Urban Transportation Projects

- Traffic System Evaluation
- Transport System Evaluation
- Transport Subsystem Evaluation

Traffic System Evaluation

- **This evaluation procedure concentrates on the benefits to road user likely to accrue from potential road investments.**
- **The principal component of the these road user benefits is the savings in travel time of road users.**
- **With this method the road system is viewed as a relatively independent entity, having little interaction with the transportation system and no non user impacts.**

Transport System Evaluation

The transport systems evaluation is used to refer to evaluation method that also concentrate on user benefits but that attempt to isolate the optimum combination of two or more modes of transport.

Transport Subsystem Evaluation

Transport subsystem evaluation procedures view transport systems as having significant non user impacts on the community as well as use impacts.

ECONOMIC and FINANCIAL Evaluation of Delhi Metro (DMRC)

Submitted By:

Akhil Gupta (05004017)
Irfan Ali (05004009)

Introduction

- The growing demand for public transport in mega cities has serious effects on urban ecosystems
- An ecologically sustainable urban transport system could be obtained by an appropriate mix of alternative modes of transport resulting in the use of environmentally friendly fuels and land use patterns.
- The Delhi Metro provides multiple benefits: reduction in air pollution, time saving to passengers, reduction in accidents, reduction in traffic congestion and fuel savings.
- The financial internal rate of return on investments in the Metro is estimated as 17 percent while the economic rate of return is 24 percent.

About Delhi Metro

- Delhi, the capital city of India, is one of the fastest growing cities in the world with a population of 13 million (year 2000 data)
- The first concrete step in the launching of an Integrated Multi Mode Mass Rapid Transport System (MRTS) for Delhi was taken when a feasibility study for developing a multi-modal MRTS system
- The Delhi Metro (DM) planned in four phases is part of the MRTS. The work of Phase I and part of Phase II is now complete while that of phase III is in progress.

Phases

- Phase I:
- consists of 3 corridors divided in to eight sections with a total route of 65.1 kms
- 13.17 kms has been planned as an underground corridor, 47.43 kms as elevated corridors and 4.5 kms as a grade rail corridor.
- Construction was spread over 10 years during 95-96 to 2004-05

- Phase II:
- covers 53.02 kilometers of which the underground portion, grade and elevated section are expected to be 8.93 kilometers, 1.85 kilometers and 42.24 kilometers respectively
- Started in 2005-2006 is expected to be complete by 2010-11

Phases III and IV of DM will cover most of the remaining parts of Delhi and even extend its services to some areas such as Noida and Gurgaon belonging to the neighbouring states of Delhi.

Overview Of MRTS

	Phase I (1995 - 2005)	Phase II (2005 –2011)
Distance	65.10 km	53.02 km
Corridors	1) Shahdara - Barwala (22)	1) Vishwa Vidhyalaya- Jahangirpuri (6.36)
	2) Vishwa Vidhyalaya- Central Secretariat (11)	2) Central Secretariat- Qutab Minar (10.87)
	3) Barakhamba Road - Dwarka (22.8)	3) Shahdra- Dilshad Garden (3.09)
	4) Barakhamba Road – Indraprastha (2.8)	4) Indraprastha- New Ashok Nagar (8.07)
	5) Extension into Dwarka Sub city (6.5)	5) Yamuna Bank- Anand Vihar ISBT (6.16)
		6) Kirti Nagar- Mundka (18.47)
Investment	Rs 6406 crores (2004 prices)	Rs 8026 crores (2004 prices)
	Phase III	Phase IV
Distance	62.2 km	
Corridors	1) Rangpuri to Shahabad Mohammadpur	1) Jahangirpuri to Sagarpur West
	2) Barwala to Bawana	2) Narela to Najafgarh
	3) Jahangirpuri to Okhla Industrial Area Phase I	3) Andheria Mod to Gurgaon
	4) Shahbad Mohammadpur to Najafgarh	

Source: RITES (2005a)

Financial Evaluation of Project

- The financial evaluation of a project requires the analysis of its annual cash flows of revenue and costs

- The investment expenditures constitutes the purchase of capital goods, cost of acquisition of land and payments made to skilled and unskilled labour and material inputs for project construction

- The operation and maintenance cost of the project constitutes the annual expenditure incurred on energy, material inputs for maintenance and payments made to skilled and unskilled labour.

- The investment goods and material inputs used by the project are evaluated at market prices, given the definition of market price of a commodity as producer price plus commodity tax minus commodity subsidy

Financial Evaluation of Project

- If the government gives some commodity tax concessions to DM, they are reflected in the prices paid by DM for such commodities
- If the financial capital cost of the project is worked out as the time flow of annualized capital cost, the annual cost of capital has to be calculated at the actual interest paid by it.
- This could be done using information about the sources of funds for investment by DM and the actual interest paid by it to each source

Source of Funding DM (phases I and II)

Cost Financed By	Phase I	Phase II
1) Equity (50% each by GOI & GNCTD)	30%	30%
2) Long Term Debt (OECF, Japan) @ 3% p.a. or less	60%	56%
(with a 10 year moratorium period and 10 year repayment period)		
3) Revenues From Property Development	7%	5%+ 5% (internal resources)
4) Subordinate Debt	3%	4%

Source: RITES (1995a)

- More than 60 percent of the funds required for investment are raised as debt capital.
- 30 percent are raised through equity capital, Government of India (GOI) and GNCTD having equal shares in it
- Remaining 10 will be covered out of the revenues it earns.

Cost Estimation of DM Phase I

(Rs. Million)

Items	Foreign Exchange	Local Cost	Total
Civil works	0	31327	31327
Electrical works	0	6970	6970
Signaling and telecommunication	2574	1930	4504
Rolling stock	4596	6403	10999
Land	0	3339	3339
General establishment and consultancy charges	322	4779	5101
Contingencies	230	1593	1823

Source: RITES (1995a)

Estimates of Financial Flows of Investment by DM

(Rs. Million)

Year	Capital Cost	Year	Capital Cost	Year	Capital Cost	Year	Capital Cost
1995	2574	2007	20411	2019	361	2031	43290
1996	3937	2008	23331	2020	1543	2032	15150
1997	6036	2009	17861	2021	18901	2033	0
1998	8625	2010	5281	2022	1183	2034	0
1999	9498	2011	1271	2023	1183	2035	0
2000	10110	2012	361	2024	1183	2036	0
2001	9069	2013	361	2025	0	2037	0
2002	7353	2014	361	2026	0	2038	0
2003	4917	2015	361	2027	0	2039	0
2004	1945	2016	361	2028	0	2040	0
2005	4061	2017	361	2029	0	2041	58770
2006	12381	2018	361	2030	0		

Estimates of Financial Flows of Operation andMaintenance Expenditures (Phase I and II)

(Rs. Million)

Year	O&M	Year	O&M	Year	O&M
2005	3123	2017	10484	2029	20149
2006	3253	2018	10981	2030	21255
2007	3387	2019	11507	2031	24628
2008	3527	2020	12127	2032	26042
2009	3674	2021	13763	2033	27562
2010	7822	2022	14374	2034	29198
2011	8006	2023	15032	2035	30958
2012	8366	2024	15738	2036	32852
2013	8745	2025	16498	2037	34891
2014	9145	2026	17316	2038	37086
2015	9568	2027	18195	2039	39449
2016	10013	2028	19141	2040	41993

These estimates are made using information about the trends of the O&M cost of Calcutta Metro and the suburban sections of the Bombay Railway and the results of some optimization studies conducted

Fare Sensitivity of Ridership on the Metro

Fare Rate (In Rs/Passenger trip)	Percentage Ridership
3	100%
4	90%
5	75%
6	50%

Source: RITES (1995b)

- Full ridership is expected to materialize on the metro with a fare comparable to the DTC bus fare of Rs. 3 per passenger trip
- The financial model consisting of Rs. 5 per passenger trip and an annual fare increase of 7.5 per cent was considered optimal by RITES.

Estimates of Financial Flows of Revenue Earned by DM (Phases I and II) during its Lifetime

(Rs. Million)

Year	Revenue	Year	Revenue	Year	Revenue
2005	15052	2018	67722	2031	128687
2006	17152	2019	74284	2032	133307
2007	19407	2020	82806	2033	134177
2008	21826	2021	92342	2034	139477
2009	24421	2022	99126	2035	140477
2010	33762	2023	106242	2036	146547
2011	37112	2024	115557	2037	147687
2012	41057	2025	116067	2038	154657
2013	44511	2026	119127	2039	155947
2014	50847	2027	119717	2040	163947
2015	49633	2028	123227	2041	165437
2016	5627	2029	123897		
2017	62209	2030	127927		

Financial Conclusion

Considering the estimates of financial flows of DM during the period 1995-2041:

- financial cost-benefit ratio is estimated as 2.30 and 1.92 at 8 percent and 10 percent

- discount rates, respectively. The financial internal rate of return of DM is estimated as 17 percent.

Economic Evaluation

- The economic costs of the Metro are calculated after excluding the tax component from the financial costs.
- If the taxes are ad valorem, it implies an increase in the revenue of the government if there is an increase in a rupee worth of expenditure on that commodity
- These taxes are also interpreted as shadow taxes. No tax payments are considered on the expenditures incurred by the DM for the employment of unskilled labour.

Economic Evaluation

Two approaches are used for the analysis:

- One approach maintains that there is a sub-optimal level of savings in the Indian economy and therefore the social time preference rate is lower than the rate of return on investment and there is a social premium on investment.
- Another approach assumes that the level of savings in the Indian economy is optimal and there are no distortions in the capital market so that the rate of return on investment or the market rate of interest could be taken as the social time preference rate.

