by government and private companies. Trams (public or private) share the road-space. The police are omnipresent

The scope of the work of the transport professional (engineer) therefore embraces much more than the physical geometrical design of transport infrastructure (roads, railways, ports, airports and pedestrian facilities). It includes how best to operate transport systems (road traffic management and control, air traffic control or bus priority schemes) and how best to mitigate the negative impacts of transport (road traffic noise barriers, air quality management plans at airports, or economic instruments such as road pricing and parking policy and charges). In all of these forms of transport, the systems approach underpins the cycle of planning, investigation, alternatives and evaluation, and implementation and operations.

Transport is especially complex given its linkage to urban form and land use development. For example, in April, 2003, *The Sydney Morning Herald* ran the headlines on page one: “Imagine if they dropped Canberra in a Sydney paddock: it’s no fantasy”. This referred to a five-day workshop by stakeholders investigating the future option of about 100 000 greenfield housing lots (300 000 people) in the urban release area of Bringelly provided it could be shown to be “environmentally sustainable.” Transport was a major part of this workshop. The systems approach that you will study would form the basis for investigating the transport options to support this, and similar kinds, of urban development.

In fact, much of contemporary practice involves “managing the demand for transport” to make better use of existing infrastructure and avoid the unnecessary waste of major capital expansion, especially of major roads. As with other topics in this course, “sustainability”, as a major contextual driver of policy and practice in transport, will be discussed in the next unit (Unit 3). This will be reinforced with a case study of the latest application of the systems approach.

Learning outcomes

After the study of this unit you will be able to:

- Understand the perspective of asset management used by many governments, utilities, transport services and infrastructure agencies.
- Understand the principles of systems engineering in managing transport technology assets.
- Discuss how the development of engineering solutions to transport problems involves a number of iterations; often coming back to ask "what really is the problem we are addressing"
- Follow the typical procedures used by transport engineers to move from problem definition to solution, and understand the many influences on the process, especially the interacting sub-systems of land use and the environment. A series of revisions and searches for optimal solutions to satisfy emerging constraints is typical.

Reading 2.1

The Woodhouse Partnership Ltd, 2010, *extract from website www.pas55.net*, The Woodhouse Partnership Ltd, Kingsclere, UK.

> This reading provides a simple overview of the principles of internationally accepted asset management framework PAS55.

Reading 2.2

Office of Financial Management, 2006, *Total asset management guideline - Asset strategic planning*, NSW Treasury, Sydney, pp. 1– 4; 6.

> This reading picks out some of the principles of the framework for asset management planning expected by the NSW government for its agencies.

Reading 2.3

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Extracts Chapter 1, pp. 21 - 23.

> In Chapter 1, a general view of systems analysis and design as applied to the land-use/ transport system is presented.

Reading 2.4

Blunden, W. R. and Black, J.A, 1984, *The Land-Use/Transport System, Second Edition*, Pergamon Press, Oxford, p.38.

> The figure (systems flow diagram) that represents the land use transport system as a key process, is an extension of Reading 2.3 because it makes explicit the linkages (interactions) amongst component parts of the system, and emphasises "feedback loops."

Reading 2.5

Blunden, W. R. and Black, J.A, 1984, *The Land-Use/Transport System, Second Edition*, Pergamon Press, Oxford, Chapter 1, pp. 1 - 9.

> A formal definition of the land-use and transport system is given. The way this "system" is represented for modelling and analysis is outlined.

Reading 2.6

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Chapter 1, pp. 23 - 33.

> This chapter is important to study because the components of the system – "land use", "traffic" and "transport" – are defined in such a way as to allow conceptual specification, measurement and quantification of each phenomenon. Systems modelling and its terminology are introduced. Systems modelling (sometimes referred to as system simulation) is an important part of systems analysis because it allows future projections to be made and suggests answers to the "what if?" questions.

Reading 2.7

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Chapter 1, pp. 33 - 43.

> A simple worked example is provided to illustrate the fundamentals of "land use and transport interaction". Note the important concept of "equilibrium" – those of you that have studied elementary economics will recognise the concept from the intersection of demand and supply curves. In the computer software you use, the "equilibrium" solution that is calculated is based on the

computational power inherent in the software, but the fundamental principles that you have learnt remain.

Reading 2.8

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Extract, Chapter 2, pp. 56 - 58.

