CHAPTER 2

Transport Planning

Introduction

- Transport projects are normally justified for the improvements in
  - Traffic flow and safety
  - Savings in energy consumption and travel time
  - Economic growth,
  - Increased accessibility, etc…

Introduction

- Some other transport projects, however, may be selected for other reasons:
  - To stimulate employment in a particular region
  - To compete with other cities or states for prestige
  - To attract industry
  - To respond to pressures from political constituency, or
  - To gain personal benefits from a particular route location or construction projects
- In some instances transport projects may not be selected because of opposition from those who would be adversely affected by the project.

What is Transport Planning?

- A rational way of furnishing unbiased information about the effects of the proposed transport project on the community and on its expected users to decision makers.

- Different Scales of transport planning: National > Regional > Local

Some Terminologies …

Journey: complete excursion (out & back)

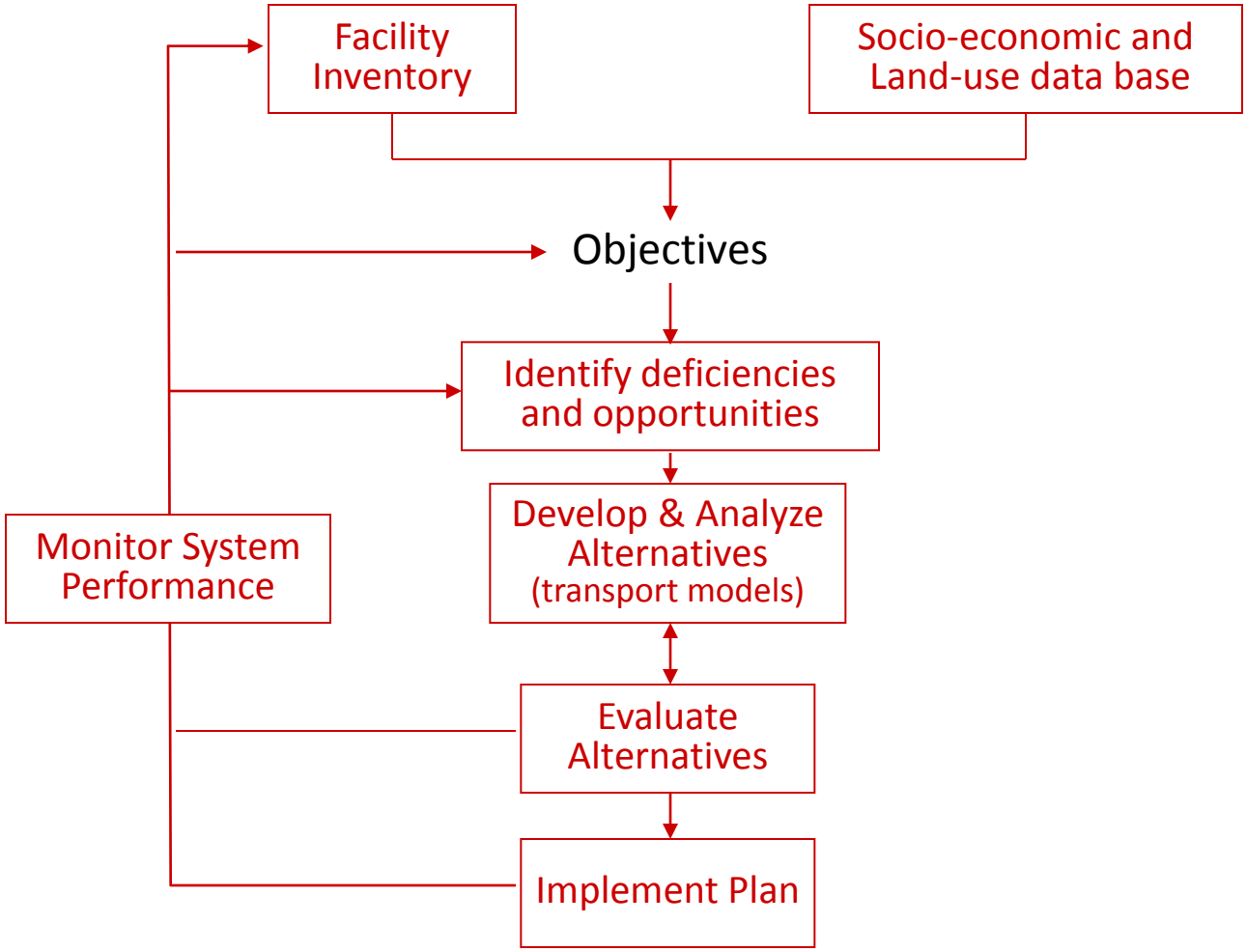
Trip: a one way journey

Mode: means of transport used (could be private/public on an aggregate level or could be solo car driver, car passenger, …)

Origin: place where trip started

Destination: place where trip ended

O-D/Demand/Trip matrix: matrix of trips from particular origins to particular destinations.