Both the approaches recognize that distortions still exist in the markets for unskilled labour and foreign exchange so that their market prices are different from the shadow prices.

Economic Evaluation

- For unskilled labour, shadow price consists of the direct and indirect opportunity cost of unskilled labour employment on investment projects in first approach while it constitutes only the direct opportunity cost for second approach.
- The direct opportunity cost constitutes the marginal productivity of unskilled labour in the alternative employment
- Indirect opportunity cost is due to the social value of loss in savings or investment due to labour employment.

estimate of the marginal productivity of unskilled labour in agriculture as Rs. 48 per day and an estimate of the shadow wage rate consisting of the direct and indirect cost of unskilled labour employment as Rs. 60 for the Indian economy.

Components of Economic Capital and O&M Cost

(Rs. Million)

	Capital Cost			O&M Cost	
	Foreign	Unskilled	Domestic	Unskilled	Domestic
Year	Exchange	Labour	Material	Labour	Material
1995	1390	257	695	0	0
2000	5460	1011	2730	0	0
2005	2193	406	1097	156	2671
2010	2852	528	1426	391	6687
2015	0	36	292	478	8180
2020	0	154	1250	606	10369
2025	0	0	0	825	14106
2030	0	0	0	1063	18173
2035	0	0	0	1548	26469
2040	0	0	0	2100	35905

Effect on Economic Agents

- **Government:**

- gets fare box revenues, revenues from property development
- advertisements and tax revenue on the goods and services bought for the investments
- operation and maintenance of the Metro while it suffers revenue losses due to the displaced public buses
- The net benefits for the government during the year 2011-12 are estimated as Rs. 31760 million at 2004 prices.

Effect on Economic Agents

- **Passengers:**

- gain to the extent of the difference between the fares paid to buses in the absence of the Metro and the fares charged by the Metro
- The net benefits to the passengers from the Metro are estimated as Rs.22440 million during the year 2011-12.

- Private Transporters:
- lose the revenue from displaced private buses but at the same time save on their capital and operating costs.
- net loss of Rs. 2860 million to the private transporters during the year 2011-12.

Effect on Economic Agents

- **Unskilled Labour:**
- employed on the construction and maintenance of Metro gain to the extent of the difference between the project wage rate and the wage rate in an alternative employment in India
- the benefit to unskilled labour is estimated as Rs. 316.4 million during the year 2011-12.

- **General Public:**
- representing the Indian society receives the benefits of social premium on investment and foreign exchange and the environmental benefits of reduced pollution due to the Metro
- public receives net benefits worth of Rs. 14260 million in the year 2011-12 due to Metro.

Estimation of NPEB and IRR

	1st approach		2nd approach	
With different scenarios	NPB (Rs. Million)	IRR (%)	NPB (Rs. Million)	IRR (%)
At market prices	265880	21.51	158900	21.51
With shadow price of unskilled labour only	272929	22.30	164408	22.30
With shadow prices of unskilled labour and foreign exchange only	294358	22.56	176330	22.56
With shadow prices of unskilled labour, foreign exchange and investment	324155	22.54	176330	22.56
With shadow prices of unskilled labour, foreign exchange and investment and environment services	432387	23.85	232051	23.88

Conclusion

- The Delhi Metro planned in four phases is part of an Integrated Multi Mode Mass Rapid Transport System (MRTS) planned for dealing with the fast growing passenger traffic demand in Delhi
- The financial cost-benefit ratio of the Metro is estimated as 2.30 and 1.92 at 8 percent and 10 percent discount rates respectively
- Financial internal rate of return is estimated as 17 %
- The economic rate of return on investments in the Metro is 21.5 percent at market prices

$$\text{Log}_e\, P = A_0 + A_1\, \text{Log}_e\, (I) \quad \text{...... (1)}$$

Where,

P = Number of vehicles registered

I = Economic indicator (GDP)

A_0 = Regression constant

A_1 = Regression coefficient

The regression analysis has yielded the Elasticity Values 'E' for different vehicle types which are given in Table 5.

Table-5: The Elasticity Values Obtained by Econometric Analysis

Vehicle Type	Elasticity
Car/Jeep/Taxi	1.90
2 Wheeler	1.85
Bus	1.18
Goods Vehicle	1.00
Tractor/Trailor	1.55

Traffic growth rates used to assess the likely future traffic growth are a product of economic growth rate and elasticity of traffic demand vis-à-vis econometric growth. This can be expressed mathematically by the following equation.

$$Tg = E \times Eg \quad \text{...... (2)}$$

Where,

Tg = Traffic growth rate,

E = Elasticity of traffic demand,

Eg = Economic growth rate.

the projected growth rates of GDP by Planning
nd the traffic growth rates in future were
of projected growth rate of GDP by Planning
Commission are given in Table 6.

Table-6: Projected Growth Rate of GDP by Planning Commission

Period	2003-2013	Beyond 2013
Growth Rate of GDP (%)	6	6.5

Thus the values of growth rates obtained for various types of vehicles by econometric analysis are given in Table 7.

Table-7: The Growth Rates Obtained by Econometric Analysis

Vehicle Type	Period			
	2001-06	2006-11	2011-16	2016-21
Car/Jeep/Taxi	11.4	11.4	12.4	12.4
2 Wheeler	11.1	11.1	12	12
Bus	7.1	7.1	7.7	7.7
Goods Vehicle	6	6	6.5	6.5
Tractors/Trailors	9.3	9.3	10.1	10.1

The IRC VISION 2021 also suggests elasticity values for traffic projection in the country. The Growth rates calculated by using elasticity values given by IRC VISION 2021 document are given in the Table 8.

Table-8: Growth Rates Calculated by Using Elasticity Values Given by IRC

Vehicle Type	Period			
	2001-06	2006-11	2011-16	2016-21
Car	9.843	9.264	8.685	8.106
Bus	8.106	7.527	6.948	6.369
Truck, MAV	8.685	8.106	6.948	6.369

International Conference on Transportation Systems Planning and Operation, IIT Madras, Chennai, India, 18-20 February, 2004

Patronage Impacts of Change in Fares and Services on Urban Rail Transit in India

S. Ponnuswamy[1]

Abstract: This short study is aimed at finding out to what extent the fare structure and service level affect the patronage of urban rail transit in India. Such analysis can be done either by a quasi- experimental approach or by non-experimental approach using aggregate data. To start with, the study makes a trend analysis of the global data to test the hypothesis. It is followed by analysis of aggregate direct demand on a corridor in Chennai, when there have been sharp changes in fare level and/ or service level and estimate demand elasticity for some corridors and stations. It is aimed at determining to what extent the patronage is elastic to changes in levels of fare or service and testing the results against the Simpson and Curtis formula. It is felt that the results can help the planners of new stand-alone MRT systems in evaluating the proposed systems at different fare levels. The study will bring out the importance of evolving a more rational fare policy on the suburban rail system.

1. Introduction

Rail transit in Indian cities has been provided till recently in form of Suburban Rail systems in three major cities. Their fare structure has been linked to the intercity rail fare policy, since they form integral part of Indian Railway system. Railways conducted a number of studies for metro rail systems in the four major metropolises in sixties and early seventies and found most of them viable, based on the then existing fare and service levels of bus and rail transit in those cities. The first Metro rail transit system was approved for Kolkatta and taken on in early seventies. It was commissioned over a 16.3 km length about ten years back. Being a stand-alone system, a different fare system has been adopted for the same, though it is operated by the Indian Railways. Since then one more Metro rail transit has been introduced in Delhi about a year back. Being a stand- alone system, its fare structure is also different.

The share of rail transit in some cities has been found to be going down since 1978, when the railways started hiking their fare, specially the minimum one. In the next ten-year period, there has been very low growth in the commuter trips by rail, while there has been fairly rapid growth in especially amongst bus commuter trips. A stark example of the comparative picture is presented by the behaviour of commuters in Chennai as indicated in Figure 1.

The design forecast for metro rail corridor at Kolkatta was over one million passengers. But, even after functioning for nearly a decade, it carries hardly 300,000 passengers[1]. It is

[1] Additional General Manager Railways (Retired), No. 58, Venkat Ratnam Nagar, Adayar, Chennai – 600 020, India

partly due to the system's inability to increase the frequency of service. The patronage level on a short length of MRTS in Chennai, commissioned six years back has been so low that it has made the critics to vociferously express their opinion that urban rail transit is not a viable proposition for Indian cities. Fare differential between rail and bus in both cases is high.

2. Objective of the Study

A superficial study of the trend in share of rail transit and vagaries in its growth indicates that out of pocket cost is a major factor influencing the choice of mode, even though level of service has some influence. Most of the demand estimation and modal split models used for forecasting rider ship level place emphasis on value of time saving more than on out of pocket expense. On the other hand, the examples quoted above would show that in Indian conditions, fare plays an important influence on rider ship. This study is aimed at finding out to what extent the fare structure affects the patronage and estimate fare elasticity of rail transit in India, both at macro level and at micro level using some readily available data. A number of studies have been conducted on the subject in other countries since 1947. Simpson and Curtin formula developed by John Curtin (1968)[4] is based on a regression analysis of 77 fare increases over a period of 20 years is in the form for shrinkage ratio:

Percent rider ship loss = 0.80 + 0.30 x Percent fare increase

The average shrinkage ratio for the 77 fare increases was found to be –0.36. Over the years, these have evolved into a rule of thumb, that a variation, increase (decrease) of 1 % in fare would result if decrease (increase) in rider ship of 0.36 %. In 1980, Ecosometrics, Inc. conducted a study for USDOT (Mayworm et al[6], 1980) collecting data from a number of systems in USA and London. According to that study, fare elasticity was in the range of – 0.17 ± 0.05 for Rapid Rail and – 0.31 for the one commuter rail they studied. The current study is aimed at checking to what extent the above findings are applicable to suburban rail system in India.

