CHAPTER ONE
INTRODUCTION

For years the transportation profession has emphasized mobility in the development of plans, programs, and projects. This emphasis on mobility—moving people and goods conveniently and efficiently between places has surely increased our society’s productivity and economic wealth. But it has also fostered the creation of homogeneous and inaccessible places, striking in their lack of character, comfort, and variety.

Transportation moves people and goods from one place to another using a variety of vehicles across different infrastructure systems. It does this using not only technology (namely vehicles, energy, and infrastructure), but also people’s time and effort; producing not only the desired outputs of passenger trips and freight shipments, but also adverse outcomes such as air pollution, noise, congestion, crashes, injuries, and fatalities.

FIGURE 1.1 TRANSPORTATION INPUTS AND OUTPUTS

This figure illustrates the inputs, outputs, and outcomes of transportation. In the upper left are traditional inputs (infrastructure (including pavements, bridges, etc.), labour required to produce transportation, land
consumed by infrastructure, energy inputs, and vehicles). Infrastructure is the traditional preserve of civil engineering, while vehicles are anchored in mechanical engineering. Energy, to the extent it is powering existing vehicles is a mechanical engineering question, but the design of systems to reduce or minimize energy consumption require thinking beyond traditional disciplinary boundaries.

On the top of the figure are Information, Operations, and Management, and Travellers’ Time and Effort. Transportation systems serve people, and are created by people, both the system owners and operators, who run, manage, and maintain the system and travellers, who use it. Travellers’ time depends both on free flow time, which is a product of the infrastructure design and on delay due to congestion, which is an interaction of system capacity and its use. On the upper right side of the figure are the adverse outcomes of transportation, in particular its negative externalities:

- By polluting, systems consume health and increase morbidity and mortality;
- By being dangerous, they consume safety and produce injuries and fatalities;
- By being loud they consume quiet and produce noise (decreasing quality of life and property values); and
- By emitting carbon and other pollutants, they harm the environment.

All of these factors are increasingly being recognized as costs of transportation, but the most notable are the environmental effects, particularly with concerns about global climate change. The bottom of the figure shows the outputs of transportation. Transportation is central to economic activity and to people’s lives, it enables them to engage in work, attend school, shop for food and other goods, and participate in all of the activities that comprise human existence. More transportation, by increasing accessibility to more destinations, enables people to better meet their personal objectives, but entails higher costs both individually and socially. While the “transportation problem “is often posed in terms of congestion, that delay is but one cost of a system that has many costs and even more benefits. Further, by changing accessibility, transportation gives shape to the development of land.

It has been said that if all the tools are hammers, then everything begins to look like a nail. Using traditional transportation measures based on travel speed and delay, urban area transportation plans and corridor studies emphasize building new or wider roads, or increasing the efficiency (increasing speed) of existing roads. They are Visine plans (not Vision plans) — as they seek to "get the red out" (red meaning severe congestion on most transportation planning maps) by using measures of speed to determine needs.

Transportation is often divided into infrastructure modes: e.g. highway, rail, water, pipeline and air. These can be further divided. Highways include different vehicle types: cars, buses, trucks, motorcycles, bicycles,
and pedestrians. Transportation can be further separated into freight and passenger, and urban and inter-city. Passenger transportation is divided in public (or mass) transit (bus, rail, commercial air) and private transportation (car, taxi, general aviation). These modes of course intersect and interconnect. Different combinations of modes are often used on the same trip.

1.1 TRANSPORT IN INDIA

Transport in the Republic of India is an important part of the nation's economy. Since the economic liberalization of the 1990s, development of infrastructure within the country has progressed at a rapid pace, and today there is a wide variety of modes of transport by land, water and air. However, India's relatively low GDP has meant that access to these modes of transport has not been uniform.

Motor vehicle penetration is low by international standards, with only 13 million cars on the nation's roads. In addition, only around 10% of Indian households own a motorcycle. At the same time, the automobile industry in India is rapidly growing with an annual production of over 2.6 million vehicles and vehicle volume is expected to rise greatly in the future.

In the interim however, public transport still remains the primary mode of transport for most of the population, and India's public transport systems are among the most heavily used in the world. India's rail network is the longest and fourth most heavily used system in the world, transporting over 6 billion passengers and over 350 million tons of freight annually.

Despite ongoing improvements in the sector, several aspects of the transport sector are still riddled with problems due to outdated infrastructure, lack of investment, corruption and a burgeoning population. The demand for transport infrastructure and services has been rising by around 10% a year with the current infrastructure being unable to meet these growing demands. According to recent estimates by Goldman Sachs, India will need to spend US$1.7 trillion on infrastructure projects over the next decade to boost economic growth, of which US$500 billion is budgeted to be spent during the Eleventh Five-Year Plan.

1.2 ENVIRONMENTAL ISSUES AND IMPACT

The National capital New Delhi has one of the largest CNG based transport systems as a part of the drive to bring down pollution. In spite of these efforts it remains the largest contributor to the greenhouse gas emissions in the city. The CNG Bus manufacturers in India are Ashok Leyland, Tata Motors, Swaraj Mazda and Hindustan Motors.
In 1998, the Supreme Court of India published a Directive that specified the date of April 2001 as deadline to replace or convert all buses, three-wheelers and taxis in Delhi to Compressed Natural Gas.

The Karnataka State Road Transport Corporation was the first State Transport Undertaking in India to utilize bio-fuels and ethanol-blended fuels. KSRTC took an initiative to do research in alternative fuel forms by experimenting with various alternatives—blending diesel with biofuels such as honge, palm, sunflower, groundnut, coconut and sesame. In 2009, the corporation decided to promote the use of biofuel buses.

1.3 TRANSPORTS IN DELHI

Delhi has significant reliance on its transport infrastructure. The city has developed a highly efficient public transport system with the introduction of the Delhi Metro, which is undergoing a rapid modernization and expansion. There are 5.5 million registered vehicles in the city, which is the highest in the world among all cities most of which do not follow any pollution emission norm (within municipal limits), while the Delhi metropolitan region (NCR Delhi) has 11.2 million vehicles. Delhi and NCR lose nearly 42 crore (420 million) man-hours every month while commuting between home and office through public transport, due to the traffic congestion. Therefore serious efforts, including a number of transport infrastructure projects, are under way to encourage usage of public transport in the city.

1.3.1 HISTORY

Prior to independence in 1930s, public transport in the city was in private hands, with people relying mainly on tongas and the bus services of the ‘Gwalior Transport Company’ and ‘Northern India Transport Company’. But with the growing city, it soon proved inadequate, thus Delhi Transport Corporation (DTC) bus system was established in May 1948. The next big leap in city transport was the opening of Delhi Metro, a rapid transit system in 2002.

1.3.2 OVERVIEW

Public transport in the metropolis includes the Delhi Metro, the Delhi Transport Corporation (DTC) bus system, auto-rickshaws, cycle-rickshaws and taxis. With the introduction of Delhi Metro, a rail-based mass rapid transit system, rail-based transit systems have gained ground. Other means of transit include suburban railways, inter-state bus services and private taxis which can be rented for various purposes. However, buses continue to be the most popular means of transportation for intra-city travel; they cater to about 60% of the total commuting requirements.
Private vehicles account for 30% of the total demand for transport, while the rest of the demand is met largely by auto-rickshaws, taxis, rapid transit system and railways.

Indira Gandhi International Airport (IGI) serves Delhi for both domestic and international air connections, and is situated in the south-western corner of the city. In 2005-2006, IGI recorded traffic of more than 20.44 million passengers. (Both Domestic and International), Heavy air-traffic has stressed on the need for a secondary airport, which is expected to come-up in the form of Taj International Airport near Greater Noida, alongside Delhi-Agra highway.

The Delhi government is planning to have 413 km of metro, 292 km of BRT, and 50 km each of monorail and light rail by 2020.

Currently, the only international service to Delhi is the Samjhauta Express to Lahore, while it is possible to change trains to board rail services to Bangladesh and Nepal which commence in other cities of India. In the future, a high-speed rail link is being considered that would link New Delhi with Kunming, China via Myanmar.

1.3.3 INTRA-CITY TRANSPORTS

A) ROAD TRANSPORT

Roads in Delhi are maintained by Municipal Corporation of Delhi (MCD), New Delhi Municipal Council (NDMC), Delhi Cantonment Board (DCB), Public Works Department (PWD) and Delhi Development Authority (DDA). At 1749 km of road length per 100 km², Delhi has one of the highest road densities in India. Major roadways include the Ring Road and the Outer Ring Road, which had a traffic density of 110,000 vehicles per day in 2001. Total road length of Delhi was 28,508 km including 388 km of National Highways. Major road-based public transport facilities in Delhi are provided by DTC buses, auto-rickshaws, taxis and cycle-rickshaws.

1) BUSES

The Delhi Transport Corporation (DTC) operates the world's largest fleet of CNG-powered buses. After Pune, Delhi was the second city in India to have an operational Bus rapid transit (BRT) system.

Delhi has one of India's largest bus transport systems. Buses are the most popular means of transport catering to about 60% of Delhi's total demand. Buses are operated by the state-owned Delhi Transport
Corporation (DTC), which owns largest fleet of Compressed Natural Gas (CNG)-fuelled buses in the world, private Blue line bus operators and several chartered bus operators. It is mandatory for all private bus operators to acquire a permit from the State Transport Authority. The buses traverse various well-defined intra-city routes. Other than regular routes, buses also travel on Railway Special routes; Metro Feeder routes. Mudrika (Ring) and BahriMudrika (Outer Ring) routes along Ring and Outer-Ring road respectively are amongst the longest intra-city bus routes in the world.

With the introduction of Bus Rapid Transit (BRT) and the development of dedicated corridors for the service, bus service is set to improve. The DTC has started introducing air-conditioned buses and brand new low-floor buses (with floor height of 400 mm and even higher on one third area as against 230 mm available internationally.) on city streets to replace the conventional buses. A revamp plan is underway to improve bus-shelters in the city and to integrate GPS systems in DTC buses and bus stops so as to provide reliable information about bus arrivals.

In 2007, after public uproar concerning the large number of accidents caused by privately-owned Blueline buses, the Delhi government, under pressure from the Delhi High Court decided that all Blueline Buses shall be phased out and be eventually replaced by low floor buses of the state-owned DTC. The Delhi Government has decided to expedite this process and will procure 6,600 low floor buses for the DTC by commonwealth games next year.

By 2010, Delhi will have over 8000 buses, of which Delhi Transport Corporation will provide 6000 while 2,000 would be blue line buses, 3125 will be low-floor, 1100 semi low floor and 1000 of them would be air-conditioned. Few buses would have GPS to prevent them from straying to other routes. The city already has 655 low-floor AC and non-AC buses. The bus routes are also being increased to 670 from the current 357 routes. Delhi plans to add at least 2500 of these new buses by the end of 2009. The city has been divided into 17 clusters. Bus services in each of these clusters will be run by private operators. The first cluster is to be awarded by September 2008. The first cluster has 32 routes, on which a total of 295 DTC and 270 private buses will run. The operators will be given the option of running 20 percent AC buses with the introduction of new buses, DTC will be recruiting 4000 drivers to run the new buses.

In November 2009, DTC piloted a program to introduce the smart card where the commuters would be able to pay the fare through the smart card. They have decided to install the machines in 10000 buses.
2) AUTO-RICKSHAWS

The auto-rickshaws (popularly known as Auto) are an important and popular means of public transportation in Delhi, as they are cheaper than taxis. Hiring an Auto in Delhi is very tricky, as very few auto-drivers agree to standard meter charges. The typical method is to haggle for an agreeable rate. This is often a source of conflict for both Indians and visitors. Drivers tend to overcharge and make exorbitant demands. But there are a few that are nice. It is recommended to tip the good ones extra.

3) TAXIS

Though easily available, taxis are not an integral part of Delhi public transport. The Indian Tourism Ministry and various private owners operate most taxis. The Tourism Ministry grants private companies permits to operate taxis. Recently, Radio Taxis have started to gain ground in Delhi. Brands such as Mega Cabs, Kreative Travel India, EasyCabs, etc., provide the on-call radio taxi service, which is slightly more expensive than conventional Black and Yellow taxis. Other than these two mentioned companies such as Hertz Car Rental and Avis Car Rental provide rent-a-car service.

4) TAXI AND AUTO FARE CALCULATOR

One can use a service at http://www.taxiautofare.com to calculate the Taxi and Auto fares in Delhi. The user has to enter in the source and destination. The service gives the estimated taxi and auto fare as well as a Google Map that shows the route.

5) CYCLE RICKSHAWS

Cycle-Rickshaws are a popular mode of travel for short distance transits in the city. The pedal-powered rickshaws are easily available throughout the city and reckoned for being cheap and environment friendly. Often, tourists and citizens use them for joyrides, too. Of late, they have been phased out from the congested areas of Chandni Chowk because of their slow pace, which often leads to traffic snarls on the streets of Old Delhi. Still, they are the great source of public transport in Delhi.

MAJOR ARTERIES

The 32 lane toll gate at National Highway 8 is the largest in Asia and third largest in the world.
1) INNER RING ROAD

Inner Ring Road is one of the most important "state highways" in Delhi. It is a 51 km long circular road, which connects important areas in Delhi. Owing to more than 2 dozen grade-separators/flyovers, the road is almost signal-free. The road is generally 8-laned with a few bottlenecks at certain stretches, which are being removed. The road has already achieved its carrying capacity of 110000 vehicles per day and would require an addition of more lanes to fulfil needs of increasing traffic by 2011.

2) OUTER RING ROAD

Outer Ring Road is another major artery in Delhi. The road which was almost neglected till early 2000s is now an important highway that links far-flung areas of Delhi. The road is 6-8 lane and has grade-separators and a large number are under construction as a part of project to make the artery signal free. The road along with the ring road forms a ring which intersects all the National Highways passing through Delhi.

3) EXPRESSWAYS AND HIGHWAYS

Delhi is connected by NH 1, 2, 8 and 24. It also has 3 expressways (6 and 8 lane) that connect it with its suburbs. 4 more expressways are also planned and are supposed to be finished by 2010. Delhi-Gurgaon Expressway connects Delhi with one of its financial hubs, Gurgaon. DND Flyway connects Delhi with its other financial hub, Noida.

Noida-Greater Noida Highway connects Noida with Greater Noida, which is an upcoming financial and commercial hub and is also to have a new international airport. The construction work for 135.6-km long Delhi Western Peripheral Expressway also known as the Kundli-Manesar-Palwal Expressway (KMP) is going on at full swing. Kundli-Manesar-Palwal (KMP) expressway expected to become operational by June 2009, Delhi will be relieved of the congestion of heavy night traffic. It will act as a bypass for the night vehicles. Ghaziabad - Faridabad - Gurgaon Expressway is a bypass corridor for traffic coming from South West and going towards East. It is currently under construction. Faridabad Road is a 4 lane highway road which connects Faridabad, major suburb to Delhi. Upgradation to expressway is underway.