> Reading 2.7 emphasised measurement and quantification so exercise 2.3 is designed to illustrate this idea based on the everyday travel that you make. In Reading 2.7 "transport supply" was measured by travel time by car in minutes. Here, we extend the concept of travel time as the impedance measure to the measurement of "generalised cost" of travel and its equivalent "generalised time." This allows different transport technologies, including walking, to be analysed and compared.

Transport – Technologies as an engineering system- The asset management approach

In the previous unit the characteristics and technical skills engineers use in enabling these technologies were discussed. The introduction to this unit discussed the need to recognise that the technologies exist as part of a system of transport. At a first level the technologies become an operational part of our community when a systems approach is used to enable the technology to move to manufacture; and energy supply and maintenance to be in place throughout the life of the technology.

Whether transport technologies are disaggregated with individual ownership, for example the private car, or are collectively managed such as bus and train fleets, all are manufactured and continue to operate with some level of systems engineering management. Cars are methodically engineered and then manufactured through a production line process before they reach the market. Once in operation they require annual safety and environmental checks for registration and scheduled maintenance as determined by the manufacturer to keep them functioning efficiently.

Most transport infrastructure is collective and managed either by government agencies or on the governments behalf by large private sector firms. Much of the infrastructure has long life expectancy, often 50 to 100 years. It is not uncommon for private sector contracts to be for 30 or 40 years at a time. The practice in countries such as Australia and many other countries is to plan the aquistion of infrastructure, its maintenance and eventual disposal in a methodical systematic process. Britain has produced a publically available specification PAS 55 that sets out a framework for matching the assets to the service it deliveries and developing the framework for managing across the whole life cycle. Reading 2-1 gives a summary of this approach.

In NSW, the treasury overseas the TAMM guidelines each agency is expected to follow in preparing a PAS 55 type of approach for their physical assets. See Reading 2-2 that shows some extracts from these guidelines. Principles include the need for assets to be aligned with the services they support, asset strategy to include an investment plan that is aligned, maintenance plan and disposal strategy. Central to these guidelines are a whole of life approach to the assets. The intent is to reduce the risk of assets being inappropriate to the services they support and losing their effectivesness with use or time.

Reading 2.1

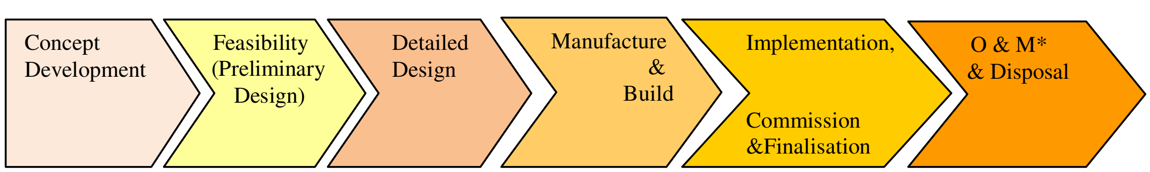
The Woodhouse Partnership Ltd, 2010, *extract from website www.pas55.net*, The Woodhouse Partnership Ltd, Kingsclere, UK.

Reading 2.2

Office of Financial Management, 2006, *Total asset management guideline - Asset strategic planning*, NSW Treasury , Sydney, pp. 1– 4; 6.

Organisations such as RailCorp are applying systems engineering to give the detail methodology to meet these guidelines and lower the risk. What risks you might ask? From the concept, a transport project may take many months or years to complete before hand-over to operations. To achieve the business objectives of the project, coordination is needed of the numerous demands and inputs. This requires continuous focus on the overall goals, particularly where multiple stakeholders are involved. The overarching purpose is to minimise the risk of designing and implementing an asset that is not the original intent of the stakeholders. It also requires skillful management over long periods of time to keep the design from drifting away from the intent.

The Systems Engineering approach provides a practical methodology for helping teams to control those potential risks. A design management team may set the relevant inputs to, and outputs from, each of the lifecycle phases of the design project, and this includes a level of emphasis on the maintenance and other support requirements. The approach can be and is applied to a range of applications, and in any sector, including for example to road and rail infrastructure projects. During the early lifecycle phases of a transport project, as seen in Figure 2-1 – Lifecycle phases, the major focus is first on the project concept, followed by a feasibility study and the detail of the assets` design.