3. Elasticity of Demand and Measurement

'The elasticity of demand is a convenient measure of relative responsiveness of transit rider ship to changes in individual factors influencing demand.' It is defined as the ratio of proportional change in rider ship to the proportional change in the factor being observed. It is easier to study the elasticity in respect of fare than in respect of other changes. In case of fare elasticity, it indicates the percentage change in rider ship or patronage resulting from one percent change in fares. There are four forms of working out the elasticity of demand in transit. They are briefly described below (Mayworm, et al[6]).

Four forms of measurement of elasticity of demand.

3.1 Point Elasticity

It is a measure of the ratio of an infinitesimal proportional change in the fare, all other influencing factors kept constant. It expresses the elasticity at a point and cannot be used for measuring relationship between finite points of change in rider ship and fare. It also requires actual form of demand curve over a wide range of changes.

3.2 Shrinkage Ratio

Otherwise known as loss ratio or line elasticity, it is calculated as percent change in rider ship divided by percent change in fare. Mathematically, it is expressed as

$$E_{ar} = (\Delta Q / Q_1) / (\Delta F / F_1) \quad (1)$$

It is simple to calculate the shrinkage ratio and it is a good approximate measure of changes in rider ship for small changes in fare. It is more extensively used by US transit operators.

3.3 Mid point Elasticity

The difference between the elasticity at rising fare and decreasing fare is eliminated by working out for mid values of fares and rider ship between two points of time. Mathematically it is expressed as

$$E_{mid} = \{(Q_2 - Q_1) \times (F_2 + F_1)\} / \{(Q_2 + Q_1) \times (Q_2 - Q_1)\} \quad (2)$$

3.4 Arc Elasticity

The arc elasticity is defined as the logarithmic definition of elasticity. It is computed as follows:

$$E_{arc} = (\log Q_2 - \log Q_1) / (\log F_2 - \log F_1) \quad (3)$$

4. Approaches for Estimating Demand Elasticity

There are three approaches for determining demand elasticity with respect to change in fare or service level. They are (a) experimental or quasi- experimental (b) non-experimental approaches. The experimental analysis is based on data obtained by a practical demonstration of actual change in current service level or current fare. This requires data of before and after a change, which an operator only can collect. Alternatively, such analysis is possible with information on actual changes over a period from historical data, which is equivalent to a quasi-experimental approach. Non –experimental approach covers analysis done using time series data or through mode choice modeling using cross sectional data. When time series data can be used by concentrating on specific fare or service changes, it also can be classifies a quasi- experimental approach.

In a suburban rail system covering a network, it is difficult to carry out a practical demonstration by changing fare and service levels for short periods to conduct experiments. Only historical data or time series data which show some noticeable change in trend at any specific time when major change in fare or service level has occurred can be used for estimating demand elasticity. This is what is attempted in this study.

The fare system on Indian commuter rail system is a complicated one. The fare for single tickets is on a slab system for 0-10, 10-25, 26- 40, 41-49 km etc. Non-transferable Monthly Season Tickets (MST), on which any number of journeys can be performed, are issued again on a 5 km slab system of at a cost equivalent to about 15 to 10 times single fare. Quarterly Season tickets (QST) are issued at 2.5 times cost of MST. About two third of passengers are MST or QST holders. Hence it becomes difficult to work out the elasticity factor precisely. Railway wise or corridor wise data available cover both types passengers. For purpose of computation, one MST is equated to 50 journeys and one QST to 150 journeys. Average fare per trip can be computed by multiplying EPKM (earning per passenger kilometer) for the year on the system and average lead on the corridor for use in the analysis.

5. Data Available

As part of a research study in 1985, author had collected annual passenger trip statistics for the suburban rail in three major cities and for bus in Chennai. As part of the current study he has been able to collect similar data for the systems in Chennai only for later years. For the country as a whole, similar data could be obtained for period since 1980, with some gaps[2]. Both these data have been used for understanding the trend and if the fare changes have any noticeable impact at all. Data on annual loading at some selected stations on the suburban system in Chennai for a continuous period of six years, which included a year when there was a sharp change in fare level has been used for a quasi- experimental approach for determining fare elasticity at micro level.

Mumbai has two predominant suburban rail corridors, one on Western Railway and another on Central Railway. In connection with an Optimisation study, some data had been collected for a period of 11 years since 1987, which includes a year when there was a sharp increase in fare. This has been used as quasi- experimental data for determining the demand elasticity with respect to fare, corridor wise.

The recently commissioned MRTS corridor in Chennai has had very poor patronage level. A number of models were developed and used in the planning stage and later to forecast rider ship on the system. The most conservative estimate by conducting opinion survey amongst commuters on parallel roads forecast a minimum of 1.98 lakh daily trips on the length. But actual loading has been hardly one tenth of that estimate, even after six years of commissioning and despite the Railways' efforts to improve the services by increasing frequency.

6. Findings of Studies

6.1 General Trend in Growth

Figure 1 shows the annual passenger volumes on the total suburban rail networks in each of the three cities, Mumbai, Kolkatta and Chennai. While data available upto 1996-97 has been plotted for Mumbai and Chennai, for Kolkatta it indicates position upto 1986 only. It is learnt that presently, Kolkatta suburban rail system carries about 8 lakh trips per day. It appears to follow the trend in Mumbai. A study of the graph would show that there have been sharp drops followed by revival of earlier growth rate a number of times. It was in about 1974 that railways revised their minimum fare and also monthly season ticket structure. In 1981, they raised the minimum fare to 50 paise from 35 paise and again raised it to 75 paise in 1982. In 1984 it was increased to one rupee and in 1985 to Rs. 1.50. In this period, increase in bus fares in all three cities has not been so sharp. Since late eighties, the differential between bus and train fares in Mumbai has not been so significant as it has been in Chennai and Kolkatta. This leads one to a general conclusion that the loading on rail transit is very sensitive to raise in fares.

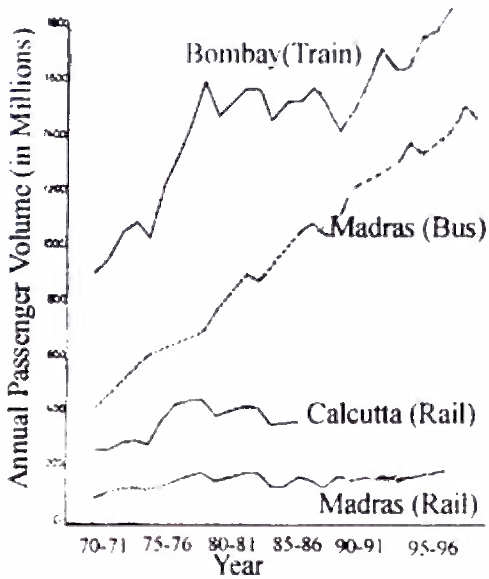


Figure 1. Trend in Growth of Traffic on Some Urban Transit

6.2 Demand Elasticity Using Data on a Corridor

6.2.1 Mumbai

Demand elasticity has been computed using data available on Central Railway and Western railway for years 1987-88 to 1997-98. There are two periods when there has been sharp drop in originating passengers on both systems viz., 1988-89 and 1993-94. Correspondingly, there have been sharp increases in EPKM in both years, amounting to about 22% on CR and 14 % on WR in first case and 33 % on both railways in the second case. Data for 1993-94 has been used for computing the different demand elasticity. Increase in number of trains operated was only 3 %. Hence the change can be attributed to rise in fare only. The elasticity worked out is as follows:

	Central Railway	Western Railway
Shrinkage Ratio	0.272688	0.157844
Arc Elasticity	0.357944	0.243165
Mid point Elasticity	0.361931	0.213048

The results would show that the demand on Western Railway is less affected by changes in fare structure than on Central Railway. The line passes through lengths with more commercial land use and if one observes the economic strata of commuters using it, he will note that they are slightly better off.

6.2.2 Chennai

There are three suburban rail corridors, which operate in Chennai. The Metre Gauge corridor is the oldest. On this there had been continuous growth of passengers till 1981 going upto 140 million, after which there has been a fall and leveling at the level of 105 to 115 million. The two main reasons are that there has been keen competition from bus transport on the road running parallel to this line for most length (with lower fare structure) and there had been no increase in number of trains. Hence this data cannot be used for any study on demand elasticity, which is affected by extraneous causes.

There are two BG corridors on towards north and one towards west. The suburban rail system using EMU services were introduced on these only in 1979. In the past over 20 years, there have been major inputs in terms of additional pair of lines and increase in number of trains on the east west corridor. There has been no such increase in the infrastructure or number of trains on the northern corridor. Data is available for 18 years during this period for passenger originating, number of trains in each year, vehicle kilometer per annum and EPKM as well as average lead. A multiple linear analysis has been done to study the effect of change in fare and change in level of service. Keeping the intercept constant, the relationship works out as follows:

$$Y = 0 + 0.0337\ X_1 + 2.7102\ X_2 - 0.9348\ X_3 \quad (4)$$
$$(0.72) \qquad (4.459) \qquad (0.573)$$
$$R^2 = 0.9051;\ \text{Adjusted } R^2 = 0.258;\ df = 3;\ F = 47.7014$$

Where,

y = Number of passengers originating in million, X_1 = Number of trains per day, X_2 = Million VKM per annum, X_3 = Earning per passenger in paise. (Combining both single journey and MST)

The relationship gives an idea of how the level of service and fare influence ridership. Number of trains represents frequency of service and VKM is a proxy variable for level of comfort with the route length of operation changing very little.