Ghaziabad Road is a 4 lane highway road which connects Ghaziabad to Delhi. As the Commonwealth Village is located close by Yamuna bridge on this highway, underpasses and flyover being built will help facilitate traffic between the eastern areas of Delhi/Western UP and the rest of the city. If the underpass, flyovers and bridges are constructed in time they might be extended to Ghaziabad.
B) RAIL TRANSPORT

Rail based transport in the city has started to gain-popularity with the introduction of Delhi Metro. Ring-Railway, which runs parallel to the Ring-Road system, is another rail-based intra-city transport facility in Delhi.

1) METRO

Rapid increase of population coupled with large-scale immigration due to high economic growth has resulted in ever increasing demand for better transport, putting excessive pressure on the city's existent transport infrastructure. Like many other cities in the developing world, the city faces acute transport management problems leading to air pollution, congestion and resultant loss of productivity. In order to meet the transportation demand in Delhi, the State and Union government started the construction of an ambitious Mass Rapid Transit system, known as Delhi Metro in 1998. The project started commercial operations on December 24, 2002. It has set many performance and efficiency standards ever since and is continuously expanding at a very rapid pace. As of 2010, the metro operates 5 lines with a total length of 190 km and 132 stations while several other lines are under construction.

Description of four Delhi Metro lines that currently operate as of April, 2010:

| TABLE 1.1  DELHI METRO LINES IN OPERATION |
|-----------------|-----------------|--------------|-----------------|
| NAME | TERMINALS | LENGTH (km) | STATIONS | ROLLING STOCK |
| Red | Dishad Garden – Rithala | 25.09 | 21 | 23 Trains |
| Yellow | Jahangirpuri- Huda City Centre | 45 | 34 | 40 Trains |
| Blue | Noida City Centre- Yamuna Bank-Dwarka Sector 9 | 47.40 | 42 | 43 trains |
| Blue | Yamuna Bank-Anand Vihar | 6.25 | 5 | 4 trains |
| Green | Inderlok-Mundka | 15.15 | 14 | 13 trains |
The second phase (Phase II) is completed which has 128 km of route length and the completion is scheduled for September 2010 just before the CWG Phases III (112 km) and IV (108.5 km) will be completed by 2015 and 2020 respectively, with the network totalling 413.8 km, making it longer than the London Underground. With further development of the city, the network will be further expanded by adding new lines, thus crossing 500 km by 2020.

2) RING RAILWAY

Ring railway is a circular rail network in Delhi, which runs parallel to the Ring Road and was conceived during the Asian Games of 1982. The system is not popular amongst people and a total failure as far as public transport is considered. The major reasons for failure of the system are lack of proper connectivity, less population density in areas of reach. The network is now utilized as a freight corridor and limited passenger train services are available during peak hours.

1.3.4 INTER STATE TRANSPORT

1) RAILWAY CONNECTIVITY

Delhi is connected to whole of the nation through Indian Railways vast network. New Delhi Railway Station which is one of the busiest stations in Indian Railway system serves as headquarter of Northern Railways. A large load of inter-state transport is borne by railways. Major railway stations in the city include New Delhi Railway Station, Old Delhi Railway Station, Hazrat Nizamuddin Railway Station, Sarai Rohilla and Anand Vihar Railway Terminal. A large number of local passenger trains connect Delhi to its sub-urban areas and thus provide convenient travel for daily commuters. Railways also share a large amount of freight traffic in Delhi.

2) ROAD

A) HIGHWAYS

The city is believed to have highest road density in the country and is well connected to rest of the nation through five major national highways, namely NH 1, NH 2, NH 8, NH 10 and NH 24. The highways around city are being upgraded into expressways with ultra-modern facilities.

B) BUS SERVICE
Regular bus services are available from inter-state bus terminals in the city. The services are extended to all the northern states and the neighbouring areas of Delhi. Services are provided by state transport corporations and several private operators. The inter-state terminals in city are:

- Kashmiri Gate ISBT in Northern Delhi
- Anand Vihar ISBT in Trans-Yamuna area
- Sarai Kale Khan ISBT in South Delhi

3) AIRPORTS

Indira Gandhi International Airport (IGI) serves Delhi for both domestic and international connections, and is situated in the south-western corner of the city, alongside Delhi-Gurgaon Expressway. In the year 2006-2007, IGI recorded traffic of 20.44 million passengers. It is currently the busiest airport in South Asia. It operates two terminals — Terminal 1 for domestic and Terminal 2 for international air travel.

The airport is witnessing massive expansion and modernization by a consortium led by GMR. The airport will get a new integrated Terminal 3 by 2010. Terminals 4, 5 and 6 will be built in a phased manner. By 2024, airport will have four runways and will handle more than 100 million passengers per year, which is more than what Atlanta airport (world's busiest airport) handles now.

Apart from the expanded IGI airport, Delhi might also receive a second airport by 2012-2013. The airport, being named as Taj International Aviation Hub, is proposed be located in Jewar in Greater Noida. It would be 75 km from IGI airport.

1.3.5 FUTURE PROJECTS

There are many transport infrastructure projects underway in Delhi. Most have their deadlines set in late 2009 and early 2010, just before the 2010 Commonwealth Games. They are listed below -

- Bus Rapid Transit corridors
- Taxi systems
- Revamp of DTC bus fleet, to include semi-low-floor, low-floor and air-conditioned buses.
- Development of Eastern and Western Peripheral Highways to take off the load of inter-state traffic from roads of Delhi.
RAIL

- Upgrading of New Delhi and Old Delhi railway stations of Northern Railways.
- Expansion of existing Delhi Metro network, including a super-fast Delhi Airport Express Line having maximum speed of 135 km/h line to connect to IGI Airport.
- Introduction of Monorail (45 km) and Light Rail Transit has been aborted till 2010
- Anand Vihar Railway Terminal (about to be completed) to reduce the train loads over Old Delhi Station and New Delhi Railway Station. Besides that the station will also serve the densely populated Eastern part of Delhi, along with the neighbouring suburbs of Ghaziabad and Noida.
- A high-speed rail link that would link New Delhi with Kunming, China via Myanmar

AIR

- Revamp of IGI Airport is underway to improve its infrastructure, passenger capacity and efficiency.
- A secondary airport is in planning stages and will come up near Greater Noida.
1.4 DELHI METRO

Delhi became the seat of Government of India in 1911 when the then Imperial Government shifted its capital from Calcutta to Delhi. Initially the capital was located on the Ridge, north of the walled city of Delhi. As this site was not found suitable to serve as the seat of the Government, a new city, namely, New Delhi, located to the south of the walled city was planned. Construction work of New Delhi started in 1912 under the supervision of renowned city planners and architects, Sir Edwin Lutyens and Sir Herbert Baker. Construction of New Delhi was completed in 1931 when the seat of the Government was shifted to this new place. The city has continued to grow since then at a fast pace.

National Capital Territory of Delhi today covers an area of 1486 sq Kms and is a Union Territory with all powers of State Government. The history of planning a Metro Project for Delhi dates back to 70's. The Central Road Research Institute (CRRI) undertook the first exhaustive study on traffic and travel characteristics of Delhi in 1969-70. While bringing out extensive data describing the traffic and travel characteristics, it developed mathematical models to project travel demand. By examining several alternatives, it recommended for a Mass Rapid Transit Network for Delhi. Metropolitan Transport Team (MTT), Indian Railways, has reviewed the above schemes. MTT sought for some modifications to recommendations of CRRI and planned for a well knit Mass Rapid Transit System for the capital city of India. The system comprised of 36 Km of underground corridors aligned two axes North-South and East-West Corridors and 96 Kms of surface rail corridors. Metropolitan Transport Project (MTP-R, set up by the Ministry of Railways, Government of India) prepared an engineering plan to construct the MTR system.

Since CRRI proposal was based on transport demand projection up to the year 1981, it was assigned to Town & Country Planning Organisation the work of further projection of demand to the year 2001. Its concept plan envisaged a network of 58 km underground & 195 km surface corridors. As a part of the techno-economic feasibility study, subsoil exploration were conducted on four specific trunk routes and by the side of existing railway tracks and recommended for taking up pilot projects.

Delhi Development Authority (DDA) prepared a perspective plan for Delhi (MPD-2001) in 1984 and recommended for a multi modal transport system comprising of 200 km of Light Rail Transit System, 10 Km of Tramway, an extension to surface rail system and extensive road network. The Urban Arts Commission suggested some modifications to the proposal of DDA and recommended for the development of the existing Ring Railway with three radial underground MRT corridors.

Due to rapid growth especially along the western and eastern parts of the city, a study group was appointed by the Ministry of Railways, Govt. of India to recommend a precise alignment for the East-West corridor.
Feasibility Report on Integrated Multi Modal Mass Rapid Transport System of Delhi (IMMRTS) prepared by RITES recommended for three-component system comprising of Rail corridors, Metro corridors and dedicated bus way totalling to 184.5 Km and further addition of 14 km increased to 198.5 km. The total network contains 16 sections to be implemented in a sequence based on passenger kilometer carried per kilometer length of each section. The first phase of the network, now (commissioned) comprises of 65.11 km of route length with 13.01 km underground called Metro corridor and 52.10 km surface / elevated called Rail Corridor.

1.4.1 NEED FOR MRTS

As cities grow in size, the number of vehicular trips on road system goes up. This necessitates a pragmatic policy shift to discourage private modes and encourage public transport once the level of traffic along any travel corridor in one direction exceeds 20,000 persons per hour.

Introduction of a rail based (MRTS) Mass Rapid Transit System is called for. Mass Rapid Transit Systems are capital intensive and have long gestation period. It has been observed that in developed countries, planning for mass transit system starts when city population size exceeds 1 million; the system is in position by the time the city population is 2 to 3 million and once the population exceeds 4 million or so, planned extensions to the Mass Rapid Transit Systems is vigorously taken up. In developing countries including India, because of paucity of funds planning and implementation of rail based Mass Rapid Transit Systems has been lagging far behind the requirements.
The city of Delhi with a population of round 12 (16.2) million should have had an MRTS network of at least 100 (300) KM by this time, whereas actually it is still (65.10 kms) at the take-off stage. Delhi has all the ideal dress-up for an excellent Mass Rapid Transit System to be brought in. It has wide roads (roads cover 23% of the city area) where road possession for construction is not difficult (except in the old city area). Implementation will also not involve demolition of large scale private properties. Most of the land required is under Government control and hence can be easily acquired.

The citizens are enlightened and would eagerly welcome introduction of people friendly MRTS though they may initially face some difficulties during the implementation phase. Added to this Delhi has an unassailable advantage in its excellent railway network comprising two rings and six spurs totalling about 120 KM within the urban area.

Unfortunately, these Rail assets are not presently fully being utilized as its share of commuter traffic is only a mere 2%.

Delhi has experienced phenomenal growth in population in the last few decades. Its population has increased from 57 lakhs in 1981 to 120 (162) lakhs in 1998 (2006) and is poised to reach 132 (190) lakhs by the year 2001 (2011). For want of an efficient mass transport system, the number of motor vehicles has increased from 5.4 lakhs in 1981 to 30 (51) lakhs in 1998 (2007) and is (increasing at the rate of 6.21 per annum). The
number of motor vehicles in Delhi is now more than that of Mumbai, Calcutta, Chennai put together. The result is extreme congestion on Delhi roads, ever slowing speeds, increase in road accidents fuel wastage and environmental pollution with motorized vehicles alone contributing to about two thirds of the atmospheric pollution.

Today the traffic on roads of Delhi is a heterogeneous mix of cycles scooters buses cars and rickshaws jostling with each other. This has resulted in a chaotic situation so much so that due to road accidents, the average number of persons killed per day has increased to 5 and of those injured to 13. The position is expected to deteriorate further in the years to come.

To rectify this situation the Government of India and the Government of National Capital Territory of Delhi, in equal partnership have set up a company named Delhi Metro Rail Corporation Ltd. under the Companies Act,1956 which has (already commissioned a 65.10 kms route in Phase-I and is proceeding ahead with another 121 kms in Phase –II).

**1.4.2 DELHI METRO RAIL- THE LIFE LINE**

Metro rail service in Delhi has come as a much awaited gift for the people of Delhi, which has indeed changed the transport facility of the city. It has become the "life line" of Delhi as people are dependent on Delhi Metro for commuting to different places within the city. Delhi Metro Project has been recognized all over the world for its specialty in terms of a hi-tech rail and better equipped transport system. The project is under the Delhi Metro Rail Corporation, DMRC and it deserves all the credit for transforming the transport service of the city.

Metro rail in the city has reduced the traffic to some extent and the pollution level has certainly declined. Construction of Metro is still in progress in other parts of the city as the network of Delhi Metro is expected to cover whole of Delhi by the year 2010. Delhi Metro is equipped with modern facilities and the state of art design makes it very different from other metro rails in the world. Security within the metro rail has been give prime importance. The train ensures the safety and comfort of passengers with hi-tech compartments having adequate security cover. The compartments are fully automatic with gates being operated automatically and there are emergency exits in the train. You can communicate with the driver of the train at any point in case of an emergency.

Metro Rail stations have been designed keeping in view the comfort of the passengers and the traffic on the road. Each and every station of Delhi Metro has sufficient parking to provide hassle free commuting where people can park their cars and use the metro service. The stations have an international in them and the immaculate facilities within the stations make feel proud of the service offered by DMRC. The stations have
special for handicaps and senior citizens with escalators and lifts in. The computerized ticketing system makes transit in and out the metro very smooth. DMRC also gives the option of possessing card if you are a daily traveller and wish to avoid standing queues for tokens.

FIGURE 1.3 DELHI METRO
1.4.3 DELHI METRO

The creation of Delhi Metro has ushered in a new era in travel. With the opening of the first line in 2002, the metro has revolutionized the mass rapid transportation system of the capital. So much so, today one cannot imagine life in Delhi without Metro.

The birth of Metro (an electrically powered train operating on reserved tracks in urban areas) dates back to 1863, when the 6 Km underground railway was constructed between Paddington & Farringdon in London.

Since then, over 130 cities in Europe, Asia and America have built their own metro systems. In Africa, Cairo is the only city with a metro system, while Australia has only tramway and light rail systems. The development potential of Metro projects is far from saturation point, as there will be some 560 cities, 300 of them in Asia, with populations of over one million by 2015.

More than just an urban mode of transport, Metro is a key factor in providing better quality of life.

The Delhi Metro is a rapid transit system serving Delhi, Gurgaon, Noida and Ghaziabad in the National Capital Region of India. The network consists of six lines with a total length of 189.63 kilometres (117.83 mi) with 142 stations of which 35 are underground. It has a combination of elevated, at-grade and underground lines and uses both broad gauge and standard gauge rolling stock. Its overhead rapid transit and there are 3 trains: Mitsubishi-ROTEM Broad gauge, Bombardier MOVIA, Mitsubishi-ROTEM Standard gauge.

Delhi Metro is being built and operated by the Delhi Metro Rail Corporation Limited (DMRC). As of November 2010, DMRC operates around 2,700 trips daily between 6:00 and 23:00 running with an interval of 2.5 minutes between trains at peak frequency. The trains are mainly of four coaches, but due to increase in passengers numbers, six-coach trains are also added on red line (Dilshad Garden to Rithala), Yellow Line (Jahangirpuri to HUDA city centre), Blue Line (Dwarka sec -21 to Vaishali/NOIDA city centre) on the network . The power output is supplied by 25-kilovolt, 50 Hertz alternating current through overhead catenaries. The metro has an average daily ridership of 1.7 million commuters, and, as of July 2011, had carried over 1.25 billion commuters since its inception.