Facility Inventory
Socio-economic and Land-use data base
Objectives
Identify deficiencies and opportunities
Develop & Analyze Alternatives (transport models)
Evaluate Alternatives
Implement Plan
Monitor System Performance

Facility Inventory

- Involves inventory of:
  - the existing transport services,
  - the available facilities and their conditions
  - location of routes and schedules
  - maintenance and operation costs
  - system capacity and existing traffic volumes, speed, delay, …
  - property and equipment
  - etc.

Example – Facility Inventory

- Road X
  - is a major arterial system
  - Has n lanes of widths w1, …, wn
  - It has a capacity of C
  - Average flow is q veh/hr, speed is d sec
  - Has 4 signalised junctions and 6 priority junctions
  - Lanes are marked
  - Etc.
- Travel time on Route Y is t sec
- Such data could be coded into GIS system and should be updated regularly!

Socio-economic and Land-use Data

- Transport plan focuses on the provision of transport facilities and services to meet the existing or expected demand for travel.
- Transport is a DERIVED DEMAND: trips are taken to accomplish some activity at the destination
- Transport Planning should be related to the types of activities (i.e. land use, *e.g. schools, shopping centres and central business districts, residential area, …*) in a region and the characteristics of the trip maker (*e.g. income, HH size, cars in HH, education, …*)

Goals & Objectives

- Goals are general statements that indicate desired ultimate achievement of a transport plan

Example:

  - "Meet the mobility needs of the population"
  - "Provide enhanced economic development opportunities"

Objectives

- Objectives are more specific statements that indicate the means by which these goals will be achieved

Examples:

  - reduce congestion, protect the environment, avoid accidents, improve accessibility

- Identification of goals and objectives is critical in that they define the evaluation criteria (measure of effectiveness) that will be used later in the planning process to asses the relative impact of alternative projects and strategies.

Possible Objectives 1

Economic Efficiency: maximizing the net benefits in resource terms, of the provision of transport (e.g. faster travel time net of increased noise and pollution),.

Environmental Pollution: reducing the impact of transport facilities, and their use, on the environment of both users and non-users. Typical impacts could be: noise, atmospheric pollution, severance, loss of intrinsically valuable objects (flora & fauna, ancient monuments, …)

Possible Objectives 2

- Safety: concerned with reducing the loss of life, injuries, and damage to property resulting from transport accidents

- Accessibility (“ease of reaching”) is concerned with increasing the ability with which people in different locations, and with differing availability of transport can reach different types of facility. It can simply be measured in terms of the time spent travelling.

Possible Objectives 2

- Sustainability: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987)
  - Considers the trade-off between efficiency and accessibility on the one hand and environment and safety on the other
- Economic Generation: involves reinforcing the land-use plans of the area. It could be just be providing new infrastructure and service OR could be by enhancing improving the image of the area.

Possible Objectives 4

- Equity: is concerned with ensuring that the benefits of transport strategies are reasonably equally distributed or are focused particularly on those with special needs (e.g. low income residents, elderly and disabled people, …)
- Finance: is defined as minimising the financial outlay (capital - revenue) for a strategy

System Deficiencies and Opportunities

- Tries to answer questions like:
  - Where do problems exist?
  - Are this problems existing now or will occur in the future?
  - Are there opportunities of better using the existing transport system

Develop and Analyse Alternatives

- Different strategies or alternatives are assessed in terms of demand, level of service, revenue, environmental pollution, etc…

Evaluate Alternatives

- Evaluations should be based on the objectives set and should be based on appropriate indicators for the stated objectives

  In the “Developed World” it has become to place money values on casualties and accidents of differing severity

- Efficiency: Vehicle Operating Costs, Travel Time Savings, …
- Safety: “Value of Life”
- …

Implement Plan

- Once the transport project is selected, a detailed design phase is begun, in which each of the components of the facility is specified.
- In case of the number of projects exceed the available funding during implementation, projects are prioritised depending on their benefits

Monitor System Performance

- Need
  - To identify where improvements could be made
- It incorporates the results of
  - Transport management system
  - Pavement management system
  - Bridge management system
  - Safety management system
  - Public transport system
  - Inter-modal management system
  - Congestion management system

Forecasting Travel Demand

- The number of persons or vehicles that can be expected to travel on a given segment or future (inc. modified) transport system under a set of given land-use, socio-economic, and environmental conditions
- Methods range from simple extrapolation of observed trends to a sophisticated computerised process involving extensive data gathering and mathematical modelling.