6.3 Quasi-Experimental Approach using Station-Wise Data

Data has been collected on the number of passengers originating at nine busy suburban stations, three on northern corridor, two on western corridor and three on southern corridor and at Chennai Beach, which is common to all three but serving the south bound MG corridor most. There has been steady growth noticed in first three years and there is sudden drop in 1992-93, except in Mambalam. This is a year in which EPKM had gone upto 11.67 paise from 9.48 in the previous year. Station wise the demand elasticity have been worked out and results are tabulated below in Table 1.

Table 1. Demand Elasticity due to change of Fare at Selected Stations in Chennai

Station	Daily ticket		Monthly Season Ticket	
	Shrinkage ratio	Arc elasticity	Shrinkage ratio	Arc elasticity
Minjur	0.43463	0.55687	0.29062	0.40146
Ennore	0.03611	0.04211	0.34858	0.50544
Thiruvottiyur	0.49783	0.66284	0.21228	0.28418
North corridor	0.33569	0.42282	0.28623	0.39693
Villivakkam	0.53693	0.64516	0.29041	0.38582
Ambattur	0.25297	0.35151	0.24696	0.33488
East west corridor	0.34567	0. 44018	0.26667	0.35801
Madras Beach	0.27491	0.33872	0.34054	0.49812
Guindy	0.16104	0.19180	0.25467	0.34379
Pallavaram	0.45038	0.58100	0.28290	0.38292
South (MG) Corridor	0.29423	0.36106	0.30393	0.43170

Note: Negative signs have not been included as they are common to all

Except in case of single journey trips from Ennore, the results are consistent. In general single journey demand is more sensitive to changes in fare structure than the season ticket journeys. This can be compared to similar analysis made in USA. In a quasi-experimental study done in off-peak hours, Boston commuter rail system showed an elasticity of – 0.31 as compared to – 0.55 on bus at the same time. Non- experimental study in London showed an elasticity of only -0.13 in London and –0.70 in New York (Mayworm et al[6])

6.4 MRTS Corridor in Chennai

As mentioned earlier, it is found that the demand on this short length corridor is highly sensitive to changes in fare and service level. The data for this corridor is available on monthly and quarterly basis for some period. It appears an ideal case to be simulated to a quasi-experimental analysis. The data on passenger booking on the stations in this 8.6 km corridor has been taken for the first quarter of 1998-99 and second quarter of 1998-99 have been considered. In end of June 1998 there was a hike in minimum fare (1-10 km slab) from Rs 2.50 to Rs 4.00. The daily ticket holder booking fell from 2841 per day to 1823 per day for one selected station. In this period, there was no significant change in number of trains run per day, which stood at 38 per day each way. Taking these figures as 'before' and 'after' patronage, analysis has been done. The period being short, natural growth factor has not been applied to estimate what should have been if there was no change in fare. The elasticities worked out are:

Shrinkage ratio	-1.07
Mid-Point elasticity	-1.10
Arc elasticity	-0.8643

Table 2 gives annual data since the section was commissioned in full. It will be seen that the single journey passengers on this section are highly sensitive to change in fare structure either on train or by bus on parallel route, as can be seen from the patronage in 1998-99 and 2000-01. It started falling in 2001-02 with the addition of safety surcharge and in 2002-03 with the minimum basic fare being increased by one rupee, thus increasing minimum single journey ticket costing Rs 6.00 against minimum of Rs 2.50 on LSS in bus. On the other hand there is steady growth in numbers of MST and QST holders, who would still find the monthly bus ticket cost to be not less than MST. Being fixed hour travelers with origin and destination within walking distance, they would find travel in train more comfortable. Also they appear to be influenced partly by increase in services, as can be seen from the rise after June 2001, when frequency was increased by resorting to shorter trains run more frequently, especially in peak hours.

Table 2. Originating Passengers, Levels of Service and Fares on MRTS Chennai

Period	Originating Passengers-Tickets issued			Total originating passengers	Number of trains per day/ average – one way	Fare on train		Bus fare –for 8km- Rs.
	Daily	MST[b]	QST[c]			Single upto 10 km- Rs.	MST >5 upto 10 km Rs	
1996-97	111545	4050	350	366545	NA	2.50	65	2.50
1997-98[a]	1171009	10959	624	1812559	38	2.50	65	2.50
1998-99	898044	16546	1217	1907894	40	4.00	75	1.75
1999-2000	768579	20188	1629	2022329	38/ 34	4.00	75	1.75/ 2.50
2000-01	896784	24075	2042	2406759	45/ 59	4.00	75	2.50
2001-02	715609	28480	2741	2550759	59	4.00/ 5.00*	75/ 85*	2.50/ 3.50
2002-03	548466	33263	3031	2666266	59	6.00	90	3.50

[a] Full section commissioned from 19th October, 1997
[b] Monthly Season Ticket;
[c] Quarterly Season Ticket- Fare at 2.7 times basic MST fare and surcharge.

* Fare includes a Safety surcharge of Re 1/- on daily ticket and Rs. 10/- on MST since 1st October 2001.
Railway fare includes a MRTS surcharge since 20th June 1998 of Re. 1/- on Daily ticket and Rs 20 on MST and Rs 60 on QST.

6.5 Study through Models using Cross-sectional Data

A number of behavioural model studies[5,7] were conducted in Anna University about 10 years back on modal choice of urban commuters in Chennai. It also corresponds to the period for which station wise analysis, mentioned above, has been done. Stratified sampling from work places was used in two studies. Multi-nomial Logit (MNL) models were developed for the sample population. Results obtained are given in Table 3

Table 3. Elasticity of Demand for Train Trips from Cross-sectional Data

Year	Study	Direct Elasticity	Cross Elasticity with respect to Bus fare
1992	Vijayakumar[5]	- 0.8190	0.2080
1993	Koteswara Rao[3]	- 0.5970	0.1390

It will be found these cross elasticities are much higher than what have been estimated using suburban rail data in earlier sections. This goes to show that the findings are in conformity with the following findings in the 1980 study of Mayworm et al.[6]

'The demand elasticities from cross sectional models are generally greater than time – series estimates. Chan and Ou (1978)[1] found that fare elasticities estimated from calibrated cross-sectional models, some of them behavioural-choice models, were almost twice as large as elasticities estimated from actual demonstrations and experiments'

7. Conclusion

Macro level analysis of data at all-India level and on two suburban rail corridors in Mumbai and one in Chennai have shown that the fare structure on the system, specially the minimum fare has definite impact on the patronage. The demand elasticity on Western Railway is the least followed by that on Central Railway. Demand elasticity of fare in Chennai is quite high, especially on short lead trips as in the MRTS. Comparatively, the MST passenger demand is less elastic to change in fare. The study shows that the demand in Indian conditions for commuter rail is more elastic with respect to fare than in western countries.

References

1. Sriramulu, C.T., Thomas, T., Reddy, K. Yagandhara, and Ponnuswamy, S., Mass Rapid Transit Systems and its Impact on Bus transport in Madras, *Highway Research Bulletin, No. 42*, Indian roads Congress, New Delhi, 1990.
2. Indian Railways, *Year Books, 1983- 84 and 2000-2001*, Ministry of Railways, Government of India.
3. Chan, Y and Ou, F.L. A Tabulation of Demand Elasticities for Urban Travel Forecasting. Presented in 57th Annual Meeting of the Transportation Research Bd., Washington, DC 1978
4. Curtin, John F. Effect of Fares on Transit Riding, *Highway Research Record 213*, Highway Research Board, Washington D.C., 1968.
5. Rao, M. Koteswara, Anantharajan, T., and Ponnuswamy, S. Mode Choice Analysis for Major Trips in Madras Using Logit Models, *ITPI Journal*, March, 1994, Indian Institution of Town Planners, New Delhi, 1994.
6. Mayworm, Patrick, Lago, Armando M., McEnroe, J. Mathew, *Patronage Impact of Changes in Transit fares and Services*, U.S. Department Of Transportation, Washington D.C., USA, 1980.
7. Ponnuswamy, S. and Vijayakumar, S. A Stochastic Approach to Modal Split Analysis of Work Trips in Madras, *Highway research Bulletin No.34*, Indian Roads Congress, New Delhi, 1994.