Yellow Line in 2004, the Blue Line in 2005, its branch line in 2009, the Green and Violet Lines in 2010 and
the Delhi Airport Metro Express in 2011.

1.4.4 GENESIS

FROM IDEAS TO ACTION: THE GENESIS OF DELHI METRO

The development of the Delhi Metro took 32 years since a Mass Rapid Transit Network for Delhi was first
recommended.

1969-70: The Central Road Research Institute carries out an exhaustive study on traffic and travel
characteristics of Delhi, based on the transport demand projection for 1981, and submits its report.

1975: The Metropolitan Transport Project (MTP), Delhi, conducts surveys and recommends a Mass Rapid
Transit System (MRTS) network comprising of 36 Km of underground corridors and 97 Km of surface/
elevated corridors.

1984: The Delhi Development Authority prepares a perspective plan for the city keeping in view traffic
projections for 2001 and recommends a multi-modal transport system comprising 200 Km of light rail transit
system, 10 Km of tramway, an extension to the surface rail system and an extensive road network. The urban
Arts Commission suggests modifications and recommends development of the existing Ring Railway with
three radial underground Mass Transit corridors.

1987: The Ministry of Railways appoints a Task force to assess the choice of technology and recommends a
pilot project based on Magnetic Levitation System and Light Rail Transit System.

1990: RITES limited submits a feasibility report on Integrated Multi Modal Mass Rapid Transport System
(IMMRTS) recommending a three – component system comprising Rail corridors, Metro corridors and
dedicated Bus way with a total length of 184.5 Km, subsequently increased to 198.5 Km.

1995: The Delhi Metro Rail Corporation Limited is registered on May 3, 1995 under the companies Act,
1956.

1996: The Union Cabinet approves the first phase of the Delhi Metro project in September, 1996.

The concept of a mass rapid transit for Delhi first emerged from a traffic and travel characteristics study which was carried out in the city in 1969. Over the next several years, many official committees by a variety of government departments were commissioned to examine issues related to technology, route alignment and governmental jurisdiction. In 1984, the Delhi Development Authority and the Urban Arts Commission came up with a proposal for developing a multi-modal transport system, which would consist of constructing three underground mass rapid transit corridors as well augmenting the city's existing suburban railway and road transport networks.

While extensive technical studies and the raising of finance for the project were in progress, the city expanded significantly resulting in a twofold rise in population and a fivefold rise in the number of vehicles between 1981 and 1998. Consequently, traffic congestion and pollution soared, as an increasing number of commuters took to private vehicles with the existing bus system unable to bear the load. An attempt at privatizing the bus transport system in 1992 merely compounded the problem, with inexperienced operators plying poorly maintained, noisy and polluting buses on lengthy routes, resulting in long waiting times, unreliable service, extreme overcrowding, unqualified drivers, speeding and reckless driving. To rectify the situation, the Government of India and the Government of Delhi jointly set up a company called the Delhi Metro Rail Corporation (DMRC) on March 5, 1995 with E. Sreedharan as the managing director.

Physical construction work on the Delhi Metro started on October 1, 1998. After the previous problems experienced by the Calcutta Metro, which was badly delayed and 12 times over budget due to "political meddling, technical problems and bureaucratic delays", the DMRC was given full powers to hire people, decide on tenders and control funds. The DMRC then consulted the Hong Kong MTR on rapid transit operation and construction techniques. As a result, construction proceeded smoothly, except for one major disagreement in 2000, where the Ministry of Railways forced the system to use broad gauge despite the DMRC's preference for standard gauge.
The first line of the Delhi Metro was inaugurated by Atal Behari Vajpayee, the then Prime Minister of India on December 24, 2002, at Seelampur Metro station and thus it became the second underground rapid transit system in India, after the Kolkata Metro. The first phase of the project was completed in 2006 on budget and almost three years ahead of schedule, an achievement described by Business Week as "nothing short of a miracle".

On Christmas Day, December 25, 2002, Delhi got a wonderful gift when commercial operations on the Shahdara – Tis Hazari section began at 6 am. On the first day itself, about 1.2 million people turned up to experience this modern transport system. As the initial section was designed to handle only 0.2 million commuters, long queues of the eager commuters wishing a ride formed at all the six stations on the line – Shahdara, Welcome, Seelampur, Shastri Park, KashmereGate and Tis Hazari. The rush was so massive that extra police had to be deployed to restrict entry into the Metro stations for the first week. Delhi Metro was forced to issue a public appeal in the newspapers – asking commuters to defer joy rides as Metro would be there on a permanent basis.

For the first time in Delhi, commuters were introduced to the contact – less tokens for travel. Anticipating difficulty in using the new system, DMRC also prepared paper tickets to act as a temporary/ emergency substitute. These paper tickets were used on the first day, while the use of the automatic fare collection system stabilized. A large number of youngsters were also hired during the first two months as volunteers by DMRC to help commuters get used to the new system and technologies at AFC gates, escalators and on the platform.

**METRO MILESTONES**

May 3, 1995: DMRC registered as a company
April 4, 1997: First employee of DMRC joins
November 5, 1997: Dr. E. Sreedharan appointed as the Managing Director of DMRC.
September 14, 1998: General Consultants (GC) for Phase I, comprising a consortium of five distinguished international consultancy companies, appointed.
October 1, 1998: DMRC commences work on the proposed Metro lines
June 5, 2000: The Metro Railways (Construction of Works) Act is extended to the Metropolitan city of Delhi.
July 19, 2002: Inauguration of Shastri Park Training School
August 30, 2002: Arrival of first Metro train from Korea
September 17, 2002: Metro’s first trial run, inaugurated by Shri L.K. Advani
October 3, 2004: Automatic Train Production (ATP) trains commence operations.
November 27, 2004: Trial run of first Automatic Train Operation (ATO) train
December 19, 2004: Automatic Train Operation (ATO) trains commence operations
July 1, 2006: General Consultants (GC) for Phase II appointed

1.4.6 DESIGNING THE METRO
The design of the structures of the Delhi Metro posed a number of engineering challenges for the Metro Design Engineers especially in the underground sections as there were no yardsticks available in India for designing civil Metro structures to withstand earthquakes.

The Delhi Metro Engineers, therefore, had to look to International standards and codes from countries such as Japan which are highly earthquake prone. The Delhi Metro structures in the capital have thus been designed in such a manner that they can handle earthquake pressures and forces which could be generated in Delhi up to Zone 4 of the seismic zones identified in India.
In the elevated construction, British Standard codes and European codes for designing have also been used to ensure structural adequacy and economy during construction apart from using the established Railway codes.

Metro Trains generate an axle weight of 17 tonnes compared to 25 tonnes generated by mainline Railway trains. Therefore, the Metro Rail Structure is designed differently from regular Railway structures existing in the country. The Delhi Metro Rail Engineers went to Germany, Singapore, Hong Kong and Bangkok to see designs available in their Metro civil structures.

In elevated Metro construction also, the Metro designs have adopted the segmental construction techniques to a great extent as small concrete segments are cast in a specialized casting yard, transported to the site and assembled using special launchers. This technique has an advantage as it enables standardization and also allows shifting in case of unchartered pipelines and cables, which may be at the exact locations where you are planning your pillars. This can easily be shifted if you use segmental construction as the pillar can always be moved back and forth in this design method. It also helps in easy transportation since each segment is 3 meters long.
The Rail level has been kept at minimum height of 10-15 meters above the ground so that less energy is spent by passengers in reaching the platform level and the pillars have been sleekly designed with a thickness of 1.6 to 1.8 meters which however can take heavier loads since these pillars use M60 L-grade concrete. The pillars are supported by pile foundations to make the metro structures extremely stable.

Most of the underground structures have been designed using top down method so that a complex strut support system is not required during the construction.

In Phase II of the Delhi Metro construction, the Delhi Metro has adopted a new approach of design and construction to be done by the metro contractors themselves with supervision by the DMRC. This will help in speeding up the construction and achieving possibly more economy.

Two remarkable efforts of Delhi Metro construction is seen at Pragati Maidan Metro Station where the first extradozed bridge in India has been built over running Railway tracks, which will be followed by another extradozed bridge at Moolchand.

1.4.7 NETWORK
The Delhi Metro is being built in phases. Phase I completed 65.11 km (40.46 mi) of route length, of which 13.01 km (8.08 mi) is underground and 52.10 km (32.37 mi) surface or elevated. The inauguration of the Indraprastha–Barakhamba Road corridor of the Blue Line marked the completion of Phase I on October 27, 2006. Phase II of the network comprises 128 km (80 mi) of route length and 79 stations, and is presently under construction, with the first section opened in June 2008 and a target completion date of August 2011. Phases III (112 km) and IV (108.5 km) are planned to be completed by 2015 and 2021 respectively, with the network spanning 413 km (257 mi) by then.

CURRENT ROUTES
As of July 14, 2011, the whole of Phase-I and parts of Phase-II are complete, with the network comprising six lines with 140 metro stations and a total length of 189.7 km (117.9 mi).
# TABLE 1.2  ROUTES OF DELHI METRO

<table>
<thead>
<tr>
<th>Line</th>
<th>First operational</th>
<th>Last Extension</th>
<th>Stations</th>
<th>Length (km)</th>
<th>Terminals</th>
<th>Rolling stock</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Red Line</strong></td>
<td>December 24, 2002</td>
<td>June 4, 2008</td>
<td>21</td>
<td>25.15</td>
<td>Dilshad Garden</td>
<td>Rithala</td>
</tr>
<tr>
<td><strong>Yellow Line</strong></td>
<td>December 20, 2004</td>
<td>September 3, 2010</td>
<td>34</td>
<td>44.65</td>
<td>Jahangirpuri</td>
<td>HUDA City Centre</td>
</tr>
<tr>
<td><strong>Blue Line</strong></td>
<td>December 31, 2005</td>
<td>October 30, 2010</td>
<td>44</td>
<td>49.93</td>
<td>Noida City Centre</td>
<td>Dwarka Sector 21</td>
</tr>
<tr>
<td></td>
<td>January 7, 2010</td>
<td>July 14, 2011</td>
<td>8</td>
<td>8.75</td>
<td>Yamuna Bank</td>
<td>Vaishali</td>
</tr>
<tr>
<td><strong>Green Line</strong></td>
<td>April 3, 2010</td>
<td>—</td>
<td>15</td>
<td>18.46</td>
<td>Inderlok</td>
<td>Mundka</td>
</tr>
<tr>
<td><strong>Violet Line</strong></td>
<td>October 3, 2010</td>
<td>January 14, 2011</td>
<td>15</td>
<td>20.04</td>
<td>Central Secretariat</td>
<td>Badarpur</td>
</tr>
<tr>
<td><strong>Airport Express</strong></td>
<td>February 23, 2011</td>
<td>—</td>
<td>6</td>
<td>22.70</td>
<td>New Delhi</td>
<td>Dwarka Sector 21</td>
</tr>
</tbody>
</table>

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RED LINE
The Red Line was the first line of the Metro to be opened and connects Rithala in the west to Dilshad Garden in the east, covering a distance of 25.09 kilometres (15.59 mi). It is partly elevated and partly at grade, and crosses the Yamuna River between Kashmere Gate and Shastri Park stations. The inauguration of the first stretch between Shahdara and Tis Hazari on December 24, 2002, caused the ticketing system to collapse due to the line being crowded to four times its capacity by citizens eager to have a ride. Subsequent sections were inaugurated from Tis Hazari – Trinagar (later renamed Inderlok) on October 4, 2003, Inderlok – Rithala on March 31, 2004, and Shahdara – Dilshad Garden on June 4, 2008.

YELLOW LINE
The Yellow Line was the second line of the Metro and was the first underground line to be opened. It runs for 44.36 kilometres (27.56 mi) from north to south and connects Jahangirpuri with HUDA City Centre. The northern and southern parts of the line are elevated, while the central section through some of the most congested parts of Delhi is underground. The first section between VishwaVidyalaya and Kashmere Gate opened on December 20, 2004, and the subsequent sections of Kashmere Gate – Central Secretariat opened on July 3, 2005, and VishwaVidyalaya – Jahangirpuri on February 4, 2009. This line also possesses the country's deepest Metro station at Chawri Bazaar, situated 30 metres (98 ft) below ground level. On 21 June 2010, an additional stretch from QutubMinar to HUDA City Centre in Gurgaon was opened, initially operating separately from the main line. However, Chhatarpur station on this line opened on August 26, 2010. Due to delay in acquiring the land for constructing the station, it was constructed using pre-fabricated structures in a record time of nine months and is the only station in the Delhi metro network to be made completely of steel. The connecting link between Central Secretariat and QutubMinar opened on September 3, 2010. Interchanges are available with the Red Line at Kashmere Gate station, and with the Indian Railways network at Delhi and New Delhi railway stations.

BLUE LINE
The Blue Line was the third line of the Metro to be opened, and the first to connect areas outside Delhi. Partly overhead and partly underground, it connects Dwarka Sub City in the west with the satellite city of Noida in the east, covering a distance of 47.4 kilometres (29.5 mi). The first section of this line between Dwarka and Barakhamba Road was inaugurated on December 31, 2005, and subsequent sections opened between Dwarka – Dwarka Sector 9 on April 1, 2006, Barakhamba Road – Indraprastha on November 11, 2006, Indraprastha – Yamuna Bank on May 10, 2009, Yamuna Bank – Noida City Centre on November 12, 2009, and Dwarka Sector 9 - Dwarka Sector 21 on October 30, 2010. This line crosses the Yamuna River.
between Indraprastha and Yamuna Bank stations, and has India's first extradosed bridge across the Northern Railways mainlines near Pragati Maidan. A branch of the Blue line, inaugurated on January 8, 2010, takes off from Yamuna Bank station and runs for 6.25 kilometres (3.88 mi) up to Anand Vihar in east Delhi. It was further extended up to Vaishali which was opened to public on July 14, 2011. A small stretch of 2.76 kilometres (1.71 mi) from Dwarka Sector 9 to Dwarka Sector 21 was inaugurated on October 30, 2010. Interchanges are available with the Yellow Line at Rajiv Chowk station, and with the Indian Railways network at the AnandVihar Railway Terminal.

GREEN LINE
Opened in 2010, the Green Line was the first standard-gauge corridor of the Delhi Metro. The fully elevated line connects Mundka with Inderlok, running for 15.1 kilometres (9.4 mi) mostly along Rohtak Road. An interchange with the Red line is available at Inderlok station via an integrated concourse. This line also has the country's first standard-gauge maintenance depot at Mundka.