Demand Forecasts - Types

- Urban Travel Demand Forecasts: requires data that give insight into characteristics of the trip maker (age, sex, income, mode of travel, …) collected using Household Interview & Roadside Interview Surveys. Such data can be used as they are (disaggregated) or can be aggregated into zones
- Intercity Travel Demand Forecasts: data is generally aggregated to a greater extent than for urban travel forecasting.

  E.g.: City Population, Avg. City Income, Travel Time (or Cost of Travel) b/n cities, …

Urban Travel Demand Forecasts

- Factors influencing travel demand
- Land-use characteristics:
  - Shopping centres
  - Residential complexes
  - Industrial
  - Office Building
- Socio-Economic Characteristics
- Availability of Transport Facilities and Level of Service (travel time, cost, convenience, comfort, safety, etc.) provided by facilities

Defining the Study Area

- Subdividing the study area into traffic zones is a necessary first step before collecting and summarizing the study area
- Criteria in Zoning:
  - Homogeneous socio-economic characteristics
  - Minimum intra-zonal trips
  - Physical, political, and historical boundaries
  - Zones should not be defined within other zones
  - The zoning system should generate & attract approximately equal trips, contain approx. equal no. of households, population, …
  - Use census tract boundaries where possible

Data Collection 1

- Road Use Studies: determine relative use of various parts of the transportation network.
  - Personal Interviews on: total mileage driven/month, frequency of travel, choice of route, …
- Transport Facility & Traffic Studies:
  - Involve determination: speeds, traffic volumes, travel times, delays, parking facilities, parking habits, …

Data Collection 2

- Travel (OD) Survey: involved data collection on:
  - Origins, Destinations, Trip Purpose, Mode of Travel, Social & Economic characteristics of trip maker, car-occupancy, type of good transported (for freight), …
  - General Classification of Travel Surveys:
    1. HH travel surveys
    2. Road-side travel surveys
    3. Modal surveys
    4. Goods movement surveys

Transportation System Modelling

- Purpose is to help transport planners make reliable forecasts of traffic demand that reflect the effects of changes in population, social, and economic conditions as well as changes in the transport network.
- Reliable forecast of future traffic reduces a risk of building facilities that will either receive little use or be prematurely overloaded.

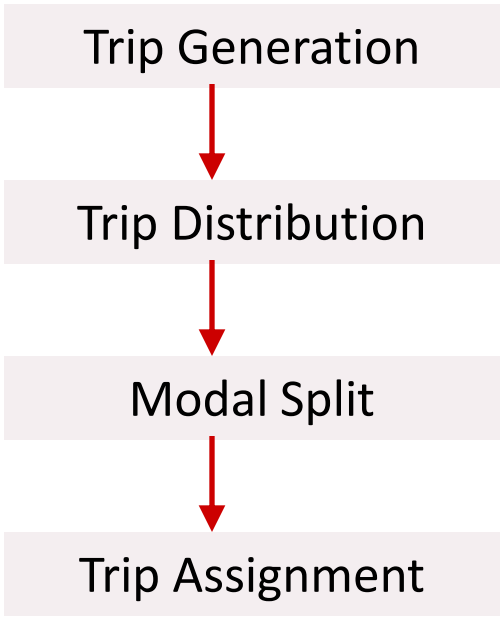
Basic concepts in Transport Systems Modelling

1. Trip making is a function of land use
2. Trips are made for different purposes
3. Trips are made at different times of the day
4. Travellers often have different options available to them
5. Modal choice is made to minimise the level of inconvenience associated with reaching a destination (travel time, cost, etc.)