CE754: Economic Evaluation & Analysis of Transport Projects

Course Project

on

Economic Evaluation

of

BANGALORE METRO

Guided By:

Prof. S. L. Dhingra

Presented By:

Pankaj Yadav (08304005)

M.Tech (1st year)

Transportation Systems Engg. IIT Bombay

Introduction

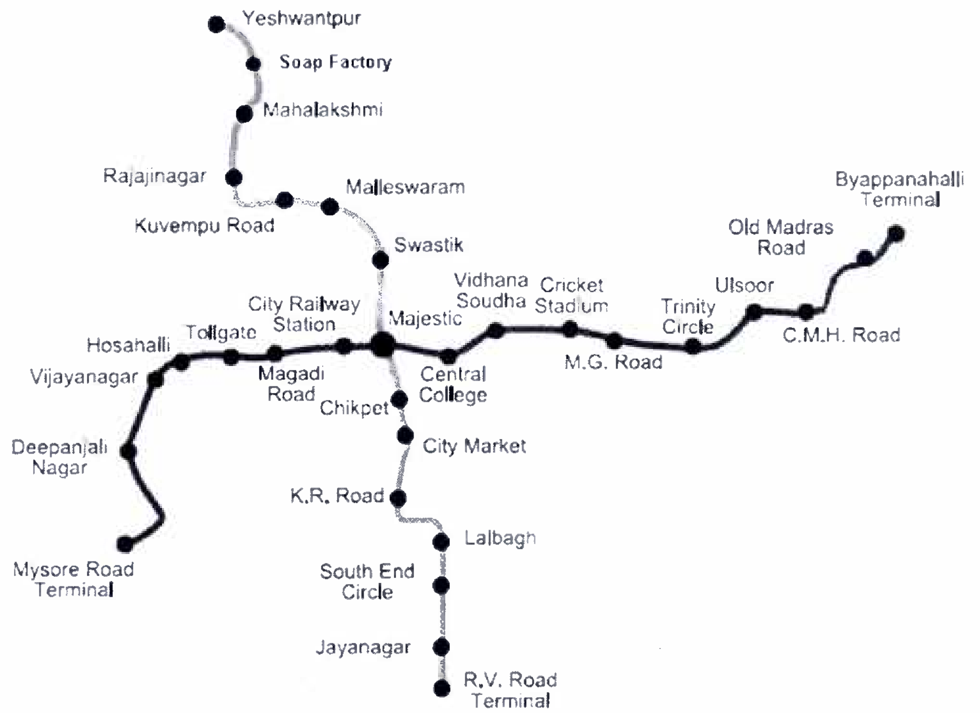
- Urbanized area with population of 6.2 millions
- Population density of 8367 per km^2
- Good Public transport facility is needed to facilitate movement of people.

Project description

The metro rail system consists of two dedicated corridors, namely East-West from Baiyappanahalli to Mysore road (Pantharapalya) and North-South from Yeshwanthpur to J.P. Nagar (R.V. Road terminal).

Total elevated stations 23, Underground 7 and Surface stations are 2 in both the corridors The total length of E-W corridor is 18.1 Km and the length of N-S corridor is 14.9 Km. The Baiyappanahalli and Yeshwanthpur terminal stations are expected to serve as depots/yards where Rolling stocks will be stabled and maintained. The electrically tractioned high tech coaches are Air Conditioned.

PROPOSED ROUTE MAP



Benfits of bangalore metro

- Comprehensive connectivity
- Convenience
- Comfort
- Frequency
- Safety
- Reduction in the pollution
- Reduction in the congestion on roads

Cost of the project

(in Rs. Crore)

Construction cost	5080 (5912)*
Interest during construction	348 (449)*
Financing charges and preoperative expenses	25 (29)*
TOTAL Current Cost	**5453 (6395)***

Figures in bracket refer to completion cost which is the current cost plus an annual escalation of 5% per year for the likely duration of the project

Stages involved in the economic analysis

- Identification and definition of the project.
- Collection of economic base data.
- Traffic surveys on existing facility.
- Traffic projections.
- Engineering design of proposed alternative schemes.
- Estimation of cost of new facility as per all alternatives considered.
- Traffic analysis on existing road and new facility.
- Estimation of road user benefits.
- Economic analysis.

Methods of economic evaluation

- Net Present Value Method (NPV).
- Benefit-Cost ratio (B/C) method.
- Internal Rate of Return Method (IRR).

Steps Followed in the Economic Evaluation

1. Estimation of economic costs of the project both, capital, as well as annual operating costs, for the assumed economic life of 25 years after the commencement of the project.

2. Estimation of annual recurring operation & maintenance costs at the current market price & its conversion into economic costs.

3. Identification and quantification of direct and indirect economic benefits to users, non-users

Estimation of Economic Costs

- Capital Cost
- Maintenance cost
- Road User Cost

The capital cost of the Bangalore Metro System is estimated at Rs 5912 crores. In addition, the project will require additional cost of Rs 478 crores to cover pre-construction planning and design cost, proof checking & supervising consultancy, legal and financial charges.

- Financial cost including other charges Rs 6395 crores.
- Economic cost with conversion factor of 0.85, i.e., Rs 5435.75 crores
- The annual cost of O&M has been estimated at Rs 320 crores in the first year of operation.

Categories of Benefits

- Reduction in travel time due to higher speeds.
- Savings in travel cost.
- comfort and convenience enjoyed by commuters.
- Environmental benefits
- Land appreciation cost

Estimated benefits (in crores)

Category of benefit	Year				
	2012	2017	2022	2027	2030
Savings in VOC	678	748.6	826.5	912.5	968.4
Savings in alternative transportation system	417	283.9	294.3	510.6	501
Environment benfits	60	75.7	81.3	89.03	8.03

Sensitivity Analysis

Sensitivity analysis takes into consideration uncertainties pertaining to forecast and critical parameters relating to cost and benefits. The analysis reveals the impact of changes in the following main variables

1.Increase in capital cost by 10%.

2. Decrease in benefits or benefits by 10%.

3. Combined effect of increase in project cost by 10% and decrease in revenue or benefits by 10%.

Result of Economic Evaluation Analysis

Sr. No.	Case	B/C	EIRR	NPV at 12% (Rs. In crores)
1	Base case	1.82	20.03	1510.57
2	Increase in capital Cost by 10 %	1.74	18.31	1099.32
3	Decrease in benefits by 10 %	1.31	15.31	788.36
4	Combined effect of increase in project cost by 10 % & Decrease in benefits by 10 %	1.25	11.87	377.52

Conclusion

The EIRR value is 20.03% for base case

The sensitivity analysis estimates that lowest EIRR value is 11.87%

The B/C ratio is 1.82 for base case

In worst condition of increase in project cost by 10% and decrease in revenue by 10% B/C is 1.25

The analysis shows that the project has a B/C ratio is more then one even for the worst case and has a good value of rate of return, so the project is economically feasible.

References:

- http://www.bmrc.co.in/.
- http://en.wikipedia.org/wiki/Bangalore_Metro
- http://www.bmrc.co.in/rrpackage.pdf

METROPOLITAN TRANSPORTATION PLANNING

DICKEY Virginia Polytechnic Institute & State University

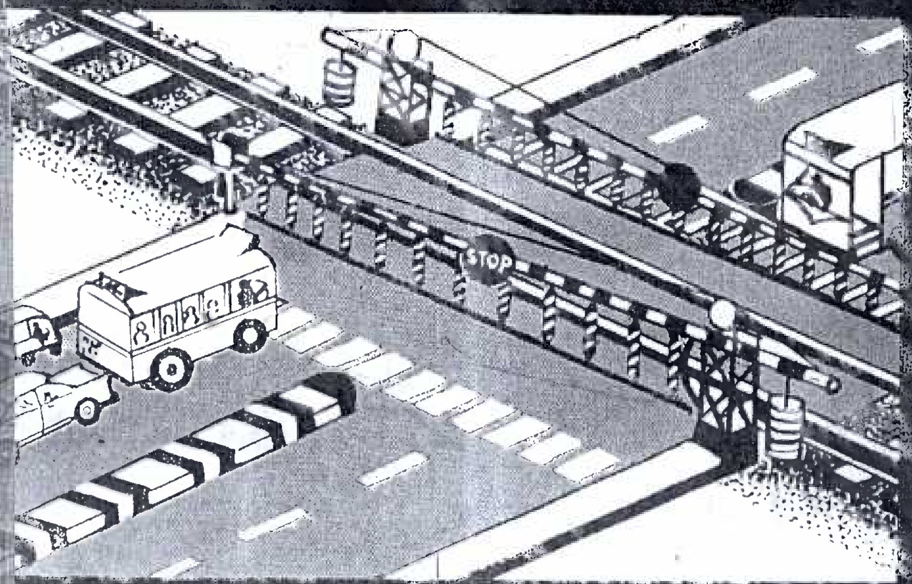
While emphasizing the transportation planning process, the contributors to this volume offer an insight into an interdisciplinary approach to solving metropolitan transportation problems. Consisting of an engineer, planner, architect, and landscape architect, these contributors provide a modular framework into which further information or various aspects of metropolitan transportation planning can be integrated.

TATA McGRAW-HILL PUBLISHING COMPANY LTD.
NEW DELHI

0-07-099278-9

METROPOLITAN TRANSPORTATION PLANNING

JOHN W. DICKEY



TMH EDITION

7.3 Memmott, F.: "Transportation Planning," in W. Goodman and E. C. Freund (eds.), *Principles and Practice of Urban Planning*, International City Managers Association, Chicago, 1968.
7.4 Southern California Regional Information Study: *An Interim, ACG-DIME Updating System, SCRIS Report No. 4, Census Use Study*, Southern California Assoc. of Governments and U.S. Bureau of Census, Los Angeles, 1970.
7.5 Southern California Regional Information Study: *The Long Beach California Experience, ACG-DIME Updating System, SCRIS Report No. 8, Census Use Study*, Southern California Association of Governments and U.S. Bureau of Census, Los Angeles, 1970.
7.6 System Development Corporation: *A Geographic Base File for Urban Data Systems*, Systems Development Corporation, Santa Monica, Calif., 1969.
7.7 U.S. Department of Commerce, Bureau of the Census: *The DIME Geocoding System, Report No. 4, Census Use Study*, Government Printing Office, Washington, D.C., 1970.
7.8 U.S. Department of Commerce, Bureau of the Census: *Use of Address Coding Guides in Geographic Coding, Proceedings to the 1970 Conference at Wichita, Kansas, Nov. 19–20*, Government Printing Office, Washington, D.C., 1971.
7.9 U.S. Department of Housing and Urban Development: *Urban and Regional Information Systems*, Superintendant of Documents, Washington, D.C., undated, c. 1968.
7.10 Urban and Regional Information Systems Association: *Geocoding-71; Papers from the Working Session on Geographic Base File Developments at the Ninth Annual Conference, Sept. 8–10, 1971*, Urban Data Processing, Inc., Cambridge, Mass., 1971.
7.11 Urban Renewal Administration and Bureau of Public Roads: *Standard Land Use Coding Manual*, Government Printing Office, Washington, D.C., 1965.
7.12 Weiss, S.: "Land Use Analysis," in W. Goodman and E. C. Freund (eds.), *Principles and Practice of Urban Planning*, International City Managers Association, Chicago, 1968.