VIOLET LINE
The Violet Line is the most recent line of the Metro to be opened, and the second standard-gauge corridor after the Green Line. The 20.2 km (12.6 mi) long line connects Badarpur to Central Secretariat, with 9 km (5.6 mi) being overhead and the rest underground. The first section between Central Secretariat and SaritaVihar was inaugurated on October 3, 2010, just hours before the inaugural ceremony of the 2010 Commonwealth Games, and connects the Jawaharlal Nehru Stadium which is the venue for the opening and closing ceremonies of the event. Completed in just 41 months, it includes a 100 m (330 ft) long bridge over the Indian Railways mainlines and a 167.5 m (550 ft) long cable-stayed bridge across an operational road flyover, and connects several hospitals, tourist attractions and a major industrial estate along its route. Services are provided at intervals of 5 min. An interchange with the Yellow Line is available at Central Secretariat through an integrated concourse. On January 14, 2011, the remaining portion from SaritaVihar to Badarpur was opened for commercial service, adding three new stations to the network and marking the completion of the line.

AIRPORT EXPRESS
The Airport Express line runs for 22.7 km (14.1 mi) from New Delhi Railway Station to Dwarka Sector 21, linking the Indira Gandhi International Airport. The line is operated, by the Delhi Airport Metro Express Pvt. Limited (DAMEL), a subsidiary of Reliance Infrastructure, the concessionaire of the line. Constructed at a cost of 2,885 crore (US$643.36 million), the line has six stations (four operational), with some featuring check-in facilities, parking and eateries. Rolling stock consists of six-coach trains operating at intervals of
ten minutes and having a maximum speed of 135 km/h (84 mph). Originally scheduled to open before the 2010 Commonwealth Games, the line failed to obtain the mandatory safety clearance, and was opened on 24 February 2011, after a delay of around 5 months.

**FIGURE 1.5 AIRPORT EXPRESS**

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**PHASE II**

Phase II consists of 127 km (79 mi) of railway lines, from Kirti Nagar to Ashok Park Main, which consist of two stations of length 3.32 Km (2.06 mi). This is a green line which operated in August, 2011

**1.4.8 PLANNED EXTENSION**

Several extensions to the Delhi Metro network have been planned.

**PHASE III: ROUTES WITHIN DELHI**

Phase III is tentatively composed of two new lines and three extensions, covering 67 new stations and 108 km of new track, with an estimated cost of 30,000 crore (US$6.69 billion). The following routes have received Delhi Cabinet clearance, but are still awaiting the final approval from the Ministry of Urban Development and the Group of Ministers.

- Mukundpur to Yamuna Vihar (35 stations, 56 km) - New line following Inner Ring Road (Line 7)
- Janakpuri (West) to Noida Botanical Garden (22 stations, 34 km) - New line (Line 8)
- Central Secretariat to Kashmiri Gate (7 stations, 9.8 km) - Violet Line extension
- Dwarka-Najafgarh (5 km) - Blue Line extension
- Jahangirpuri to Badali (3 stations, 4.48 km) - Yellow Line extension
ROUTES BEYOND DELHI BORDER

The violet line has received approval to be extended further from the Badarpur station towards Faridabad. The proposal is currently being forwarded to a group of ministers within the central government for final approvals. The first phase of the extension will run for 13.875 km and have 9 stations. It is expected to be operational within 2 years from the start of construction work.

In addition, the Red Line is proposed to be extended further into Ghaziabad by 7.5 km with four additional stations - Shaheed Nagar, Rajbagh Colony, Rajendra Nagar and Mohan Nagar. Also plan to extend Airport express to Gurgaon Huda City Centre is on the cards.

PHASE IV:

Phase IV has a 2020 deadline, and tentatively includes further extensions to Sonia Vihar, ReolaKhanpur, Palam, Najafgarh, Ghazipur, Noida Sector 62, Gurgaon and Faridabad, having a total length of 108.5 km (67.4 mi). Apart from these lines in Phases I to IV, plans have been mooted to construct a new line from Noida Sector 62 to Greater Noida which will intersect Indraprastha – Noida Sector 32 line. The Ghaziabad Development Authority is planning to extend Delhi Metro lines deeper into Ghaziabad in three phases, including the extension of the Blue Line from Anand Vihar to Vaishali, and subsequently to Mehrauli via Indirapuram, as well as the extension of the Red Line from Dilshad Garden to the new Ghaziabad bus stand. The independently operated Gurgaon Metro, work on which is going on and has a deadline of 2013, will also interchange with the Delhi Metro.

1.4.9 ADVANCED TRACK TECHNOLOGY

The Delhi metro runs on advanced ‘ballast less tracks’, thus minimizing the need for track maintenance and negating any change in the alignment of the line at any time. The integration of turnouts into Long Welded Rails (LWRs) means that the complete tracks are almost “joint less”, thus providing greater riding comfort, minimum vibration and reduced noise levels. The specially designed turnouts have thick web switches with welded leg-extensions and explosive hardening. To ensure uninterrupted provision of LWRs even on long and continuous viaduct spans, a specially designed fastening system with reduced toe load was used for the first time in India. The Vossloh 336 Fastening System for ballast less tracks used by DMRC was designed by Vossloh of Germany.

The rails used for the Delhi Metro project are the first of their kind used for any rail-based system in India. These Rails have been manufactured by Corus (Europe) and Voestalpin (Austria). The steel rail is head
hardened with the grade strength of 1080. Each rail is 18 meters long, with a weight of 1086.12 Kg. These rails are joined together using the flash butt technique whereby heat is generated for seamless and durable joining. The rail has a base of 150 mm, web of 16.5 mm and head of 74.3 mm of which a 15 mm depth from the top is hardened. The top head of the rail is hardened to resist wear and tear through an Air Quenching Process whereby the head of the rail is heated followed by instant cooling making the molecule contact thus making it harder. A number of tests, i.e. Chemical Analysis Test, Hydrogen Content Test etc., are done before heating followed by Macroscopic, Tenstile and Hardness Tests after the heat treatment.

1.4.10 ROLLING STOCK: ENSURING PASSENGER COMFORT, SAFETY AND RELABILITY

The Delhi Metro introduced modern 3.2 meters wide, lightweight stainless steel coaches with 3-phase AC drive, regenerative braking and pneumatic suspension, this was done because the traditional 3.66 meters wide Indian railways type EMU coaches with conventional DC drives were not advisable even on the elevated/at-grade corridors for reasons of safety, power, efficiency and maintenance. The Railway Board of the Government of India approved the recommendation for the modern Metro coaches in November 2000.

At that time, the country did not have the expertise required to manufacture light-weight rolling stock with advanced features like sensor based automatic door operation and automatic train integrated management system for the Metro. The technology that existed was quite outdated for twenty-first century Metro operations. Even the coaches supplied by the Integral Coach Factory of Indian Railways to the Metro rail at Kolkata and elsewhere were completely different from those required by the Delhi Metro Rail Corporation and it would have taken over three to four years for any Indian company to acquire the technology required to build the rolling stock in India itself.

The task on hand was thus quite clear, DMRC had to select a company or a consortium that could custom design the rolling stock and manufacture it under a gradual transfer of technology agreement. Global bids were invited for the supply of coaches for the Delhi Metro. Several Indian companies submitted bids but failed to clear pre-qualifying requirements. After a transparent bidding process, followed by detailed negotiations, the contract for designing, manufacturing, supplying, testing and commissioning Passenger Rolling Stock consisting of 240 coaches was placed on a consortium compromising of Mitsubishi Corporation of Japan (Consortium leader), ROTEM (previously KOROS) of Korea and Mitsubishi Electric Corporation of Japan in May, 2001.

The contractual clauses provided for the technology transfer to an Indian company and an Indian public sector company, Bharat Heavy Earth Movers Limited, was identified to progressively manufactured world
class Metro coaches in the country, of the total number of 240 coaches, 60 coaches (15 train sets) were fully manufactured abroad and the remainder manufactured in the country with gradually increasing antagonization. The decision catapulted India on the road to becoming a major, highly competitive supplier of state-of-the–art Metro rail rolling stock.

After the inspection of the mock-up of the coach by a team from the General Consultants and the DMRC at the manufacturer’s works, the delivery of the final design document was affected in January 2002. To compensate, as much as possible, for the time lost in deciding between standard and broad gauge, DMRC’s engineers were stationed in Korea to speed up the decision making process.

As the civil construction gathered speed, the production of the rolling stock also rolled ahead at great pace. In just 14 months’ time- believed to be a world record in the redesigning and production of rolling stock – the first train was built and dispatched from the Changwon factory in South Korea in July 2002.

FIGURE 1.6 INSIDE VIEW OF DELHI METRO COACH
The first train was flagged off on its ceremonial trial run on 17th September 2002 by then Deputy Prime Minister Shri L K Advani. The rolling stock was put to stringent tests and trials. Besides tests conducted by DMRC and the manufacturers, Research Design and Standard Organization (RDSO) of the Indian Railways also conducted intensive trials in two stages.

But the tests themselves caused a major controversy when a leading newspaper published a report claiming that the RDSO had recommended that ‘the Metro’s entire Rs 1500 crore rolling stock…… should be junked’. The report, which appeared on 14th December, 2002, just days before the metro’s first public run, said that the Metro train brakes had cracked during the trails. What it did not mention was that the brake blocks had cracked because emergency brakes had been applied 154 times in just two days, a most extraordinary circumstance. In reality, the braking distance during tests was 231 meters, well within the international standards of 241 meters. It was also found that the RDSO had never said the rolling stock should be junked. Soon the Metro coaches were certified as safe for travel by the commissioner for Metro Rail Safety, paving the way for their induction into service.
The first 240 coaches were all inducted into services in phases by 19th May 2006. Subsequently, another 40 coaches (10 train sets) were added to the Metro fleet in 2007 in view of the increasing ridership.

All Metro trains were designed for fast acceleration/deceleration and maximized energy efficiency and are equipped with electronic passenger information displays, audio announcement facilities, uniformly lit interiors and skid and fire resistant floors. All trains permit two-way communication between the driver and the Operations Control Centre and every coach also has passenger emergency alarms for communication between the passengers and the train operators.

For Phase-II of the Delhi Metro project to be completed by 2010, DMRC has placed orders for 616 coaches. Of this, 424 will be broad gauge coaches will be manufactured by Bombardier Transportation of Germany. There will be 37 train sets of four coaches and 46 train sets of six coaches. The first nine train sets (of four coaches) will be manufactured in Germany. The rest will be assembled and subsequently manufactured at a factory being set up in Savli near Vadodara by Bombardier.

The standard gauge coaches will be made by a consortium of Mitsubishi, ROTEM, Mitsubishi Electric Corp. and BEML. All 48 train sets will have four coaches each. The first train set will be manufactured in Korea. The rest will be assembled/manufactured at BEML’s factory in Bangalore.

All the new trains will have additional features such as close-circuit cameras in the train operator’s cab and passenger saloons. Thus, all passengers’ movements inside Metro trains and stations can be monitored as CCTVs are already installed inside the station premises. The phase-II trains will also have better humidity control, charging points for mobile phones and laptops and more prominent destination display. In addition to the coaches ordered by DMRC for Phase-II, the consortium Reliance Energy – CAF will procure trains for the Airport Express line.

**BROAD GAUGE:** Coach width: 3.2 m, Coach length: 22.24 m (motor car), 22.60 m (driving trailer car), Axle load: 17 tons, Coach accommodation: 50 passengers sitting and 330 standing per coach, Train acceleration: 0.82 meter/second/second, Average Scheduled Speed: 32 to 35 Kmph over an average distance of 1.1 to 1.3 Km, Braking rate: 1 m/sec/sec (80 Kmph to standstill in 22 seconds in a distance of 250 m)

**STANDARD GAUGE:** Coach width: 2.9 m, Coach length: 22.24 m (motor car), 22.34 m (driving trailer car), Axle load: 16 tons, Coach accommodation: 50 passengers sitting and 292 standing per coach, Train
acceleration: 0.8 metre/second/second, Average Scheduled Speed: 34 Kmph over an average distance of 1.1 to 1.3 Km, Braking rate: 1m/sec/sec (80 Kmph to standstill in 22 seconds in a distance of 250m).

1.4.11 MODERN TELECOMMUNICATION FACILITIES
Recognizing the pivotal role of telecommunication in ensuring successful operation of the mass rapid transit system, DMRC designed and adopted a trend setting telecommunication system to streamline normal operations, handle out-of-routine operations and manage unforeseen incidents and emergencies instantly. The high-tech system interlinks the Operations Control Centre, stations, trains, headquarters, depots, ancillary buildings and all important areas and facilities through voice, data and video communication.

MAIN COMPONENT OF THE SYSTEM

FIBRE OPTIC TRANSMISSION SYSTEM: Optic Fibre Cables form the main communication media and the backbone of the digital transmission system. The cables are laid in a ring configuration, one on either side of the track to provide redundancy and protection in case of failure. Special consideration has also been given to the security of the system and redundancy has also been provided in Key equipment interfaces to counter the possibility of failure. The transmission system, which is compatible with international standards, is controlled by a Network Management System installed at the Operations Control Centre.

TRAIN MOBILE RADIO SYSTEM: Based on TETRA specifications, the system includes fully equipped multi-channel radio-based stations linked to a network management system at Operations Control Centre. The system is designed to provide full duplex/semi-duplex/ simplex modes of operation, facility of group/individual broadcast, emergency and direct mode calls and enable constant communication between the traffic controller, depot controller and the train operator. It includes mobile radio transceivers in the front and rear cabs of the trains, consoles for depot radio communication, portable handheld units for maintenance, supervisory and security personnel and distress call facility in all trains.

TELEPHONE SYSTEM: Electronic exchanges are installed at all the stations and are connected to a network with direct dialling facility managed by the Operations Control Centre.

CLOSED CIRCUIT TELEVISION (CCTV) SYSTEM: All Metro stations and main premises are monitored round-the-clock through a CCTV system, providing a top-notch security system. While 1,237 cameras have been installed in the operational Metro stations, more than 2000 cameras will be installed in the stations of Phase-II.
The visuals from the CCTVs can be monitored at the stations where they are installed. The Operations Control Centre, however, can monitor CCTV visuals from all stations. The recordings of the footage are maintained for a week for surveillance purposes.

All the trains being procured for Phase-II will have CCTVs in the train operator’s cab and passenger saloons also for wider coverage.

**PA/PID SYSTEM:** fully automatic Public Address/Public Information Display System is present to display train-related information on platforms and concourses of all stations. The system also allows manual announcements from the stations or Operations Control Centre in case of an emergency.

**AUTOMATIC FARE COLLECTION SYSTEM: A TICKET TO THE FUTURE**
DMRC uses one of the most advanced Automatic Fare Collection (AFC) systems in the world which provides real time data on fare collection and passenger flow. The system uses contact-less smart cards for multiple journeys and contact-less tokens for single journeys. In fact, it was Delhi Metro that introduced contact-less tokens for the first time in the word, later adopted by other Metros like Hong Kong, Bangkok and Taipei.

Tokens were initially available in two colours: red and blue, later also in black, as operations began on Phase-II. Tourist passes are also available for unlimited travel for one day or for three days. Passes and tokens can be read from a distance of 10 cm from the target fixed on the access control gates. Automatic flaps facilitate quick entry and exit. The extra-wide gates make it convenient for the unhindered movement of wheelchair-bound persons.

The fare collection equipment is connected on a local area network, controlled by a station server which is further linked to the central computer at the Operations Control Centre at Shastri Park through optic fibre communication channels. The system is equipped to handle more than two million transactions every day and provide up-to-date reports, real time data of fare collection and passenger flow analysis.