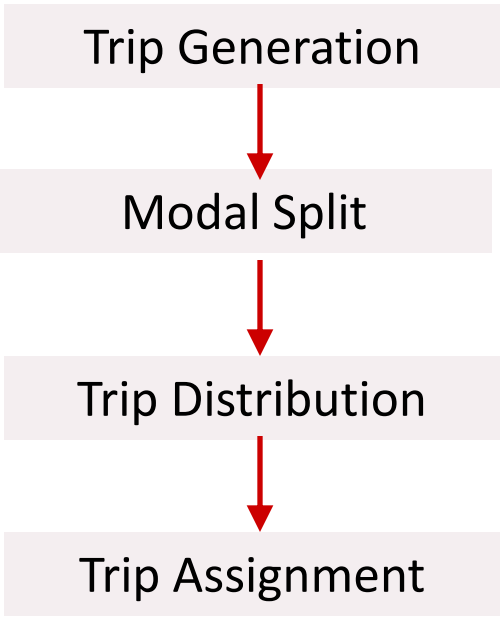
The Four Stage Model

- Trip Generation (predicts origins, destinations, and frequency)
- Trip Distribution (predicts the O-D matrix)
- Modal Split (predicts mode)
- Trip Assignment (predicts route choice)

Alternative Approaches to the 4-stage model



Trip Interchange Model



Trip-end model

Trip Generation

- Tries to answer questions like:
  - How many trips will be generated from zone x (from a residential area)?
  - How many trips will be attracted to zone y (to a shopping complex)?
- Rates of trip making is closely related to
  - Intensity of land use (dwelling unit/sq.km, employees/sq.km, etc.)
  - Character of land use (income , car ownership, etc.)
  - Location relative to major economic activity
- Methodologies Used:
  - Trip rates from national/ local sources
  - Category (cross-classification) Analysis
  - Regression Analysis
  - etc.

Trip Generation (Cont'd.)

- Trip rates from National/ local sources
  - Rates established by studies conducted to determine the number of trips associated with different types of land-use.
  - Example :
    - Traffic counts at the driveways, stores or restaurants to account attracted traffic

Trip Generation (Cont'd.)

- Cross-Classification Analysis
  - is a method by which the relationship between socio-economic variables and trip making is used to develop trip rates by cross classification *or categorization.*
- Some thought should be given to:
  - What dimensions to cross-classify (no of cars owned ***OR*** No. of HH members)
  - What groupings of these levels (0,1,2+ ***OR*** 0,1,2,3+)

Example 1

Suppose a survey finds the data on weekly trip making as given in (2) and the distribution of HH car ownership as is tabulated in (3). In (4) the avg. number of trips per HH is calculated to be 43.

If the distribution of HH with a certain no. of cars changes as shown in (5), category analysis holds (2) constant and calculates new average trips per house hold.

(1)	(2)	(3)	(4)	(5)	(6)
Number of cars owned by HH	Weekly Number of trips made by HH	Initial Distribution of HH	(2)*(3)	New Distribution of HH	(2)*(5)
0	30	50%	15	30%	9
1	50	40%	20	50%	25
2+	80	10%	8	20%	16
			43		50

Trip Generation (Cont'd.)

- Regression Analysis: the procedure for establishing an equation to express the relationship between one (dependant) variable and one or more other (explanatory) variables.

$$Y = \alpha + \beta_1 X_1 + \ldots + \beta_n X_n + \varepsilon$$

Example

Let:

T_i = *number of trips in a month, by zone i*
D_j =*no. of trips attracted to zone j*
P_i = *population for zone i*
U_i = *dwelling units in zone i*
A = *no. of automobiles in zone i*
E_i = *total employment in zone i*

$$T_i = 0.34P_i + 0.21U_i + 0.12A$$

$$D_j = 57.2 + 0.87E_i$$

So far …

Generation

Category analysis

Regression Analysis

Trip rates

Other methods

Predictions of Origins, Destinations, or Both for zones in the study area

Trip Distribution

Trip Distribution

- What total number of trips would there be between Origin and Destination Pairs?
- The result of trip distribution is an O-D matrix that shows the number of trips originating in the study zone and where these trips are destined to.

Methods

- Gravity Model
- Growth Factor Models

Gravity Model

- Named due to similarity with Newton's law of gravitation:

$$T_{ij} = \left[\frac{A_j /(D_{ij})^n}{A_1 /(D_{i1})^n + A_2 /(D_{i2})^n + \ldots + A_m /(D_{im})^n} \right] \times P_i$$

- Modified gravity model

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum A_j F_{ij} K_{ij}} \right]$$

Growth Factor Method

- Simple and easy to understand/explain
- Rely very heavily on patterns in the old O-D matrix so not suitable for very long term planning
- Take no account of changing costs, policies, etc.