8 Transportation Evaluation and Decision Making

The need to evaluate proposed alternatives and make decisions among them is one of the most pressing yet difficult requirements in the transportation planning process. When one considers the beneficial and disbeneficial impacts which transportation systems can have—among them the development of access to employment opportunities, the movement of valuable natural resources to places where they can be utilized more effectively and, on the other side of the ledger, the creation of hazardous and unsafe conditions for both users and nonusers of the system—he surely must have some feelings of uneasiness about the manner in which decisions affecting these important aspects of life might be made. He certainly would want to ensure that all possible avenues of approach had been explored so that the alternative providing the maximum benefits for the required financial outlays would be both detected and chosen.

The difficulties inherent in the evaluation and decision-making process are many and, unfortunately, of great consequence. While these will not be covered in depth now, it should be pointed out that the problems of making adequate predictions of the consequences of alternatives and of determining the relative importance of these consequences have made the responsibility of decision making a heavy burden to public officials.

Who, for example, could have foreseen years ago that the automobile would take the place of the front porch swing, that it would change building design to allow for drive-in banks and restaurants, or that it would help to create the spread of suburbia? Who can determine with any assurance that the value of a life saved from an automobile accident is $34,000, that a dollar spent on the appearance of subways is equally as beneficial as a dollar spent for added speed, or that private ownership of transit facilities is to be preferred by the public to governmental ownership or control? These are several of the many vexing problems which face the planner, engineer, and public official.

This chapter is divided roughly into three sections. First, the general theory of the benefit-cost evaluation technique is presented, followed by a detailed discussion and an example taken from the American Association of State Highway Officials (AASHO) *Road User Benefit Analyses for Highway Improvements* [8.1].[1] This presentation forms a basis for an evaluation of the advantages and limitations of evaluation techniques and leads into the more general approach of cost-effectiveness. Finally, having shown how decisions theoretically *should be* made, we proceed to discuss how some decisions *are* made and who makes them.

8.1 A FRAMEWORK FOR EVALUATING BENEFITS AND COSTS

Economists and others concerned with the benefits and costs of various alternative policies and actions long have worked with the "willingness to pay" idea summarized by Wohl and Martin [8.5, pp. 183-84]:

> For the case of public projects . . . all factors or elements of concern and value to the owning public and for which value the public would willingly pay to gain, or to keep from losing, will be included. . . . Generally, then, social or political factors enter the analysis only in those instances where society would be willing to forego financial or *other resources of value* in their stead. This assumption is made, first, since most tangible and so-called intangible objects of concern have a history of experience and have been valued at the marketplace (at least implicitly). . . . Second, this assumption is made to point out that factors of *presumed* concern to the owning public and for which they are *not* willing to forego something else of value (which *must* be foregone to achieve the object of concern) are just that--presumed rather than real.
>
> Also, it must be emphasized that lack of willingness to pay for some social objective (or at least to forego something else of value in order to achieve that goal) suggests the lack of real value associated with the objective.

The idea of "willingness to pay" is brought into reality through the "demand curve" which shows what quantity of a given product people are willing to purchase at a given unit cost for the product.[2] In the case of highways, the product that is offered is "trips" of a given type, while the unit cost is composed of such items as

[1] Because of its long title and red cover, this document usually is referred to as the "Red Book." This shortened title will be the one utilized throughout the remainder of this text.

[2] Most demand curves show the relationship between quantity and *price*, not cost. But most economists view "price" as something which evolves through a market interaction. But, since there is not explicit market interaction to establish a price for highway service, we prefer to use the word "cost" in this connection rather than "price."

vehicle operating and maintenance costs, tax payments, parking fees, and the time of the driver and his passengers.

As a basis for an example of a demand curve for a highway, consider the overly simplified situation presented in Fig. 8.1. Trips are made between cities A and B

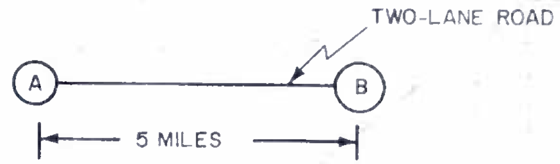


Fig. 8.1 A simple example of a roadway connecting cities A and B.

over a two-lane road which presently is 5 miles long. These trips, made during a given 1 year period, are all for the same purpose, are all done at one time of day, are all made by people of a similar socioeconomic background, and so forth. Under these conditions, and using procedures for travel prediction similar to those in Chap. 6, it is possible to construct a curve, such as that in Fig. 8.2, showing the number of trips made if the unit cost per mile of each trip were as indicated. Generally, it can be expected that as the unit cost per mile of each trip gets higher, there will be few yearly trips made over the road: thus the reason for the negative slope in the demand curve in Fig. 8.2.

In Fig. 8.2 it also can be seen that if the unit cost of travel were C_1, there would be v_1 yearly trips made. Further, it can be seen that some people would be willing to pay *more than* C_1, but would not be required to do so. For instance, v_2 trips would be made even if the cost were C_2 which is greater than C_1. As a consequence, there is a surplus (known as the "consumer surplus") which accrues to the people who are willing to pay more: they can take the money they are willing to pay but do not have to $(C_2 - C_1)$ and use it for some other purpose. This consumer surplus thus can be thought of as a benefit arising from tripmaking, and the summation of these benfits for all trips which are made gives the total benefit on yearly trips made by travelers.[3]

At this juncture, it should be noted that demand curves often are difficult to establish in practice. The correlation coefficients for trip generation presented in Chap. 6 certainly verify this statement. Of particular difficulty is the establishment of the end points in Fig. 8.2. It is a rare occurence when travel is either free or is so expensive that none is made. Because of these uncommon situations, observations at the extremes have been lacking, and no firm commitment can be made of exact

[3] The usual definition of benefits as proposed by economists includes the entire area between the demand curve and abscissa, whereas the definition employed in the Red Book follows that presented above. The distinction between the two concepts is not a crucial one for purposes of the exposition in this book, and so the Red Book definition will be adopted here. Economists usually denote the total consumer surplus as the "net benefits."

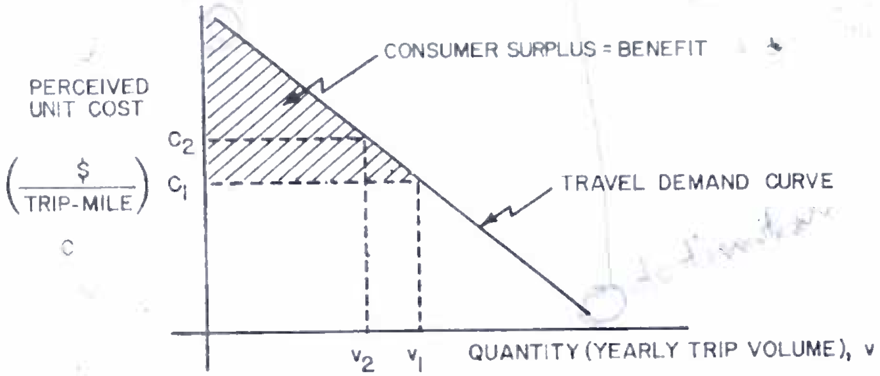


Fig. 8.2 Travel demand curve showing consumer surplus.

locations.[4] The result is that consumer surplus measurements also have been difficult to make.

Laying these problems aside temporarily, we can continue to develop the theoretical framework and at least determine what would be *desirable* insofar as an evaluation technique is concerned. The next step after establishing the demand curve would be to construct its counterpart—the supply curve. To do this, it is necessary to consider the short run elements of perceived cost associated with each mile driven on the example two-lane highway. Following the example of Wohl and Martin [8.5], the first of these costs might be for tax payments on gasoline, tires, and so forth. These would not be expected to vary greatly with the number of yearly trips made on the highway, so that an almost horizontal curve in Fig. 8.3 probably would be realistic.

[4] For an elaboration of this point see [8.21].

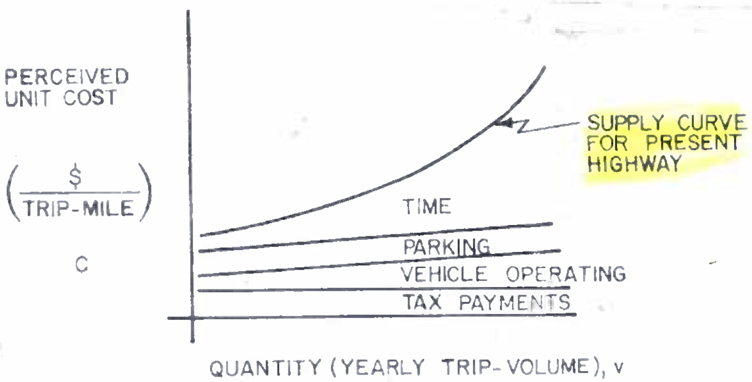


Fig. 8.3 Supply curve for travel.