**STATE-OF-THE-ART LIFTS AND ESCALATORS**
All DMRC stations have been equipped with heavy duty reversible escalators capable of continuous operation under full load of up to 12,000 passengers per hour for 20 hours a day. All escalators include
features like speed governor, handrail safety, comb-plate safety, floor plate safety, missing plate detection and dress guard. The escalators have energy saving features and decelerate while running idle, thus saving about 30% in terms of energy consumption. Emergency stop switches can bring them to a halt in case of emergency. At present, there are 160 escalators in the operational stations of Delhi Metro and another 269 will be added in Phase-II.

Every DMRC station is also equipped with world-class low-maintenance, energy saving lifts with Variable Voltage Variable Frequency (VVF) - control three-phase drives. They have safety features like sensor-controlled doors and do not need a machine room for their operation – an aspect that makes the lifts space-savings as well as aesthetics-friendly. While there are 158 lifts in the operational stations of Delhi Metro, another 211 will be added in Phase-II.

**UNINTERRUPTED POWER SUPPLY TO RUN THE METRO**
DMRC has adopted a 25 KV AC overhead electrification system, similar to the Indian Railways mainline, with rigid centenary system being used in the underground sections and flexible centenary on the elevated sections. The power supply is obtained through traction transformers with 100% stand-by arrangement to ensure supply changeover from one transformer to another or from one feeder to another without interruption so that there is no power failure even for a minute.

The DMRC system is an upgradation on the Indian Railways system in several ways. The additional features include:

- On-load tap changers on primary side of transformers for proper voltage regulation
- Use of ‘fit and forget’ type fittings for minimal maintenance
- Pole-mounted interrupters to save ground space
- Use of light-weight section insulators, axle and cardon type arrangement in the cantilevers, etc.
- PLC based SCADA system for continuous power and energy management

The Delhi Metro draws power from three sources, the Northern Grid, Indraprastha Gas Turbine Plant and the Main Line Railway (in case of emergencies). It already has six sub-stations of its own at Kashmere Gate, Rithala, Subhash Nagar, Indraprastha, New Delhi and Dwarka in Phase-I. For the second phase, seven more sub-stations are being built at Jahangirpuri, Ambedkar Colony, Mundka, SushankLok, Botanical Garden-NOIDA, Central Secretariat Bus Depot and SaritaVihar.
Power supply is taken from the sources at 220/66 KV and then stepped down to 25 KV and 33 KV at the sub-stations. While the 25 KV electricity is supplied to the overhead electrification system, 33 KV power supply is extended to each stations by a rings main. The supply is then stepped down further to 415 V at each station. The system ensures that in normal course, the power supply to DMRC’s stations will not be interrupted and will be available for operating auxiliaries like lifts, escalators and lighting equipment. To meet any major breakdown or grid failure, all stations have been provided with a diesel generator set to handle essential loads such as signalling, lifts, essential lighting and fire pumps. All stations have also been provided with Uninterrupted Power Supply (UPS) system with 30 minutes battery back-up for emergency lighting in all areas, particularly exists, staircases and signages, so that passengers can be safely evacuated in the unlike event of a supply failure plus generator failure.

In case of complete breakdown of power supply at one sub-station, the supply from other sub-stations can run trains without interruption.

The overall electricity consumption for stations and trains is about 5.5 lakhs units/day at present.

**AT WORK 24x7 FOR PASSENGER COMFORT AND SAFETY: THE METRO NEVER SLEEPS**

Even after the last train completes its journey and the last passenger leaves, work continues at Delhi Metro. It’s then that the maintenance crews start duties that continue till operations begin the next day. Various departments work 24X7 to ensure flawless passenger services across all the lines.

**ROLLING STOCK DEPARTMENT**

Among the most active departments during the night is the Rolling Stock (RS) department. The outer bodies of the trains are cleaned in washing plants on their return after revenue service to the depot. The exterior of the train is wiped and interior is cleaned by the housekeeping staff. Every day, one train in each depot is taken for roof cleaning.

After the cleaning, data is downloaded from the train cab regarding failures and anomalies and they are rectified. RS staff issues Fitness Certificates to Depot Control Centre (DCC) by 4 a.m. to ensure that trains start rolling out from depot in time for revenue services. The DCC hands over the fitness certificate to individual Train Operators (TO).

There is 10 to 15 RS staff in each depot including Maintainers, Junior Engineers, Officers, and 30-35 people in housekeeping.
PERMANENT WAY (P.Way) DEPARTMENT

P.Way department carries out its activities only at night and is concerned with track maintenance. About 40 P.Way staff members work on all lines during night hours. The activities include:

- Inspection of curves, points, gradients and cross overs
- Foot patrolling of the entire line to fix any loose nuts/bolts
- Greasing of curves, points etc. to reduce friction
- Regular tightening of fittings and fastening
- Cleaning of the viaduct
- Ultra Sonic Flaw Detection (USFD) machine is used to detect defects in the track
- Dressing and re-coupmen of ballast
- Gross cutting at Grade level

PILOT TRAIN

At 3.45 a.m. every day, three pilot trains start from each depot which criss-cross the entire network to ensure that the system is fully ready for revenue services. Each pilot train carries four persons, the train operator, representatives from Over Head Equipment (OHE), P way and signalling departments. The OHE person keeps a close watch on the masts and wires to observe any anomaly and the P Way person keeps focus on the track while the signalling person keeps a watch on the movement of points, signals and beacons.

The pilot train runs with a speed restriction of 40 Kmph so that all three can get a proper view. Once the entire trip is completed, fitness certificates are submitted to station controllers who in turn inform OCC. The revenue service starts only after obtaining clearance from all of them.

OVER HEAD EQUIPMWNT DEPARTMENT

OHE department ensures that the overhead equipment from which the trains draw power is properly maintained and there is no external interference. The department, which has staff deployment of 25, looks after the maintenance of transformers, tightening loose wires, and removal of bird nests, kites, threads, etc. which get entangled in the wires. The department uses a special vehicle called Cantilever Maintenance Vehicle (CMV) to fix OHE wires whenever necessary.

SIGNALING AND TELECOM (S&T) DEPARTMENT

During operation hours, every train remains in constant contact with the Operations Control Centre (OCC) and stations through the train radio, which is crucial to the Metro’s communication infrastructure. The S&T
department, therefore, checks the radio of every train on a daily basis. About 45-50 persons are deployed every night on all lines to carry out cleaning and dusting of the public information display system (PIDS), clocks, close-circuit television (CCTV), alignment of announcement speakers, etc. They reset all Local Area Train Supervision (LATS)/Control-cum-Indication Panel (CCIP) before the start of revenue services and check the recordings made by CCTVs during the day. The installation, updating and removal of S&T equipment by contractor’s staff are also done in the night.

**OPERATIONS CONTROL CENTRE (OCC)**

OCC plays a vital role in regarding the activities at night and decides which department will be given the required time for maintenance. Every department has to submit their required maintenance. Every department has to submit their required maintenance schedule to OCC by 4 p.m. every Friday and OCC prepares a weekly maintenance chart on every Saturday. No department can carry out maintenance activity, even when OHE is shut down, if it does not have the requisite permission.

Surprise inspections conducted by officers are also an essential part of night activities. All departments have to submit the status of their activities during night hours by 7 a.m. every morning. The average deployment per department per night comes out to be about 30 and the total deployment during the night on all lines/depots is 150, excluding officers, housekeeping staff and labourers.

**EARTHQUAKE RESISTANT STRUCTURES**

**FULLY GEARED AGAINST NATURAL HAZARDS**

The city of New Delhi falls in Zone 4, one of the most earthquake prone areas of the country, with zone 5 being the most active. According to estimates, the maximum magnitude that can be generated by the known faults in the vicinity of zone 4 is 6.7 on the Richter scale.

To ensure that the elevated structures and the underground tunnels are fully saved even during such a strong earthquake, they are built with sufficient strength and ductility to endure maximum stress and strain. All relevant Indian and international codes like IS-1893-2002 and IRC are followed for construction. Regular quality monitoring during the construction stage and the best quality of cement aggregate and mental ensure that the design of life of Metro structures is more than 100 years.
On the underground sections, monitoring systems are installed which communicate any ground movement to the Operation Control system. Services can be immediately suspended in order to avoid damage to life and property.

DELHI METRO: (OPERATIONS AND MAINTENANCE) ACT 2002

The activities of the Delhi Metro are governed by the Delhi Metro Railway (Operation and Maintenance) Act 2002 which received the assent of the president on India on December 17, 2002.

The Delhi Metro Railway (Operation and Maintenance) act is a legislation that provides for the operation, maintenance and regulation of working of the Metro Railway and all matters connected therewith and incidental thereto. The Act spells out the code of conduct for Delhi Metro, provides for the appointment of a Claims Commissioner for accidents and resultant compensation and also empowers DMRC to enter into working arrangements with other agencies.

The Act covers provisions for laying down the fare structure on the recommendations of a three-member Fare Fixation Committee (with a maximum term of three months) to be set up by the Centre from time to time.

The Act also lists offences related to the usage of Metro services and properties and makes provisions for penalties and fines. The offences include creating nuisance, taking offensive material, unlawfully entering or walking on the Metro track, obstructing running of trains, travelling on roof of train, travelling without a train or causing sabotage, maliciously hurting or attempting to hurt persons travelling by Metro Railway, damage to or destruction of Metro property, etc. The offences can be punishable with fines ranging from Rs 50 (travelling without valid token/pass) to Rs. 5,000 (obstructing running of trains), imprisonment ranging from a term of one month (travelling without valid token/pass) to life (maliciously hurting or attempting to hurt persons travelling by Metro Railway). The offence of maliciously wrecking a train or causing sabotage can be punishable even by death penalty.

Delhi Metro is one of the most eco-friendly projects undertaken in the country. Motivated by a concern for the environment, all measures have been taken for protection of the environment and to minimize any negative impact from the construction stage itself.
1.5 THE STUDY

1.5.1 NEED OF PROPOSED RESEARCH WORK

This study addresses the geographical limits of Delhi & NCR region where the Delhi Metro is either operational or going to be operational soon. For finding out the impact arising from the operations of Delhi Metro on the government and stakeholders, cost benefit analysis is required. The study will analyse the revenue generated by Delhi Metro. The study focuses on finding out the areas where Delhi Metro is lagging behind and can improve in terms of lowering down its cost & exploring new areas from where revenue can be generated so as to make it more profitable venture.

NCR area is one of the most populated areas and existing transport system is adding lot of congestion problem, road accidents and pollution. In this study, all the costs and benefits arising out of metro system will be involved so that this kind of arrangements can be planned in other metro cities, big cities in order to develop good transportation networks in those areas also. It also enhances the business opportunities of Delhi Metro Rail Corporation through outsourcing contracts from other cities and countries.

It will also help in finding out the feasibility of expansion of the existing network of Delhi Metro in the adjacent cities like Meerut, thereby increasing the coverage area and ambit and the revenue generation purview.
1.5.2 OBJECTIVES OF THE STUDY

Every course of study is carried out for achieving some specified purpose or objective. A study without any objective is like body without soul. Certain objectives are worked upon to achieve them. They are:

1. To study & analyse the benefits accrued by Delhi Metro & the cost incurred to achieve these benefits.
2. To analyze the SWOT analysis of the Delhi Metro from socio-economic perspective.
3. To study the cost volume profit analysis of Delhi Metro and estimate of revenue for the next five years.
4. To study the factors influencing preference of using Delhi Metro.

1.5.3 LIMITATIONS OF THE STUDY

1. The study is restricted to Delhi & NCR region.
2. The study has subjective nature related to the cost & benefit.
3. The study makes certain assumptions which may not hold true over the duration of the Delhi Metro project.
4. We have used convenience sampling to study the factors influencing commuters’ preference for Delhi Metro. Since the sampling frame is not known, and the sample is not chosen at random, the inherent bias in convenience sampling means that the sample is unlikely to be representative of the population being studied. This undermines the ability to make generalisations from the sample to the population being studied.
1.5.4 COST BENEFIT ANALYSIS

Smart consumers investigate all costs and benefits before making major purchase decisions. Prior to buying a car one wants accurate information on its fuel, maintenance, repair and insurance costs. Similarly, before buying a train or airline ticket one wants to know about all fees and taxes, and the ease of schedule changes. One also wants information on each option’s reliability, comfort and safety.

Just as consumers need accurate and comprehensive information when making personal travel decisions, communities need accurate and comprehensive information on all significant impacts when making transport policy and planning decisions.

Most people have limited knowledge of transport economics. They would say that they just want to be able to travel conveniently, safely and affordably, without higher taxes, pollution or conflict with other road users. Yet, they are actually expensive, complex and contradictory. Accommodating ever-growing motor vehicle travel requires significant resources to continually expand roadway and parking capacity, and provide traffic services, in addition to accident risk, pollution emissions and other undesirable impacts. A motorist thinks, “I pay vehicle taxes and fees so I should get parking and traffic services,” little realizing that their user charges are insufficient to cover the full costs imposed by their driving.

Transportation policy and planning decisions affect virtually every aspect of life. Such decisions often involve trade-offs between conflicting objectives. For example, strategies to increase vehicle travel speeds can increase crash risk and degrade walking conditions. Some emission reduction strategies increase vehicle costs or reduce total motor vehicle travel. Expanding parking supply increases building costs and taxes. This report provides a framework for evaluating and rationalizing such decisions.

Some transport impacts, such as vehicle operation costs and travel time values, have been widely studied and estimates of their magnitude are easily available, making them relatively easy to evaluate. Other impacts, such as changes in walking conditions and greenhouse gas emissions, are more difficult to quantify, and so are often dismissed by decision-makers as intangibles, with the implication that they are less important than tangible impacts. The result is decision-making biased in favour of easy-to-measure impacts at the expense of more-difficult-to-measure impacts.

Cost-benefit analysis is a formal analysis of the impacts of a measure or programme, designed to assess whether the advantages (benefits) of the measure or programme are greater than its disadvantages (costs). Cost-benefit analysis is one of a set of formal tools of efficiency assessment. Efficiency assessment refers to
analyses made for the purpose of identifying how to use scarce resources to obtain the greatest possible benefits of them. Cost-benefit analysis is a technique which is based on welfare economics.

The main steps of a cost-benefit analysis are as follows:

- Develop measures or programmes intended to help reduce a certain social problem (e.g. road accidents or environmental pollution).
- Develop alternative policy options for the use of each measure or programme.
- Describe a reference scenario (sometimes referred to as business-as-usual or the do-nothing alternative).
- Identify relevant impacts of each measure or programme. There will usually be several relevant impacts.
- Estimate the impacts of each measure or programme in “natural” units (physical terms) for each policy option.
- Obtain estimates of the costs of each measure or programme for each policy option.
- Convert estimated impacts to monetary terms, applying available valuations of these impacts.
- Compare benefits and costs for each policy option for each measure or programme.
- Identify options in which benefits are greater than costs.
- Conduct a sensitivity analysis or a formal assessment of the uncertainty of estimated benefits and costs.
- Recommend cost-effective policy options for implementation.