* O&M – Operations and Maintenance

Figure 2-1 – Lifecycle phases

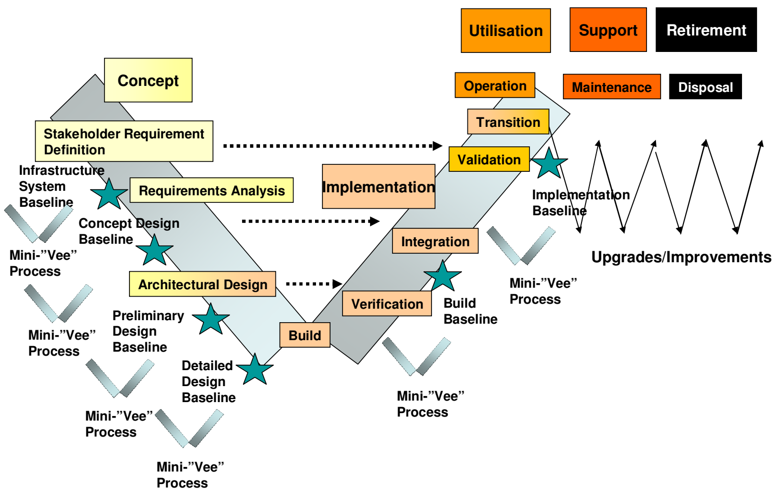


Figure 2-2 – System engineering approach to life cycle

Overall, a primary focus moves from requirements definition; to maturity in design; to build and then to integration of subsystems, commissioning and handover as a project progresses through the phases of development and delivery.

The central process of systems engineering consisting of defining requirements, synthesis, verification and establishing the baseline is repeated at each phase. Each iteration builds more maturity into the requirements definition and configurations as the focus moves from a highlevel infrastructure system to the component systems and subsystems, see Figure 2-3. When the fully developed subsystem baseline has been defined, the next phases move into building of the subsystems and the progressive integration up to the high level infrastructure system ready for transition into operations.

At each development phase the complete cycle of design takes place based on the maturity of knowledge on the system at that point. A baseline is produced at each phase to guide the next phase, see Figure 2-4.