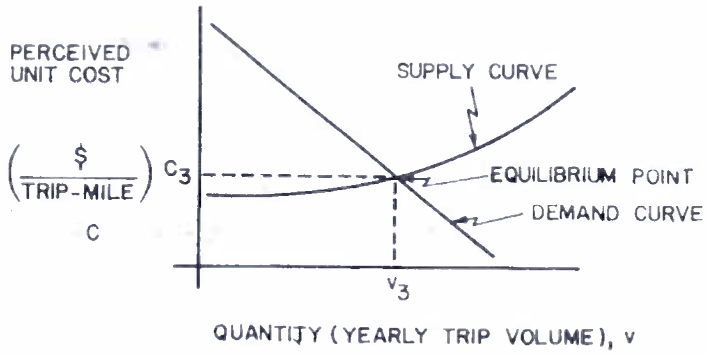


Fig. 8.4 Equilibrium of demand for and supply of travel.

In addition to tax payments, there would be the perceived unit vehicle operating costs to consider. A reasonable assumption would be that these would rise somewhat with increases in travel volumes since more traffic would mean more delays, more idling of engines, longer times on the road (and thus more gas consumption), and so forth. These prices, when added to those for tax payments, would bring the total unit costs *up to* the second lowest curve in Fig. 8.3. Following a similar line of reasoning, we would anticipate that parking costs would not vary significantly with volume but that travel time costs, the fourth and final type, might increase rather sharply with volume as congestion on the highway slows traffic and increases the time for each trip. The sum total of these four unit costs,[5] calculated for each yearly tripmaking level, is represented by the topmost line in Fig. 8.3. It should be remembered that this line is indicative only of the particular highway used in the example, and depicts the perceived cost to *supply* or handle the given number of yearly trips by that existing facility.

The combination of the supply curve for the example highway in Fig. 8.3 and the demand curve in Fig. 8.2 is diagrammed in Fig. 8.4. The crossing of the two curves forms an equilibrium point (v_3, C_3), which can be interpreted as follows:

> No amount of trips greater than v_3 will be made since, after a period of time, some people will find that the cost of making the additional trips is greater than they are willing to pay (the supply curve lies about the demand curve). Similarly, no amount of trips less than v_3 will be made since, after a period of time, some people will realize that the cost of making a trip is less than that which they are willing to pay (the supply curve lies below the demand curve). Thus, additional trips will be made until the unit costs equals that which the travelers are willing to pay.

The equilibrium point (v_3, C_3) therefore indicates the volume (v_3) of traffic that will use the example highway and the cost per trip mile (C_3) that the travelers

[5] It is not intended that these four costs represent an exhaustive set, but the general feeling seems to persist among transportation planners that these are the major costs which the automobile driver *perceives* as being significant. Other costs, such as car depreciation and insurance, do not appear to be important to the driver in determining whether to make *additional* trips.

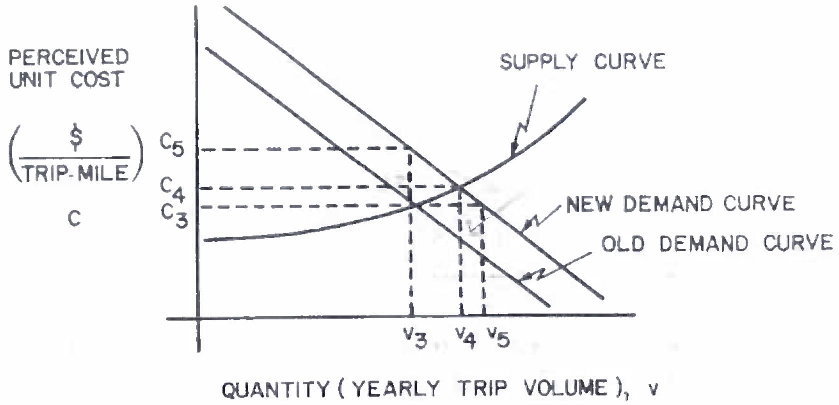


Fig. 8.5 Changes in tripmaking and unit trip cost resulting from increased demand.

will pay for making their trips. This cost then can be employed to calculate total benefits in a manner similar to that outlined in connection with Fig. 8.2.

The supply and demand curve concepts can be enlarged to take into account the consequences both of changes in demand and proposals for possible alternative highway improvements. By way of introduction to the first case, it has generally been true in the United States that overall income levels are rising,[6] and these increases usually lead to corresponding increases in the willingness of people to pay for certain goods or services. Thus, in referring back to Fig. 8.4, it can be seen that the perceived unit cost for a given number of trips, say v_3, will tend to increase over time or, stated another way, greater number of yearly trips will be made for a given cost. This type of change is indicated in Fig. 8.5, which also incorporates the demand curve from Fig. 8.2 and the supply curve from Fig. 8.3. The "new" demand curve rises above the "old" one for the reasons cited above.

One important point to notice in Fig. 8.5 is that a new equilibrium point (v_4, C_4), results from the establishment of the new demand curve. Interestingly enough, both the amount of money paid for travel and the number of trips increases the former from C_3 to C_4, the latter from v_3 to v_4. This situation implies that rising economic levels lead to increases in travel and explains to some extent why many transportation facilities are used to their capacity long before expected. These increases are part of what is known as "induced traffic."

Figure 8.6 shows the effect of a proposed new highway on the unit trip cost, number of trips, and benefits as regards travel between A and B. It is assumed that the new highway will be an "improvement" over the old one (which, for purposes of this example, will be eliminated after the new one is opened) in that there will be fewer and flatter curves, slighter grades, dual lanes in each direction, and so forth. With these conditions, it then follows that the new highway most likely will lead to

[6] For some relevant data, see Table 3.14 in Chap. 3.

a reduction in both the operating and travel time costs that help to make up the short run supply curve in Fig. 8.3.

The former costs would be lower primarily because of decreases in motor fuel needs brought about by the straightening of horizontal curves, the smoothing of vertical curves, and, in general, the creation of a more direct route between A and B, whereas the latter costs would be lower because of the ease of passing associated with the dual laning and, in general, the increased capacity of the new facility. The result of these effects, displayed in Fig. 8.6, would be a new short run supply curve associated with the new highway and lying below that for the present facility.

Also resulting from these travel cost reductions would be an increase in yearly tripmaking. By building a highway with a lower unit cost of travel, we can anticipate that more people would be willing to travel, and this is the case since at the new equilibrium point (v_6, C_6), the cost has been reduced from C_4 to C_6 while the number of trips has gone up from v_4 to v_6. This increase is another major component of "induced traffic."

Another result of a reduced cost of travel usually (and in this particular example) is an increase in benefits (as defined in Fig. 8.1). Looking at Fig. 8.7, which summarizes most of the information from the previous diagrams in this chapter, we can see that the benefits, B_p, of the present facility at the present time (old demand curve)[7] are

$$B_p = \tfrac{1}{2}(C_7 - C_3)(v_3 - 0) \qquad (8.1)$$

Similarly, the future benefits (new demand curve) that would result if the present highway were not replaced by the proposed one, would be

[7] For simplicity, and to follow the general procedure in the Red Book, a linear demand curve is assumed in the calculations to follow.

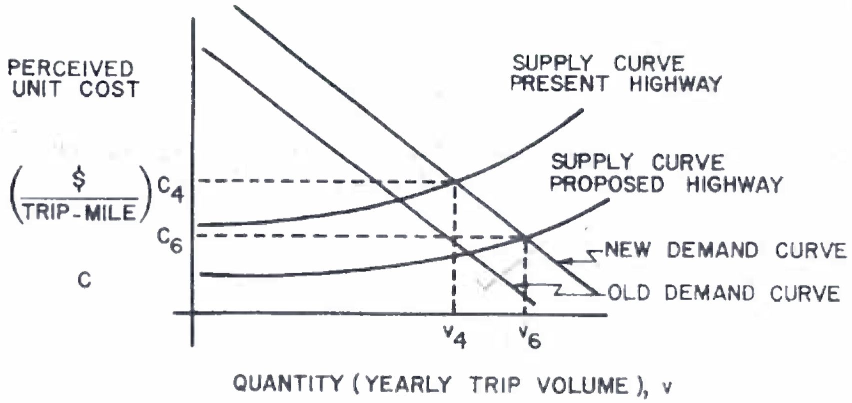


Fig. 8.6 Changes in tripmaking and unit trip cost resulting from a new highway facility.