Cost-benefit analysis is typically applied to help find efficient solution to social problems that are not solved by the market mechanism.

Typical characteristics of problems to which cost-benefit analysis is applied include:

- They involve public expenditures, often investments. Projects are sometimes financed by direct user payment, but more often by general taxation.
- There are multiple policy objectives, often partly conflicting and requiring tradeoffs to be made. It is assumed that policy makers want solutions that realize all policy objectives to the maximum extent possible.
- One or several of the policy objectives concern the provision of a non-marketed public good, like less crime, a cleaner environment or safer roads.
- It is assumed that an efficient use of public funds is desirable, since these funds are scarce and alternative uses of them numerous.
Road safety problems have these characteristics. Efficiency is a technical term in welfare economics. Without going into details, a measure or programme is judged to be efficient if the benefits are greater than the costs. In principle, it will then be possible for those who gain from the measure to compensate those who lose from it, so that nobody becomes a net loser.

To identify relevant measures or programmes, a broad survey of potentially effective road safety measures should be conducted. A measure is regarded as potentially effective if it has been shown to improve road safety – and has not already been fully implemented – or if there is reason to believe that it will improve road safety by favourably influencing risk factors that are known to contribute to accidents or injuries.

For each road safety measure, alternative options for its use should be considered. If the problem to be solved is bicyclist injuries, and the measure considered is bicycle helmets, alternative policy options could be:

- Do nothing; leave to each bicyclist to decide whether or not to wear a helmet.
- Conduct a campaign for bicycle helmets, while leaving their use voluntary.
- Make the use of bicycle helmets mandatory for children.
- Make the use of bicycle helmets mandatory for everybody.

These are distinct and mutually exclusive options. For very many road safety measures, however, options for their use are best conceived of as a continuous variable. Thus, one may convert 50 junctions to roundabouts, 51 junctions, 52 junctions, and so on. Most infrastructure-related road safety measures can be applied in very small gradual steps like this. These steps can be approximated as a continuous variable, since there would normally be thousands of junctions or thousands of kilometres of road that are candidates for the use of a certain road safety measure.

Policy options in cost-benefit analysis are always compared to a reference scenario and represent changes from that scenario. Often the reference scenario will be to do nothing, i.e. not introduce the road safety measure for which a cost-benefit analysis is performed. In some cases, however, one may foresee that a certain road safety measure will be introduced without any action from government.

As an example, electronic stability control is now rapidly becoming standard equipment on new cars and will spread in the car fleet during the next 10-15 years. In such cases, the foreseen rate of introduction should be regarded as the reference scenario.

The most relevant impact of a road safety measure is of course changes in the number of accidents or injury severity. Some road safety measures may, however, have additional impacts on mobility (travel time) and
the environment. If a measure has such impacts, they should be included in a cost-benefit analysis. One of the objectives of such analyses is to help make trade-offs between different, and sometimes conflicting, policy objectives. Impacts that are relevant for all policy objectives must therefore be included.

All relevant impacts should first be estimated in “natural” units, for example number of accidents prevented, number of additional hours of travel, and so on. Then all impacts should be converted to monetary terms, applying monetary valuations of the various impacts. More will be said later about the economic valuation of road safety.

Cost-benefit analysis is designed to identify policy options for which benefits are greater than costs. According to the theory underlying cost-benefit analysis, a policy option should normally not be adopted if benefits are smaller than costs. It will, however, often be the case that costs and benefits are not known with certainty.

**USE OF COST-BENEFIT ANALYSIS**

Cost-benefit analysis is a prescriptive technique. It has an explicit normative basis and is performed for the purpose of informing policy makers about what they ought to do. It is based on welfare economics and requires all policy impacts to be stated in monetary terms.

Some people find the very idea of assigning a monetary value to lifesaving or to quality of life, which is an essential element of cost-benefit analysis, meaningless and ethically wrong.

Human life, it is argued, is not a commodity that can be traded against other goods. It should therefore not carry a price tag. However, the purpose of assigning a monetary value to human life is not to engage in trading in the usual sense of that term. It is simply to provide a guideline with respect to the amount of resources we would like to spend on the prevention of accidents or injuries, given the fact that not all of our resources can be spent for this purpose. Some form of economic reasoning – that is some form of thinking that recognizes the fact that resources are limited and can be put to very many alternative uses – is simply inevitable, given the following basic facts:

- A limited amount of resources is at our disposal for the prevention of accidents or injuries, or indeed for catering to any human need.
- Human needs and value systems are complex and multi-dimensional. While safety is certainly one of the more basic human needs, it is not the only one and no society would ever be able to spend more than a fraction of disposable resources on the prevention of accidents or injuries.
How much to spend on the prevention of accidents or injuries will depend, and ought to depend, on how important people think this good is, seen in relation to all other goods they would like to see produced.

It is, in principle, possible both to provide too little safety and to provide too much of it.

The objective of cost-benefit analysis is to help us find the right balance between safety and other goods.

The main reason for doing cost-benefit analyses of road safety measures are to help develop policies that make the most efficient use of resources i.e. that produce the largest possible benefits for a given cost. Cost-benefit analysis seeks to identify the cheapest way of improving road safety. While one can think of arguments for choosing expensive solutions, one should never forget the fact that once resources have been committed to an expensive solution to a problem, they are no longer available for alternative, and possibly more beneficial, uses.

**BASIC RULES OF THE GAME**

There are four main principles of cost-benefit analysis:

- Consumer sovereignty
- Valuation of goods according to willingness-to-pay
- Pareto-optimality as the criterion of welfare maximisation
- Neutrality with respect to income distribution

**Consumer sovereignty** is the principle that the choices made by consumers with respect to how to spend their income are accepted and are treated as data. Economists are not moralists. They will not say that someone who spends most of his income on alcohol, tobacco and unhealthy foods is a fool, whereas someone who saves part of his income for old age, while spending the rest prudently on safe foods and safe activities is a wise person. Economists simply treat individual demand for various goods and services as data.

**The value of improving road safety** is indicated by the willingness-to-pay for reduced risk of injury. Willingness-to-pay is the measure of benefits used in cost-benefit analysis. Assessing willingness-to-pay for non-market goods like road safety is a complex task, involving many potential sources of error. Hence, a common objection to the willingness-to-pay principle is that it is not possible to obtain credible estimates of willingness-to-pay. A more fundamental objection is that willingness-to-pay depends on ability to pay. The rich can afford to pay more for road safety than the poor. If the distribution of income is highly unequal, an indiscriminate use of the willingness-to-pay principle may lead to the provision of non-market goods, like road safety or cleaner air, only to the richest groups of the population. Since road accidents represent a threat
to human health, one could argue that all groups of road users ought to have equal access to measures intended to improve road safety, irrespective of their individual demand for it.

In response to these points of view, three arguments can be made in favour of basing the provision of road safety on the demand for it, as manifested in the amounts that individuals are willing to pay for safer roads. In the first place, it is never the case that the provision of road safety – at least when it is a public good – can be matched exactly to individual demand for it.

The rich may state that they want to pay a lot for road safety, the poor may state that they cannot afford to pay anything, but both groups benefit when roads or cars are made safer. It is just not possible to match supply and demand at the individual level, as opposed to the case for most market goods (in the sense that, as a rule, we buy the mix of commodities that gives us the greatest satisfaction). In the second place, it is in principle possible to convert the amounts of money individuals are willing to pay for road safety to utility terms, by estimating the marginal utility of money. By converting monetary amounts to units of utility, one may account for the fact that giving up 1,000 Euro is a much smaller sacrifice for a rich man than giving up, say, 250 Euro would be for a poor man.

At present, however, converting money to utility is not an easy task. In general, economists will recommend using the willingness-to-pay principle provided it does not lead to unacceptable changes in income distribution. What counts as “unacceptable” in this respect is, of course, ultimately a matter of politics. In the third place, basing the provision of road safety on the demand (willingness to pay) for it ensures that it is not overprovided. Road safety is overprovided if overall welfare can be improved by transferring resources from the provision of road safety to the provision of other commodities.

**Pareto-optimality** is the third principle of cost-benefit analysis. A measure is Pareto-optimal if it improves the welfare of at least one person without reducing the welfare of any other person. In practice, few measures taken by government will be strictly Pareto-optimal. There will almost never be only gainers and no losers. Hence, the criterion commonly applied in cost-benefit analysis is a weaker criterion, the criterion of a potential Pareto-improvement. This criterion is satisfied when those who gain from a measure can compensate those who lose from it (in utility terms), while still retaining a net benefit. A measure is commonly regarded as satisfying this criterion if its benefits are greater than the costs.

The fourth principle of cost-benefit analysis is that it remains **neutral with respect to the distribution of benefits and costs among groups of the population** (or groups of road users, for that matter) – provided of course that benefits in total exceed costs. Cost-benefit analysis not intended to help find the most equitable solution to a social problem, only the most efficient solution. To the extent that realising a desired
distribution requires the use of other policy instruments than those sanctioned by cost-benefit analysis, it follows that actual policy priorities cannot be based on cost-benefit analyses exclusively.

BARRIERS TO THE USE OF COST-BENEFIT ANALYSES

In the thematic network ROSEBUD, an attempt was made to describe potential barriers to the use of cost-benefit analysis of road safety measures. The following list of potential barriers, arranged from the more basic to the more superficial was developed.

A) FUNDAMENTAL BARRIERS (BARRIERS OF A PHILOSOPHICAL NATURE)

- Rejecting the principles of welfare economics
- Rejecting efficiency as a relevant criterion of desirability
- Rejecting the monetary valuation of risk reductions

B) INSTITUTIONAL BARRIERS (BARRIERS RELATED TO THE ORGANISATION OF POLICY MAKING)

- Lack of consensus on relevant policy objectives
- Formulation of policy objectives inconsistent with cost-benefit analysis
- Priority given to policy objectives unsuitable for cost-benefit analysis
- Horse trading/vote trading
- Political opportunism
- Unfunded mandates and excessive delegation of authority
- Abundance of resources
- Rigidity of reallocation mechanisms
- Wrong timing of EAT information in decision-making process.

C) TECHNICAL/METHODOLOGICAL BARRIERS (BARRIERS RELATED TO INHERENT ELEMENTS OF THE EFFICIENCY ASSESSMENT TOOLS)

- Lack of knowledge of relevant impacts
- Inadequate monetary valuation of relevant impacts
- Indivisibilities
- Inadequate treatment of uncertainty
D) BARRIERS RELATED TO THE IMPLEMENTATION OF COST-EFFECTIVE POLICY OPTIONS

- Social dilemmas
- Lack of power
- Vested interests in road safety measures
- Lack of incentives to implement cost-effective solutions
- Lack of marketing of efficient policies

DEFINING COST

What most people call problems, economists call costs. For example, if somebody says, “Traffic congestion is a terrible problem,” an economist might say, “Traffic congestion is a significant cost.” The term cost is more neutral. Problem implies something is flawed and must be corrected, while cost recognizes that solving a problem involves tradeoffs. Calling congestion a problem implies that it must be fixed, but describing it as a cost recognizes that a certain amount of congestion may be acceptable compared with the costs involved in eliminating it. Also, costs imply that impacts can be quantified. Calling congestion a problem indicates nothing about its magnitude but calling congestion a cost suggests that it can be measured and compared with other impacts.

Cost refers to the trade-offs between uses of resources. This can involve money, time, land, or the loss of an opportunity to enjoy a benefit. Costs and benefits have a mirror-image relationship: a cost can be defined as a reduction in benefits, and a benefit can be defined in terms of reduced costs. For example, time spent travelling is a cost if the same time could be used in other beneficial ways. Lee states,

“The economist’s notion of cost—which is used here—is the value of resources (used for a given input) in their best alternative use . . . If less time were used in travel, how valuable would the time be for whatever purpose travellers chose to use it? If clean air were less consumed in dispersing vehicle pollutants, how much would society benefit from using the air to disperse non-highway pollutants or from breathing cleaner air? This concept of costs depends, then, on benefits foregone; there is no separate measure of cost that is distinct from valuation of benefits.”
Costs have various attributes that affect their impacts, which are described below.

INTERNAL, EXTERNAL AND SOCIAL COSTS

Internal (also called user or private) costs are borne by a good’s consumer. External costs are borne by others. Social costs are the total costs to society, including both internal and external impacts.

Some costs, such as traffic congestion and crash damages are largely imposed by motorists on other motorists, and so are external to individuals but internal within a group (sector). Whether such costs should be considered internal or external depends on the type of problem being addressed.

VARIABLE & FIXED COSTS

Variable (also called marginal) costs are the incremental costs resulting from an incremental change in consumption, and so reflect costs that can be reduced by reduced consumption, for example, if motorists reduce their annual mileage. Fixed costs are not affected by consumption. Sunk costs are fixed costs incurred in the past which cannot be recovered. For example, equipment, buildings and land are fixed cost, but they can be sold and their value partly recovered. Expenditures such as planning for a project that is never built or building a structure with no value are sunk costs, resources spent on them cannot be recovered in the future.

Fuel, travel time and crash risk are variable vehicle costs; they increase with mileage. Depreciation, insurance, and registration fees are considered fixed. The distinction between fixed and variable often depends on perspective. For example, although depreciation is usually considered a fixed cost, a vehicle’s operating life and resale value are affected by its mileage, so depreciation is partly variable over the long term.

MARKET & NON-MARKET COSTS

Market costs involve goods that are traded in a competitive market, such as vehicles, land and fuel. Nonmarket costs involve goods that are not regularly traded in markets such as clean air, crash risk, and quiet. Monetary costs are called expenditures.

PERCEIVED OR ACTUAL COSTS

There is sometimes a difference between users’ perceived and actual costs. Consumers tend to be most aware of immediate costs such as travel time, fuel, parking fees and individual transit fares, while costs that are only paid occasionally, such as insurance, depreciation, maintenance, repairs and residential parking, are often underestimated.
PRICE

Price refers to perceived-internal-variable cost, that is, the incremental costs that a user bears for consuming a good. These are the costs that directly affect consumption decisions. For example, a change in fuel prices, parking fees and transit fares affect consumers’ travel decisions. Economic efficiency requires that prices reflect the full costs of producing a good to give accurate market signals. Price is often defined narrowly to only include monetary costs, but it can also include nonmarket user impacts such as time and risk, since they also affect consumption decisions. Transport planners call this the generalized cost of travel.

DIRECT OR INDIRECT COSTS

Some impacts are indirect, with several steps between an activity and its ultimate outcomes. For example, expanding urban freeways tends to stimulate low-density, urban-fringe development (sprawl) and reduce mobility options for non-drivers, resulting in various economic, social and environmental costs. Although it may be difficult to measure a particular vehicle-mile’s contribution to such costs, the cumulative impacts are significant and so should not be ignored. This is similar to the effects of tobacco and alcohol: a single cigarette or drink may do little harm, but is no question that smoking and excessive drinking impose significant costs on society that justify public campaigns to encourage responsible use. Quantifying indirect impacts requires an understanding of the various steps connecting an activity with its ultimate effects. Whether an activity imposes an indirect cost can be determined using a “with and without” test: the difference in impacts with and without a policy or project.