Growth Factor Method

- The Fratar method

$$T_{ij} = t_i G_j \left[\frac{t_{ij} G_j}{\sum t_{ix} G_x} \right]$$

Example

Present trip generation and growth factors in 5 years

Zone	present No. of trips/day	growth factor	No. of trips in 5 years
1	600	1.2	720
2	700	1.1	770
3	700	1.4	980
4	400	1.3	520

Example (cont'd.)

Present trips between zones				
zone	1	2	3	4
1	-	400	100	100
2	400	-	300	-
3	100	300	-	300
4	100	-	300	-
Total	600	700	700	400

Example (cont'd.)

First estimate of trips b/n zones				
zone	1	2	3	4
1	-	428	141	124
2	428	-	372	-
3	141	372	-	430
4	124	-	430	-
Total	693	800	943	554

Calculated trips	Actual trips
693	720
800	770
943	980
554	520

Mode Split

- A model to predict the percentage of individuals who will choose one mode over others for making a particular trip
- Mode choice is affected by:
  - Type of trip [trip purpose (work, leisure); time of day; …
  - Characteristics of the trip maker (income, age, car-ownership)
  - Characteristics of the mode (relative travel time, reliability, comfort, price, …)

Mode Split

Mode utilities are attributable:

- to the user (time, price, …),
- to the service characteristics of a mode (reliability, safety, comfort),
- others

The Utility of a mode is the “satisfaction” a user derives from using a certain mode of transport. It is a linear combination of cost attributes a transport mode presents to its user

e.g. $U = \omega - \alpha TT - \beta$ Price $+\gamma$ Comfort

Mode Split

The Logit Model

$$P_{it} = \frac{e^{Uit}}{\sum_{All\ j} e^{Ujt}}$$

P_{it} = *probability of individual t choosing mode i*

U_{it} = *Utility of mode i to individual t*

U_{jt} = *Utility of mode j to individual t*

Note that the method is based on one individual's Utility from the different modes.

Example

Assume there are 1000 trips being made between zones A and B, and that there are three mode available to make this trip. The utility of the individual modes is defined as

$U_{auto}=1 - 0.1\mathbf{TT} - 0.05\ \mathbf{TC}$
$U_{bus}=-0.1\mathbf{TT} - 0.05\ \mathbf{TC}$
$U_{walk}=-0.05 - 0.01\ \mathbf{TT}$

TC=Travel Cost (birr) and **TT**=Travel Time (min)

Predict how many people would be using each of the modes if: TT_{auto}=5min, TT_{bus}=15min, TT_{walk}= 20min, TC_{auto}=2birr, and TC_{bus}=1birr .

Trip Assignment

- Allocates the T_{ij}^{k} matrix to links (routes) in the network (*i=Origin, j=Destination, k=mode*)
- Inputs in Assignment Models
  - the T_{ij}^{k} Matrix
  - the Network
    - with the cost of using each link defined (e.g. in terms of travel time)
  - Route Selection Rules
    - Most rules are based on the idea that a traveller will choose the route which is expected to offer the lowest perceived cost

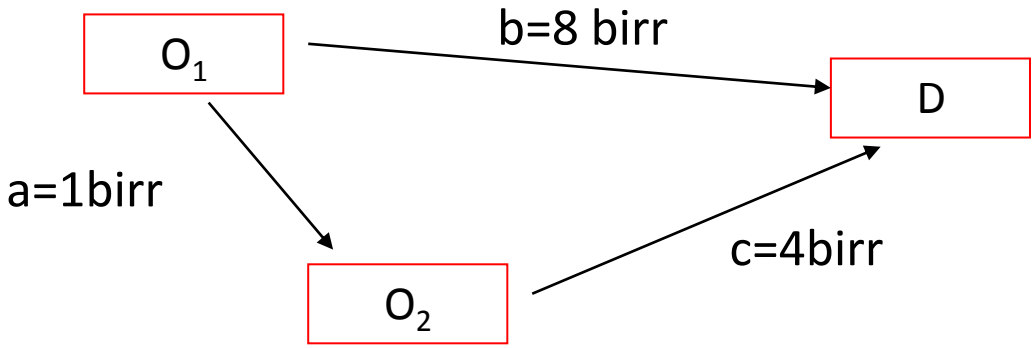
Trip Assignment

- Outputs
  - Flows on links
  - Zone to zone travel costs for a given level of demand
  - Composition of traffic on a link or route
  - All alternative routes for a particular O-D pair

Trip Assignment

- Models
  - Diversion curve
  - All or Nothing Assignment (minimum time path)
  - Capacity restraint method

AON - example



Note the costs are not related to flow on the links and capacity of the link.