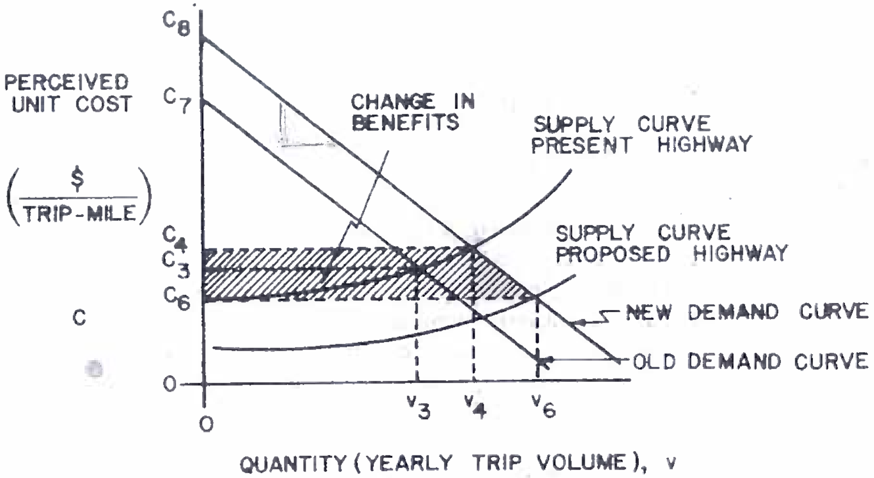


Fig. 8.7 Change in benefits from an increase in demand and from a proposed highway.

$$B_o = \tfrac{1}{2}(C_8 - C_4)(v_4 - 0) \tag{8.2}$$

Finally, if the new highway were constructed and the old one eliminated, the benefits, B_n, would be

$$B_n = \tfrac{1}{2}(C_8 - C_6)(v_6 - 0) \tag{8.3}$$

The increase in future benefits attributed to the new highway thus could be calculated via

$$B_n - B_o = \tfrac{1}{2}(C_8 - C_6)(v_6 - 0) - \tfrac{1}{2}(C_8 - C_4)(v_4 - 0) \tag{8.4}$$

which can be reduced to

$$B_n - B_o = \tfrac{1}{2}[C_8(v_6 - v_4) - C_6 v_6 + C_4 v_4] \tag{8.5}$$

Under the assumption of linearity and with a slope of $-(C_4 - C_6)/(v_6 - v_4)$ and an intercept of C_8, the general equation of the demand curve is

$$C = -\frac{C_4 - C_6}{v_6 - v_4} v + C_8 \tag{8.6}$$

Since the point (v_4, C_4) falls on the line, we obtain

$$C_4 = -\frac{C_4 - C_6}{v_6 - v_4} v_4 + C_8 \tag{8.7}$$

or

$$C_8 = C_4 + \frac{C_4 - C_6}{v_6 - v_4} v_4 \tag{8.8}$$

Substituting this into Eq. (8.5) results in

$$B_n - B_o = \tfrac{1}{2}\left[\left(C_4 + \frac{C_4 - C_6}{v_6 - v_4} v_4\right)(v_6 - v_4) - C_6 v_6 + C_4 v_4\right] \tag{8.9}$$

which, after algebraic manipulation, becomes

$$B_n - B_o = \tfrac{1}{2}(C_4 - C_6)(v_6 + v_4) \tag{8.10}$$

which is also the formula for the area of the shaded trapezoidal section in Fig. 8.7.

A point to be stressed at this time is that some benefits (or disbenefits) may accrue even if the proposed improvement is not built. In the example presented here, the change in benefits over time caused by the increase in demand is

$$B_o - B_p = \tfrac{1}{2}(C_8 - C_4)(v_4 - 0) - \tfrac{1}{2}(C_7 - C_3)(v_3 - 0) \tag{8.11}$$

This quantity may or may not be positive, depending on the magnitude of each of the unit costs and volumes. However, there most likely will be a change in benefits even if nothing were done. This situation implies that the "do nothing" alternative is one that has to be considered in its own right: it has an impact that may be significant. In fact, the existence of this alternative is one of the main reasons why the evaluation stage has been placed before the solution generation stage in the transportation planning process outlined in Chap. 2. It is imperative that the consequences of *not changing* from the present state be evaluated before any solutions are proposed. Otherwise, the planner or engineer has no basis by which to *compare* the benefits which may arise from various "improvement" schemes.

8.1.1 Accounting for Capital and Maintenance Costs

After the analysis of benefits is completed, it is necessary to look on the other side of the ledger—on the facility cost side. The primary component costs to be considered are those for right-of-way (land), grading and drainage, major structures, pavement, and, in a slightly different category, those for maintenance. The former set of costs, known as capital costs, generally are the most extensive, yet maintenance costs also can be significant. In either case, the objective at this point is to compare the benefits that will accrue from the expenditure of funds for the construction and maintenance of alternate highway facilities.

It should be noted at this juncture that the "benefits" calculated by means of Eq. (8.10) are stated in dollar terms just as the capital and maintenance costs are.

Each of the unit costs is expressed in dollars per mile per trip and volume of trips, of course, is expressed in "trips/year." Therefore, since in each equation we have the unit cost multiplied by the number of trips, we get (\$/trip-mile) × (trips/year) = (\$/mile/year) as the units for benefits. Benefits and costs thus are commensurate, that is, measurable in the same units. Commensurability naturally is desirable in an evaluation procedure since we do not, as the expression goes, want to "mix apples and oranges."

Another consideration which must be taken into account at this stage is that the benefits and costs associated with a transportation facility vary over time. Referring to the hypothetical curves in Fig. 8.8, we can see that if a new highway facility were constructed, the benefits would not start until its completion and probably would build over time as travel increased. The costs, on the other hand, would be extremely high at the beginning when the full amount of capital had to be expended, then would decrease sharply, followed by a slight increase over time as the facility started to approach the end of its service life and subsequently require more maintenance.

It would be quite cumbersome to calculate the area between the two curves in Fig. 8.8 to get the total difference between benefits and costs. As a consequence, most analysts will calculate average (over time) benefits and costs and use these for comparison purposes. The averages for the hypothetical curves in Fig. 8.8 also are presented in that diagram. The assumption of this procedure, at least insofar as cost to the agency responsible for evaluating the facility is concerned, is that the *initial* cost is not as important as the average long run cost. This assumption may not always be the correct one.

8.1.1.1 Interest rates A final consideration to be brought out before the comparison of benefits and costs can be made is that funds for capital costs often must be borrowed, and, of course, there are interest payments to be made if borrowing is necessary. Even if borrowing were not necessary, we should take into

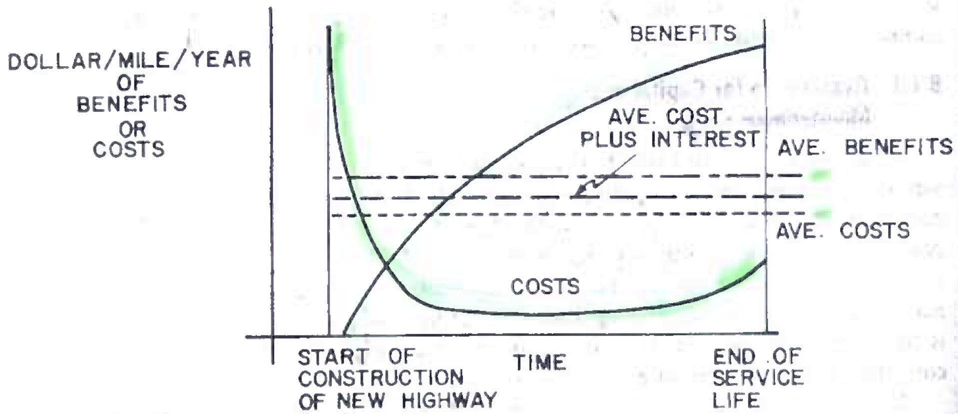


Fig. 8.8 Hypothetical changes in benefits and costs over time.

account the time value of money, which can also be represented by the interest rate. To understand this point one has only to remember that if an investment in a transportation facility cannot create monetary returns of at least, say, 3 percent per year (simple interest),[8] then the investor, be it a city, state, or federal government, or a private firm, would be better off financially by putting its funds into a savings account at a local bank. In other words, we would expect that all funds should be allocated in such a manner that they will have a return that compares favorably with any other of their possible uses: a 3 percent return is "no return" in the sense that most other investments would give back at least this amount. In conclusion, then, the benefits from a proposed or existing transportation facility should exceed the costs plus interest in order for it to be a worthwhile investment. The "average costs plus interest" curve has been superimposed in Fig. 8.8 to demonstrate this point.

What interest rate to use in a given situation is a matter of some debate. Of course, if funds are being borrowed, the actual interest rate can be employed. If not, then some other means must be found for making such a determination. Wohl and Martin [8.5] go into a considerable discussion on this issue and their book should be consulted for further information. While they come to no firm conclusions, they do appear to agree with quoted statements which set the rate at not lower than 4 percent and, hopefully, greater than 10 percent. We do not make any further recommendations except that the line of thinking of Wohl and Martin be followed in each case under study.

8.1.1.2 Calculating yearly costs With the adoption of an interest rate, it is then possible to calculate the average yearly payments for capital and interest together. This is accomplished through the use of the capital recovery factor ($CRF_{i,N}$), which shows the percentage (expressed as a decimal) of the capital costs which must be paid each year with a given interest rate (i) and service life (N). The equation[9] for $CRF_{i,N}$ is

$$CRF_{i,N} = \frac{i(1+i)^N}{(1+i)^N - 1} \tag{8.12}$$

Table 8.1, taken from the AASHO Red Book, allows for the $CRF_{i,N}$ to be read directly.

A common example of the utilization of the capital recovery factor is found in house payments. Suppose a mortgage (loan) of \$20,000 at 6 percent interest rate for 20 years is made on a house. What percentage of the \$20,000 must be paid each year?[10] To begin, let us note that if no interest were involved, the yearly payment would be \$20,000/20 years = \$1,000/year. This corresponds to a yearly percentage of \$1,000/\$20,000 = 5 percent. Thus, with interest involved, the percentage

[8] This figure has been chosen to represent a probable lower bound on the interest rate.
[9] This equation is not correct when $i = 0$. In that special case, $CRF_{0,N} = 1/N$.
[10] House payments generally are on a monthly basis, but this example is intended to have carryover to transportation facilities payments which usually are made annually.