ECONOMIC TRANSFERS, RESOURCE COSTS AND TAXES

Economic transfers involve costs or benefits shifts that do not change the total amount of resources available. Pricing and taxes are economic transfers; they are a cost to one group and a benefit (revenue) to another; only additional transaction costs of paying or collecting such fees are true resource costs. Economic transfers can involve nonmarket costs. For example, larger vehicles tend to increase safety for their occupants but increase risk to other road user, a transfer of risk. When evaluating such impacts it is important to account for both the benefit and the costs of economic transfers.

Taxes require special consideration in cost analysis. Taxes are usually considered an economic transfer from consumers to governments, and are excluded when calculating costs and benefits. Special charges, such as fuel taxes and vehicle registration fees can be considered user fees that internalize external costs, but general taxes, such as standard sales taxes on vehicles, are not, since consumers pay such taxes on other goods. For example, if automobile travel imposes external costs of 10¢ per mile, a policy that adds one million vehicle-miles of travel would impose $100,000 in additional external costs. However, if motorists pay 3¢ per mile on
average in special fuel taxes, the additional driving would generate $30,000 in additional fuel tax revenue so the net external cost is $70,000. Similarly, a mobility management program that reduces a million vehicle-miles of travel provides $100,000 in cost savings, minus $30,000 in reduced fuel tax revenue, resulting in a net $70,000 gain. General taxes are not considered to offset costs because motorists who drive less are assumed to spend their fuel cost savings on other taxed goods (e.g. rents, clothing, and entertainment), so general tax revenue would not change.

If special taxes are charged instead of, rather than in addition to, general taxes, then only the level of tax above the general tax rate is considered a user fee. For example, if a jurisdiction charges a 6% general tax, but charges only a 20¢ per gallon special tax on fuel, and gasoline costs $1.50 per gallon, the first 9¢ of the fuel tax can be considered a general tax equivalent, and only the remaining 11¢ would be considered a user fee.

**DISCOUNT RATE IN COST ANALYSIS**

When an economic impact occurs can affect its economic value. In general, future impacts are discounted. Discount rates reflect the time value of money, which recognizes that wealth can be invested to generate profits (increased benefits), so current resources have greater value than future resources, even after adjusting for inflation. Nominal discount rates include inflation, while those that are net of inflation are called real discount rates. Selecting the correct discount rate is particularly important when evaluating impacts that occur many years in the future, such as highway improvement benefits or changes in land use development. The higher the rate, the more weight is given to present over future benefits. Capital investment discount rates are typically 6-10%. These rates reflect the return capital could earn in typical alternative investments.

A debate exists as to the discount rate to use for impacts on future generations. Conventional discounting implies that costs many years in the future are of little concern now. For example, at 8% discount, costs and benefits occurring 20 years in the future (a typical planning horizon) are worth less than a tenth their current value. Some analysts argue that these financial assumptions are inappropriate for evaluating human health risk and irreversible environmental impacts. They recommend using a lower, or zero, discount rate for human health and irreversible environmental costs to give fair consideration to future generations’ interests.

**VARIABILITY AND UNCERTAINTY:** Any cost or benefit estimate incorporates some degree of variability and uncertainty. Consider, for example, the valuation of a common commodity such as an apple. At first, it may seem easy to estimate apple costs since they are sold almost everywhere. But their cost varies depending on which apple, and when, where and how it is bought. If purchased in bulk directly from a
farmer an apple might cost just a few cents, but if purchased individually at a convenience store, the same apple may cost more than a dollar. Apples are cheaper if purchased wholesale, in bulk or during a special sale, and more expensive if they are imported, out-of-season, organic, or specialty varieties. Estimates of apple costs can vary significantly depending on how they are defined and measured.

Similarly with transport costs and benefits. The values in this report are generic. Of course, actual costs vary depending on factors such as location, time, vehicle condition, etc. For example, average air pollution costs may not apply to a particular situation because vehicle or exposure conditions are not average. Ideally, each cost value should be adjusted to reflect each specific application. For example, when calculating parking cost savings from reduced automobile trips in a particular area, an analyst might first use the generic numbers from this report, and adjust them based on local conditions (such as land values). If even greater precision is needed, a detailed study of local parking costs could be done, in which case some references in this report may be useful guides.

Because transport cost analysis involves new areas of research, limited data sources, and complex modelling, estimates incorporate various levels of uncertainty. This is not a unique problem; individuals, businesses, and society often face uncertainty when assessing costs and benefits. For example, a business must invest in a new factory without knowing exactly what the project will cost or the future prices they will get from the factory’s products. As stated by one expert in non-market costing, “A crude approximation, made as exact as possible and changed over time to reflect new information, would be preferable to the manifestly unjust approximation caused by ignoring these costs, and thus valuing environmental damage as zero.”

‘CONSERVATIVE’ COST ESTIMATES: Some economic analyses only include costs that are commonly accepted and easily quantified, and dismiss difficult-to-quantify impacts as intangibles (impacts that cannot be perceived by the senses). This tends to bias decision-making toward easy-to-measure impacts (such as project costs, vehicle operating expenses, and travel time savings) at the expense of more difficult-to-measure social and environmental impacts, and concentrated, short-term impacts at the expense of more dispersed, long-term impacts. This biases decision-making in various ways. For example, it tends to favour economic objectives (because they involve market resources) over social and environmental objectives; industries (which have more financial transactions) over communities (which involve more non-market transactions); wealthier people (because they purchase more market goods) over poorer people; and the current generation over future generations.
FINANCIAL ANALYSIS

Financial analysis comprises of capital budgeting. Capital budgeting (or investment appraisal) is the planning process used to determine whether an organization's long term investments such as new machinery, replacement machinery, new plants, new products, and research development projects are worth the funding of cash through the firm's capitalization structure (debt, equity or retained earnings). It is the process of allocating resources for major capital, or investment, expenditures. One of the primary goals of capital budgeting investments is to increase the value of the firm to the shareholders.

Capital budgeting is the planning of long-term corporate financial projects relating to investments funded through and affecting the firm's capital structure. Management must allocate the firm's limited resources between competing opportunities (projects), which is one of the main focuses of capital budgeting. Capital budgeting is also concerned with the setting of criteria about which projects should receive investment funding to increase the value of the firm, and whether to finance that investment with equity or debt capital. Investments should be made on the basis of value-added to the future of the corporation. Capital budgeting projects may include a wide variety of different types of investments, including but not limited to, expansion policies, or mergers and acquisitions. When no such value can be added through the capital budgeting process and excess cash surplus exists and is not needed, then management is expected to pay out some or all of those surplus earnings in the form of cash dividends or to repurchase the company's stock through a share buyback program.

Choosing between capital budgeting projects may be based upon several inter-related criteria. (1) Corporate management seeks to maximize the value of the firm by investing in projects which yield a positive net present value when valued using an appropriate discount rate in consideration of risk. (2) These projects must also be financed appropriately. (3) If no positive NPV projects exist and excess cash surplus is not needed to the firm, then financial theory suggests that management should return some or all of the excess cash to shareholders (i.e., distribution via dividends).

Capital budgeting involves allocating the firm's capital resources between competing project and investments. Each potential project's value should be estimated using a discounted cash flow (DCF) valuation, to find its net present value (NPV). (First applied to Corporate Finance by Joel Dean in 1951.) This valuation requires estimating the size and timing of all the incremental cash flows from the project. (These future cash highest NPV (GE).) The NPV is greatly affected by the discount rate, so selecting the proper rate—sometimes called the hurdle rate—is critical to making the right decision. The hurdle rate is the Minimum acceptable rate of return on an investment. This should reflect the riskiness of the investment, typically measured by the volatility of cash flows, and must take into account the financing mix. Managers
may use models such as the CAPM or the APT to estimate a discount rate appropriate for each particular project, and use the weighted average cost of capital (WACC) to reflect the financing mix selected. A common practice in choosing a discount rate for a project is to apply a WACC that applies to the entire firm, but a higher discount rate may be more appropriate when a project's risk is higher than the risk of the firm as a whole.

Ideally, businesses should pursue all projects and opportunities that enhance shareholder value. However, because the amount of capital available at any given time for new projects is limited, management needs to use capital budgeting techniques to determine which projects will yield the most return over an applicable period of time.

Popular methods of capital budgeting include net present value (NPV), internal rate of return (IRR), Profitability Index and many more.

**FACTORS INFLUENCING CAPITAL BUDGETING**

- Availability of funds
- Structure of capital
- Taxation Policy
- Government Policy
- Lending Policies of Financial Institutions
- Immediate need of the Project
- Earnings
- Capital Return
- Economic Value of the Project
- Working Capital
- Accounting Practice
- Trend of Earning
PROBLEMS AND DIFFICULTIES IN CAPITAL BUDGETING

The capital budgeting decisions are not only critical and analytical in nature, but also involve various difficulties which a finance manager may come across. The problems may be as follows:

a) **FUTURE UNCERTAINTY:** All capital budgeting decisions involve long term which is uncertain. Even if every care is taken and the project is evaluated to every minute detail, still 100% correct and certain forecast is not possible. The finance manager dealing with the capital budgeting decisions, therefore, should try to be as analytical as possible. The uncertainty may be with reference to cost of the project, future expected returns from the project, future competition, expected demand in future etc.

b) **TIME ELEMENT:** The implications of a capital budgeting decision are scattered over a long period. The cost and benefit of a decision may occur at different point of time. As a result, the cost and benefits of capital budgeting decision are generally not comparable unless adjusted for time value of money. The cost of the project is incurred immediately; however, it is recovered in number of years.

c) **MEASUREMENT PROBLEM:** Sometimes a finance manager may also face difficulties in measuring cost and benefits of a project in quantitative terms. For example, the new product proposed to be launched by a firm may result in increase or decrease in sales of other products already being sold by the same firm. But how much? This is very difficult to ascertain because the sales of other products may increase or decrease due to other factors also.

TECHNIQUES OF CAPITAL BUDGETING

1) **NET PRESENT VALUE (NPV)**

The NPV of an investment proposal may be defined as the sum of the present values of all cash inflows less the sum of present values of all the cash outflows associated with a proposal. In other words, the NPV of any proposal, that involves cash inflows and outflows over a period of time, is equal to the net present value of all the cash flows.

A rate of discount must be specified and applied to both inflows and outflows in order to find out their present values. This rate of discount should be the rate of return, the investor normally enjoys from investments of similar nature and risk. In effect, it is the opportunity rate of return.

\[
NPV = \sum_{i=1}^{n} \frac{CF_i}{(1 + k)^i} - C_0
\]
TABLE 1.3 CALCULATION OF NET PRESENT VALUE

<table>
<thead>
<tr>
<th>TIME</th>
<th>CASH FLOWS (Rs.)</th>
<th>PVF (10%)</th>
<th>PRESENT VALUES (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₀</td>
<td>-1,70,000</td>
<td>1.000</td>
<td>-1,70,000</td>
</tr>
<tr>
<td>T₁</td>
<td>20,000</td>
<td>0.909</td>
<td>18,180</td>
</tr>
<tr>
<td>T₂</td>
<td>50,000</td>
<td>0.826</td>
<td>41,300</td>
</tr>
<tr>
<td>T₃</td>
<td>60,000</td>
<td>0.751</td>
<td>45,060</td>
</tr>
<tr>
<td>T₄</td>
<td>40,000</td>
<td>0.683</td>
<td>27,320</td>
</tr>
<tr>
<td>T₅</td>
<td>75,000</td>
<td>0.621</td>
<td>46,575</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>8,435</td>
</tr>
</tbody>
</table>

The total cash inflow for the year T₅ is Rs. 75,000 (consisting of the annual inflow of Rs. 30,000 + working capital released of Rs. 20,000 + salvage value of Rs. 25,000). In the same case, if the total initial cost is taken at Rs. 1,80,000 instead of Rs. 1,70,000, then the NPV of project will be Rs. -1,565.

The higher the rate of return, lesser would be the NPV and lower the rate of return, higher would be the NPV.

THE DECISION RULE: The decision rule under NPV method is as follows:

a) Accept the proposal if its NPV is positive and reject the proposal if the NPV is negative. The proposals with negative NPV should out rightly be rejected as these entail decrease in wealth of the shareholders.

b) In case of ranking of mutually exclusive proposals, the proposal with the highest positive NPV is given the top priority and the proposal with the lowest positive is assigned the lowest priority.

c) However, if the NPV of the proposal is 0, than the firm may be indifferent between the acceptance and rejection of the proposal.

2) PROFITABILITY INDEX (PI)

PI is defined as the benefits (in present value terms) per rupee invested in the proposal. This technique which is a variant of the NPV technique is also known as Benefit-cost ratio, or Present Value Index. It is ascertained by comparing the present value of future cash inflows with the present value of the future cash outflows.
\[ PI = \frac{\text{Total Present Value of Cash Inflows}}{\text{Total Present Value of Cash Outflows}} \]

For Example, a firm is evaluating a proposal which requires a cash outlay of Rs. 40,000 at present and of Rs. 20,000 and at the end of third from now. It is expected to generate cash inflows of Rs. 20,000, Rs. 40,000 and Rs. 20,000 at the end of 1\(^{st}\) year, 2\(^{nd}\) year and 4\(^{th}\) year respectively. Given the rate of discount of 10%.

**TABLE 1.4 CALCULATION OF PROFITABILITY INDEX**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CASH FLOWS (Rs.)</th>
<th>PVF (10%)</th>
<th>PRESENT VALUES (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-40,000</td>
<td>1.000</td>
<td>-40,000</td>
</tr>
<tr>
<td>1</td>
<td>20,000</td>
<td>0.909</td>
<td>18,180</td>
</tr>
<tr>
<td>2</td>
<td>40,000</td>
<td>0.826</td>
<td>33,040</td>
</tr>
<tr>
<td>3</td>
<td>-20,000</td>
<td>0.751</td>
<td>-15,020</td>
</tr>
<tr>
<td>4</td>
<td>20,000</td>
<td>0.683</td>
<td>13,660</td>
</tr>
</tbody>
</table>

Present value of cash outflows = Rs. 40,000 + Rs. 15,020 = 55,020

Present value of cash inflows = Rs. 18,180 + Rs. 33,040 + Rs. 13,660 = 64,880

\[ PI = \frac{64,880}{55,020} = 1.18 \]

In present value terms, for every Re. 1 invested, the proposal is expected to give a return of Rs. 1.18.

**THE DECISION RULE:** Under PI technique, the decision rule is: Accept the project if its PI is more than 1 and reject the proposal if the PI is less than 1. However, if the PI is equal to 1, then the firm may be indifferent because the present value of inflows is expected to be just equal to the present value of the outflows.

In case of ranking of mutually exclusive proposals, the proposal with the highest positive PI will be given top priority while the proposal with the lowest PI will be assigned lowest priority. The proposals having PI of less than 1 are likely to be rejected.

The PI will be greater than 1 only for that project which has positive NPV; the project will be acceptable under both the techniques. On the other hand, if the PI is equal to 1 then the NPV would also be 0. Similarly, a proposal having PI of less than 1 will also have negative NPV.
For example, a firm is evaluating two proposals, A and B, having NPV of Rs. 20,000 and therefore, is alike. In this case, the PI technique seems to give a better result. PI of proposal A is 1.20 while PI of proposal B is 1.25.