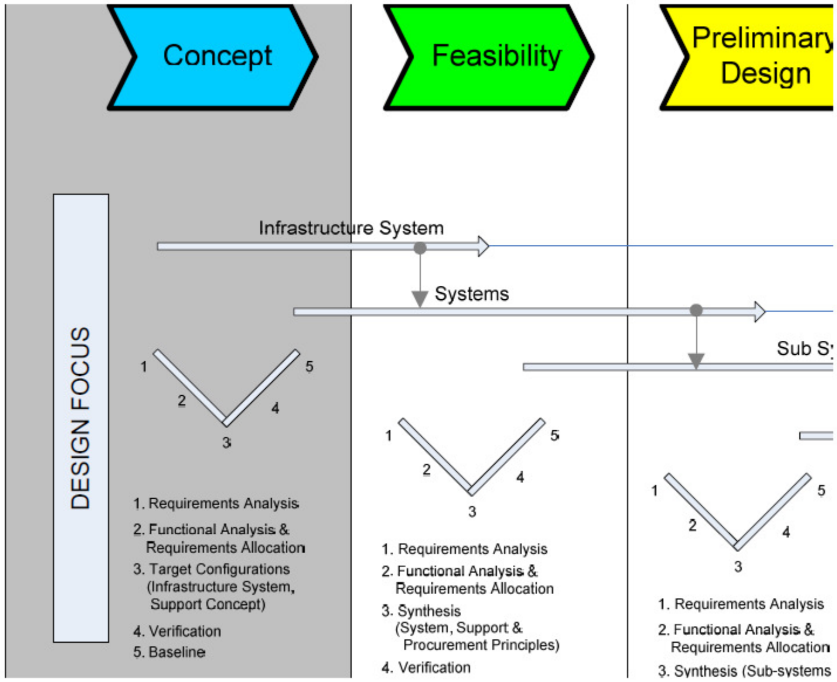


Figure 2-3 – System engineering focus at each phase

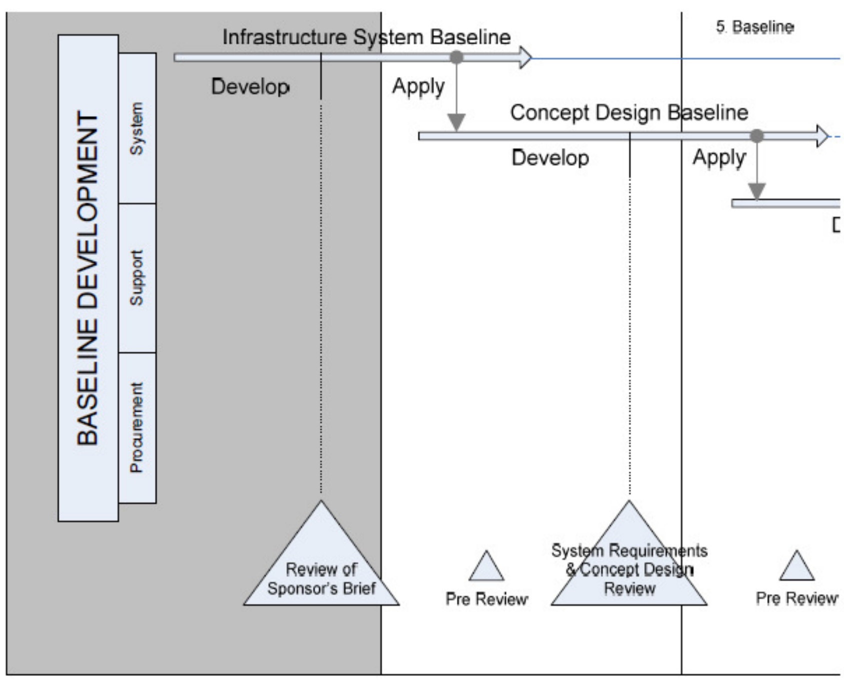


Figure 2-4 – System engineering baselines

Throughout each phase, parallel design focus occurs. Not only is a system designed for capacity, reliability etc it is also designed for maintenance and eventual disposal. The whole of life is the design focus. This is managed through the development of three baselines, namely system, support and procurement. The system baseline includes design for the key functions and requirements in terms of capacity, reliability etc. The support baseline results from the design focus on maintainability, maintenance regime and support logistics such as spares. The latter ensures specifications and agreement approaches that incorporate support and sustainability characteristics such as material and carbon footprint minimisation.

Each phase concludes with a phase gate hold point where a formal review of the phase outcomes is confirmed before baseline is issued as input to the next phase. The phase actions necessary to satisfy the review should be progressively planned so there are no surprises at the review.

The process of systems engineering continues throughout the life of the asset, the knowledge of operations and failure management is used to continuously improve the engineering system anad the tehnologies that they are made from. This knowledge helps mature the technology and inform the engineers making decisions about upgrades and technology choices beyond the end of the assets service life.

Exercise 2.1

Refer to diagram 1 in Readings 2.2. Look at Risk Analysis in Corporate Plan column and track across to Step C and Step D. Speculate on what are some of the risks that need managing for the proposed CBD Metro. Based on what you now know about systems engineering from this Unit suggest which risks this process helps to manage and how.

Transport – The landuse/transport systems approach

The second level of systems thinking is focused on the "land use/transport/environmental" system at the regional and sub-regional scales; sometimes called master planning scale or macro scale. The first recognition that planning for transport required a systematic understanding of land use patterns from which travel patterns are derived emerged in the USA in the early 1950s. The results of the steps or procedures to follow were expressed in the Chicago Area Transportation Study that gave rise to the "comprehensive land use and transportation studies" that were emulated in most major US cities in the 1960s, in Australian cities from 1961 (Canberra) to 1974 (Sydney), and in many cities in the developed and developing world.

In these early studies, systems analysis was extensively applied. Advances in computing allowed massive amounts of data on land use activities, travel patterns and transport supply characteristics to be stored and manipulated. The main steps of the "systems approach" are described in Reading 2.3 – a book written in 1980. The author claimed, in the concluding chapter, that the methodology of systems analysis would stand the test of time and be equally relevant to changing societal issues and challenges.

> "…future transport policy will be based on more sophisticated techniques of data collection and analysis, better information, and a truer appreciation of the wide-ranging implications of alternative courses of action. The systems approach should prove to be adaptable to this new challenge ." (Black, 1981, p. 221).

The systems approach remains relevant to the needs of contemporary practice at the beginning of the 21st Century and still forms the framework around which transport studies at the national, regional, sub-regional, and local scales are designed.

Reading 2.3

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, pp. 21 – 23.

Reading 2.4 takes the systems approach and articulates it in more specific detail as applied to the land use /transport system. Pay careful attention to the place of system inputs, systems modelling and systems outputs. Note the directional arrows and feedback loops. After completing the computer-based assignment you should study this reading once more. You will discover that the computer software took you through all of the steps of this process, except for the evaluation model and the implementation model.