If the Demand is: O_1-D=2500 trips and O_2-D=3500 trips, how much traffic will be using links a, b, and c?

General Example

Road Financing Options for Addis to Nazareth Road Project – Feasibility of Road Tolls

Addis to Nazareth: Buses, Rapid Transit, Roads

Section	2004 ADT	% Heavy	Growth 1992-2004
Addis – Akaki Beseka	19061	40%	19%
Akaki Beseka - Debrezeit	7860	52%	10%
Debrezeit - Mojo	5797	51%	8%
Mojo - Nazareth	4002	51%	7%

Evaluation of Transport Alternatives

Introduction

- A certain transport project is usually proposed in order to achieve some stated objectives
- Different project will have different impact on the different
- The evaluation procedure should as much as possible be objective! Values are given to different attributes that are affected by a transportation system improvement (e.g. travel time, safety, …). For some attributes for which finding a value is difficult other methods (e.g. Multi-Criteria Analysis) have been used.
- A Social project's evaluation is different from a private project's evaluation

Cost-Benefit Analysis

- In CBA it is assumed that
  - All costs and benefits can be expressed in money terms (but, multi-criteria analysis)
  - Future costs and benefits are known with certainty (but, risk analysis)

Example CBA

"A project is socially beneficial if the gainers could compensate the losers and still be better off them selves"

Crudely put, if B (Benefit) > C (Cost)

e.g. If a bus company hires extra drivers to improve reliability and the costs and benefits are as shown: is the proposal worth going for?

Group	Costs (birr)	Benefits (birr)
Operator	10000	
Users		13000
Total	10000	13000

Future Costs - Benefits

- How do we summarize future benefits and costs to a single value?
- How are future benefits worth, viewed from today?
  - Opportunity Cost and Time preference

1Birr spent on Project A today could instead be invested elsewhere to generate a return of r%. (Banks' lending interest rate-determined by Govt.).

Summarizing Techniques

Methods discussed here include:

- Net Present Value, NPV
- Internal Rate of Return, IRR
- Benefit Cost Ratio, BCR

Net present value

$$NPV = PVB - PVC$$

$$NPV = B_o - C_o + \frac{B_1 - C_1}{(1+r)} + \ldots + \frac{B_n - C_n}{(1+r)^n}$$

$$= \sum_{t=0}^{n} \frac{B_n - C_n}{(1+r)^n}$$

Where: Bt=benefit in year t

Ct=cost in year t

$(1+r)^{-n}$ =discount rate

n=horizon year (any thing beyond will be considered only in the form of residual value)

Internal Rate of Return

- Is the rate of discount at the projects NPV is zero.
- Found by a search procedure

  Example: What is the IRR for the project shown?

Year	Net Benefit
0	-50000
1	25600
2	25600
3	25600

  Ans: IRR=25%

  (Check if it given a 0 NPV)

When comparing two projects would you go for the one with a bigger or lesser IRR?

Benefit Cost Ratio

Is a value for money measure

$$"gross" BCR = PVB / PVC$$

$$"net" BCR = (PVB - PVC) / PVC$$

Example

Calculate NPV, BCR, and IRR for the following stream of benefits and costs if the discount rate is 7%

Yr	Costs	Benefits	Discount Factors (7%)	Discounted Costs	Discounted Benefits	Discounted net benefits
0	20000	8000				
1		8000				
2		8000				
3		8000				
4		8000				

Example

A heavily used intersection in an urban area is to be improved to achieve three goals: improve travel speed, safety, reduce operating costs for motorists. The annual value of savings compared with existing conditions for each criterion as well as additional construction and maintenance costs is shown below. If the economic life of the road is considered to be 50 years and the discount rate is 3%, which alternative should be selected?

Cost & Benefits for improving the intersection with respect to the existing conditions					
Alt	Construction Cost (Br)	Annual Saving in Accidents (Br)	Annual TT savings (Br)	Annual Op. Cost savings (Br)	Annual additonal Maintenance Cost (Br)
1	185,000	5000	3000	500	1500
2	220,000	5000	6500	500	2500
3	310,000	7000	6000	2800	3000

Reference

Brundtland G. et. al. (1987). *Our common future*: Report of the 1987 World Commission on Environment and Development, Oxford, Oxford University Press