Reading 2.4

Blunden, W. R. and Black, J.A, 1984, *The Land-Use/Transport System, Second Edition*, Pergamon Press, Oxford, Figure 11.9, p.38.

Exercise 2.2

Based on your understanding of the two figures in Readings 2.3 and 2.4, list (a) the inputs, and (b) the outputs to this process. Speculate on what parts of this process involve societal or political values being imposed.

Transport – System components and definitions

System analysis requires the decomposition of the system of interest into component parts, the conceptual identification of the interrelationship amongst component parts, and precise definitions of the system variables so that they can be measured and quantified. Our system of interest is decomposed into:

- Land Use
- Traffic
- Transport
- Environment.

In Reading 2.5, you will find a description of land use, transport, and traffic and how this system might be represented for analytical purposes. First, it is important to stress the distinction between traffic (movement of people and goods) and transport (the infrastructure and services that allow movement to occur). Some languages (Chinese, Japanese) are somewhat ambiguous when dealing with traffic and transport.

Traffic can be simply thought of as "demand" (derived from land-use activities) and transport as "supply". Secondly, the reading does not describe the "environment" component, although any revision of the book would include this additional component. Later, in a worked example that you will study, performance measures are given for the system: it is straightforward to extend social impacts (such as accessibility), to health and environmental impacts (noise, air quality) of transport.

Thus the environmental component of the land use/transport system analyses the social, economic and environmental impacts of the plan (or policy) to include both transport user impacts (road user costs, road safety) and non-user (or "transport externalities") impacts (noise, severance caused by infrastructure as a physical barrier or by vehicular traffic flow as a dynamic barrier to people wanting to cross that road, vehicle emissions, risk to community health). Many of these impacts can be scientifically defined, measured and modelled, to allow prediction of impacts for alternative designs.

Reading 2.5

Blunden, W. R. and Black, J.A, 1984, *The Land-Use/Transport System, Second Edition*, Pergamon Press, Oxford, Chapter 1, pp. 1 - 9.

Transport – Systems modelling

Systems' modelling plays a central role in the way that engineers analyse transport systems and make recommendations to decision makers. It is also a politically sensitive area: professional credibility is challenged by the community when investigations (and there are many of them!) fail to document adequately procedures and assumptions, and engineers try to hide behind a veil of "pseudo-scientific" accuracy that is unwarranted. A good example is the court challenges that have surrounded the accuracy (misleading) of traffic forecasts and toll revenue for the proposed Melbourne toll system released in the private-sector company's investment prospectus.

Conflict arises because of misunderstandings of the role of models in systems analysis and planning. Careful study of Reading 2.6 is required.

Reading 2.6

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Chapter 1, pp.23 - 33.

Some key points:

- Models are simplifications of the real world designed for a specific purpose;

- The purpose is frequently to investigate the implications of different land use, traffic management, and transport plans and policies assumed to be implemented at some future time horizon – sometimes 25 to 30 years in the future. These are the "what would happen if?" scenarios

- Uncertainty pervades such a process both in terms of the accuracy of future land use and transport inputs, the temporal stability of systems model parameters, and the accuracy of social, economic and environmental impacts (outputs of system performance). Assumptions must be clearly specified as in best engineering practice. There are books on "Beware of the Pitfalls of Systems Analysis". Sensitivity analyses should be conducted on key parameters and variables to determine the robustness of any conclusions drawn.

- Alternative plans and policies can be assessed and ranked on a comparable basis, in the knowledge that the uncertainty is inherent in all alternatives investigated.

Transport – Fundamentals of systems interactions

An introduction to the fundamentals of land use and transport interaction is provided in Reading 2.7 and the description of system interactions will provide you with enough background to confidently participate in the computer-based assignment that will follow. You are not required to become experts in transport engineering and so a deep understanding of the modelling fundamentals is not necessary. However, you should study carefully the two zone, two route worked numerical example, and even if you have forgotten some high school mathematics, you can still solve the "equilibrium" solutions with graphical plots (as illustrated in the reading example, only journeys from home to work, all trips are by car and we consider only road-based transport systems).

Reading 2.7

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Chapter 2, pp.33 - 43.

However, it demonstrates the key processes that under-pin all commercially available software packages such as TRANSCAD (UNSW has licenses for this for teaching purposes: for instance, the Faculty of Built Environment teaches a subject on this GIS/T application).

The worked example in this reading makes it clear that there are two types of planning investigation – the short and the long term.

- The short term takes the land-use pattern as fixed (the demand is derived from this land use) and explores changes to the existing transport system. This is in fact "transport system management" and if prices are introduced (see Exercise 2.3) into the generalised cost of any transport supply function, road pricing can be investigated as a tool for managing transport demand (travel demand management – TDM), as will be demonstrated in the next section. Short-term alternative plans are compared in terms of their "performance measures" against the existing situation as the base case.

- For long-term planning where land-use changes (such as investigations at Bringelly in the south-west sector of Sydney) the "base case" is the existing transport supply system over-loaded with the future traffic demands from the future land use postulated. Alternatives for transport are analysed with the future traffic demand from that land use plus the future transport supply specified.

Today, transport plans and policies are evaluated by decision makers on sustainability criterion (see final section of these notes). These are the "triple bottom line" of economic, social and environmental impacts. The worked example in Reading 2.7 shows the calculation for accessibility to employment (a social indicator) for the different alternatives (see, Table 1.2, p.40). It is straightforward to calculate other impacts once the equations of state have been specified.

- Road traffic noise (at a receptor point at a specified distance from the road) is a function primarily of hourly (or daily) traffic flow, the speed of vehicles, and the proportion of heavy trucks in the traffic stream. There are equations with parameters for Australian driving conditions (CORTN – Calculation of Road Traffic Noise) used by road authorities in assessing the environmental impacts of road proposals. From the equilibrium solutions in the worked examples, traffic flow is known, the speed can be derived from distances and travel times, and the proportion of trucks is zero, and so the noise output measured in decibels on the A-weighted scale can be calculated.
- Similarly, vehicle emissions (for different types of pollutants) per kilometre travelled by cars have been measured by instruments as a function of traffic speed. Thus, for the two roads, the traffic flow is multiplied by the unit emission rate for the speed, and multiplied by the length of the road to give total vehicle emissions per hour.
- Dynamic severance may be quantified by the risk of pedestrians crossing a road away from designated traffic control devises. Probabilistic pedestrian accident risk models (fatalities) are a function of traffic flow and vehicle speed.
- The performance indicators for environmental, social and economic impacts are unweighted. Evaluation requires values to be attached to their relative importance by decision makers. There are numerous decision-making tools, but transport investigations often attempt to summarise complex information in the form of cost-benefit analyses.

Exercise 2.3

The worked numerical example in Reading 2.7 was based on travel time as the model variable that represented transport supply impedance between two places. In practice both "generalised cost" or "generalised time" are specified in the equations to allow a variety of public transport operational and pricing policies to be investigated, along with the imposition of tolls and parking charges for motorists. Reading 2.8 explains "generalised cost" and "generalised time". The exercise is a simple illustration of "modelling" something with which you are routinely involved.

Reading 2.8

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Chapter 3, pp. 56 - 58.

Select any journey that you regularly make (for example home to university, or home to work). Think of three different transport means – car, public transport and walking – and calculate the generalised cost and generalised time of each transport mode (of course, the journey may be too far for walking so estimate it at a mean walking speed of 5km per hour). Work out the data you need to collect and observe their values (or estimate them). Show your workings and assumption below. Assume the monetary value of travel time is $15 per hour (these kind of evaluation parameters are available in government manuals for the "Economic Evaluation of Road Projects."

Readings

Contents

Reading 2.1

The Woodhouse Partnership Ltd, 2010, *extract from website www.pas55.net*, The Woodhouse Partnership Ltd, Kingsclere, UK.

Reading 2.2

Office of Financial Management, 2006, *Total asset management guideline - Asset strategic planning*, NSW Treasury , Sydney, pp. 1– 4; 6.

Reading 2.3

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, pp. 21 – 23.

Reading 2.4

Blunden, W. R. and Black, J.A, 1984, *The Land-Use/Transport System, Second Edition*, Pergamon Press, Oxford, p. 38.

Reading 2.5

Blunden, W. R. and Black, J.A, 1984, *The Land-Use/Transport System, Second Edition*, Pergamon Press, Oxford, pp. 1 – 9.

Reading 2.6

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Chapter 1, pp. 23 - 33.

Reading 2.7

Black, J., 1981, *Urban Transport Planning: Theory and Practice*, Croom Helm, London, and John Hopkins University Press, Baltimore, Chapter 1, pp. 33 - 43.

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