Thus, in terms of NPV technique, both proposals are alike, but in terms of PI technique, the proposal B is better.

3) INTERNAL RATE OF RETURN (IRR)

The IRR of a proposal is defined as the discount rate which will equate the present value of cash inflows with the present value of cash outflows. In the IRR technique, the time-schedule of occurrence of the future cash flows is known but the rate of discount is not. Rather this discount rate is ascertained by the trial and error procedure. This rate of discount so calculated, which equates the present value of outflows, is known as IRR.

A positive NPV indicates the need for a higher discount rate, while negative NPV calls for lowering the discount rate.

For example, NPV of the project for two rates are:

At 12%, NPV = Rs. 2,775
At 13% NPV = Rs. -50

Exact IRR can be calculated by interpolating between 12% and 13%.

\[
IRR = L + \frac{A}{(H-L)} (H-L) \]

Where, L = lower discount rate, at which NPV is positive
H = higher discount rate, at which NPV is negative
A = NPV at lower discount rate, L
B = NPV at higher discount rate, H

So, calculating IRR by this formula we get

\[ IRR = 12.98\% \]

**THE DECISION RULE:** The firm has to determine its own required rate of return. This rate, K, is also known as the cut-off rate or the hurdle rate. A particular proposal may be accepted if its IRR, r, is more than
the minimum rate i.e. K, otherwise rejected. However, if the IRR is just equal to the minimum rate, K, then the firm may be indifferent.

In case of ranking of mutually exclusive proposals, the proposal with the highest IRR is given the top priority while the project with the lowest IRR is given the lowest priority.

NEED FOR CAPITAL BUDGETING

- As large sum of money is involved which influences the profitability of the firm making capital budgeting an important task.
- Long term investment once made cannot be reversed without significance loss of invested capital. The investment becomes sunk and mistakes, rather than being readily rectified, must often be borne until the firm can be withdrawn through depreciation charges or liquidation. It influences the whole conduct of the business for the years to come.
- Investment decision are the base on which the profit will be earned and probably measured through the return on the capital. A proper mix of capital investment is quite important to ensure adequate rate of return on investment, calling for the need of capital budgeting.
- The implication of long term investment decisions are more extensive than those of short run decisions because of time factor involved, capital budgeting decisions are subject to the higher degree of risk and uncertainty than short run decision.
1.5.5 COST VOLUME PROFIT ANALYSIS

Cost-volume-profit (CVP) analysis is used to determine how changes in costs and volume affect a company's operating income and net income. In performing this analysis, there are several assumptions made, including:

- Sales price per unit is constant.
- Variable costs per unit are constant.
- Total fixed costs are constant.
- Everything produced is sold.
- Costs are only affected because activity changes.

If a company sells more than one product, they are sold in the same mix.

Cost-Volume-Profit (CVP) Analysis is an important tool of profit planning. It provides information about the following matter:

- The behaviour of cost in relation to volume
- Volume of production or sales, where the business will break even.
- Sensitivity of profits due to variation in output.
- Amount of profit due to variation in output
- Quantity of production and sales for a target profit level.

Cost Volume Profit analysis may therefore be defined as a managerial tool showing the relationship between various ingredients of profit planning, viz., cost (both fixed and variable), selling price and volume of activity, etc.

Such an analysis is useful to the finance manager in the following respects:

- It helps him in forecasting the profit fairly accurately.
- It is helpful in setting up flexible budgets, since on the basis of this relationship, it can ascertain the costs, sales and profits at different levels of activity.
- It also assists him in performance evaluation for purposes of management control.
- It helps in formulating price policy by projecting the effect which different price structures will have on cost and profits.
CVP analysis may be used in setting selling prices, selecting the product mix to sell, choosing among alternative marketing strategies, and analysing the effects of cost increases or decreases on the profitability of the business enterprise.

**BASIC ASSUMPTIONS IN CVP ANALYSIS**

CVP analysis is based on several assumptions. Whether income is computed under the absorption or marginal (variable) costing concept, these assumptions include the following:

- Selling prices and pricing policy will remain constant at all sales levels; no quantity discounts are assumed to be available. If this is not true, sales revenue cannot be plotted as a straight line.
- All costs and expenses can be separated into fixed and variable components.
- The total of the fixed costs is constant at all sales levels; the unit variable costs remain the same and there is a direct relationship between costs and volume. If this is not true, straight lines cannot be drawn.
- Production and sales quantities are equal.
- Managerial policies, technological methods, and efficiency of men and machines will not change and cost control will be neither strengthened nor weakened.
- Volume is assumed to be the only important factor affecting cost behaviour; other influencing factors such as unit prices, sales mix, labour strikes, and production methodology are ignored. Any change in cost behaviour will need the breakeven point to be modified.

**ROLE OF CVP ANALYSIS**

Cost-Volume-Profit analysis can be used to measure the effect of factor changes and management decision alternatives on profits. These factors include possible changes in selling prices, changes in variable or fixed cost, expansion or contraction of sales volume, or other changes in operating methods or policies. CVP analysis is also useful for problems of product pricing, sales mix, adding or deleting product lines, and accepting special orders. Some situations where CVP analysis can be used are:

**CHANGES IN SELLING PRICES**

The CVP graph is frequently used to illustrate the potential profit effect of contemplated price changes. A change in the selling price of a product changes its profit-volume ratio (P/V ratio), which in turn has two effects on the profit pattern, first, a new break-even point is established, second, profits above and below the break even sales volume are different. Effects on the profit pattern are as follows:
a) **INCREASE IN SELLING PRICE:** If the selling price is increased it increases the P/V ratio, and the rate of fixed costs recovery is increased. The break-even point (break-even volume) declines, profits beyond the break-even point increases; losses below the break-even point decreases.

b) **DECREASE IN SELLING PRICE:** If the selling price decreases, it decreases the P/V ratio and the rate of fixed cost recovery declines. The break-even point moves at a higher point; profits beyond the break-even point decreases, losses below the break-even point increases.

Assume, for example, that a company produce a product with a selling price of Rs. 10 per unit and a variable cost of Rs. 4 per unit. Fixed costs are Rs. 36000 per year. The effect of a 20% increase and a 20% decrease in the present selling price is given below:

**TABLE 1.5 EXAMPLE OF SELLING PRICE CHANGES**

<table>
<thead>
<tr>
<th>PARTICULARS</th>
<th>PRESENT</th>
<th>20% INCREASE</th>
<th>20% DECREASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selling price per unit</td>
<td>Rs. 10</td>
<td>Rs. 12</td>
<td>Rs. 8</td>
</tr>
<tr>
<td>Variable cost per unit</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Margin contribution per unit</td>
<td>6</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>P/V ratio</td>
<td>60%</td>
<td>66.66%</td>
<td>50%</td>
</tr>
<tr>
<td>Fixed costs</td>
<td>36,000</td>
<td>36,000</td>
<td>36,000</td>
</tr>
<tr>
<td>Break-even point in units</td>
<td>6,000</td>
<td>4,500</td>
<td>9,000</td>
</tr>
<tr>
<td>In volume</td>
<td>60,000</td>
<td>54,000</td>
<td>72,000</td>
</tr>
<tr>
<td>Changes in break-even point:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In units</td>
<td>0%</td>
<td>-25%</td>
<td>+50%</td>
</tr>
<tr>
<td>In sales volume</td>
<td>0%</td>
<td>-10%</td>
<td>+20%</td>
</tr>
</tbody>
</table>
FIGURE 1.8 EFFECTS OF CHANGES IN SELLING PRICES ON PROFITS

CHANGES IN VARIABLE COSTS:

The CVP graph is used to evaluate the impact of increases and decreases in variable costs per unit. Changes in variable cost change the P/V ratio, change the break-even point, and affect profit and loss at different volumes. The effects of changes in variable costs can be summarised as follows:

a) INCREASE IN VARIABLE COSTS: An increase in variable costs has the same effect as a decrease in the selling price. It decreases the P/V ratio and the rate of fixed cost recovery is slower. The break-even point moves to a higher level, profits after the break-even point decrease, and losses before the break-even point increase.

b) DECREASE IN VARIABLE COSTS: A decrease in variable costs has the same effect as an increase in the selling price. A higher P/V ratio is achieved and the rate of fixed costs recovery is increased. The break-even point declines; profits beyond the break-even point are higher; losses before the break-even point are lower.

To illustrate the effect of change in variable costs, assume a company is selling a product for Rs. 40 a unit and has a variable cost of Rs. 20 per unit. Fixed costs total Rs. 48000 per year. The effects of a 20% increase and a 20% decrease in variable cost are given in the following table:
TABLE 1.6 EXAMPLE OF CHANGES IN VARIABLE COST

<table>
<thead>
<tr>
<th>PARTICULARS</th>
<th>PRESENT VARIABLE COST (Rs.)</th>
<th>20% INCREASE</th>
<th>20% DECREASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit selling price</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Variable cost per unit</td>
<td>20</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>Marginal contribution</td>
<td>20</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>P/V ratio</td>
<td>50%</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Fixed costs</td>
<td>48,000</td>
<td>48,000</td>
<td>48,000</td>
</tr>
<tr>
<td>Break-even point:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales volume</td>
<td>96,000</td>
<td>1,20,000</td>
<td>80,000</td>
</tr>
<tr>
<td>Units</td>
<td>2400</td>
<td>3000</td>
<td>2000</td>
</tr>
</tbody>
</table>

CHANGES IN FIXED COST

Increase and decrease in the fixed cost do not have any impact on the P/V ratio, but they change the break-even point. With the same P/V ratio, the rate of fixed costs recovery remains the same.

a) **INCREASE IN FIXED COSTS:** If fixed costs are increased, the break-even point (break-even volume) is higher. Profits above the break-even point are lower by the amount of the increase in fixed costs; below the break-even point losses increase by the amount of increase.

b) **DECREASE IN FIXED COSTS:** If fixed costs are decreased, it lowers the break-even point. The profits are greater by the amount of the decrease, and losses are smaller by the amount of the decrease in fixed costs.

Assume that a company has a P/V ratio of 40% and present fixed costs of Rs.50, 000. The effects of change in the fixed costs by Rs. 10,000 are as follows:

TABLE 1.7 EXAMPLE OF CHANGES IN FIXED COST

<table>
<thead>
<tr>
<th>PARTICULARS</th>
<th>PRESENT FIXED COSTS</th>
<th>INCREASE BY Rs. 10,000</th>
<th>DECREASE BY Rs. 10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed costs</td>
<td>Rs. 50,000</td>
<td>Rs. 60,000</td>
<td>Rs. 40,000</td>
</tr>
<tr>
<td>P/V ratio</td>
<td>40%</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>Break-Even Point</td>
<td>1,25,000</td>
<td>1,50,000</td>
<td>1,00,000</td>
</tr>
<tr>
<td>Decrease</td>
<td>0</td>
<td>+25,000</td>
<td>-25,000</td>
</tr>
</tbody>
</table>
From the above example it is clear that the P/V ratio is the same in each situation and break-even point can be determined by dividing the amount of the change by the P/V ratio:

\[
\text{Change in fixed cost} / \text{P/V ratio} = 10,000 / 40\% = \text{Rs. 25,000}
\]

1. **DESIRED OR TARGET PROFIT**

Sometimes, management faces two decisions: (i) to increase sales volume through reduction in selling prices, and (ii) to increase selling prices in case the P/V ratio is low, with the expectation that a higher profit will be earned. These decisions should be taken carefully after studying the profit pattern and other factors, otherwise the results can be harmful particularly for those companies whose P/V ratio are already low. Also, if reduction in selling price does not increase the sales volume, the price reduction will result only in lower profits. Price cuts, like increase in variable unit costs, decrease the contribution margin.

On a unit basis, price decreases may appear to be insignificant, but when the unit differential is multiplied by thousands of units, the total effect may be significant. Perhaps, many more units will have to be sold to make up the loss in profit or to earn a target profit.

2. **MULTI-PRODUCT SITUATIONS**

When there are multiple products with different contribution margins, the mix of the product has a direct effect on the fixed costs recovery and total profits of the firm. Different products have different P/V ratio because of different selling prices and variable costs. Some products make larger contributions to fixed cost recovery and profit than others. The total profit depends to some extent upon the proportions in which the products are sold.

3. **SALES MIX AND BREAK-EVEN POINT**

Sales mix is the relative proportion of each product line to the total sales of various products sold by an enterprise. If there are no constraints or limitations, management should try to maximize the sales of the product(s) with higher P/V ratio. However, a sales mix results because there are limits to the quantities of any given product that can be produced and there may also be certain market limitations on how much can be sold.

When different products have their own different production facilities, selling prices, variable costs and fixed costs separately, cost-volume-profit analysis can be done for each product separately. But, in many
situations, this is not found and different products share common facilities and have common fixed costs. In such a situation CVP analysis is performed by averaging the data using the sales mix as weights.

**TECHNIQUES OF CVP ANALYSIS**

CVP analysis uses the following techniques or analyses while answering many questions in the area of managerial planning and decision making:

a) Contribution Margin Concept  
   b) Break-Even Analysis  
   c) Profit-Volume (P/V) Analysis

**CONTRIBUTION MARGIN CONCEPT**

Contribution margin concept indicates the profit potential of a business enterprise and also highlights the relationship between cost, sales and profit. Contribution margin is the excess of sales revenue over variable expenses. From the contribution margin, fixed expenses are deducted giving finally operating income or loss. Contribution margin is thus used to recover fixed costs. Once the fixed costs are recovered, any remaining contribution margin adds directly to the operating income of the firm. Contribution margin is a highly useful technique for planning and decision making by the management.

**CONTRIBUTION MARGIN RATIO (ALSO KNOWN AS C/S RATIO OR P/V RATIO)**

The contribution margin can also be expressed in the form of a percentage. The contribution margin ratio is also known as “contribution to sales” (C/S) ratio or profit-volume (P/V) ratio. This ratio denotes the percentage of each sales Rupee available to cover the fixed costs and to provide operating income to a firm.

Taking an example:

**TABLE 1.8 EXAMPLE OF P/V RATIO**

<table>
<thead>
<tr>
<th>PARTICULARS</th>
<th>AMOUNT (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>10,00,000</td>
</tr>
<tr>
<td>Variable Costs</td>
<td>6,00,000</td>
</tr>
<tr>
<td>Fixed Costs</td>
<td>3,00,000</td>
</tr>
</tbody>
</table>
Contribution is calculated as follows:

<table>
<thead>
<tr>
<th></th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>10,00,000</td>
</tr>
<tr>
<td>Less: Variable Costs</td>
<td>6,00,000</td>
</tr>
<tr>
<td>Contribution margin</td>
<td>4,00,000</td>
</tr>
<tr>
<td>Less: Fixed Costs</td>
<td>3,00,000</td>
</tr>
<tr>
<td>Profit</td>
<td>1,00,000</td>
</tr>
</tbody>
</table>

Contribution Margin Ratio (or C/S or P/V ratio) =

\[
\text{Contribution Margin Ratio} = \frac{\text{Sales} - \text{Variable Costs}}{\text{Sales}}
\]

\[
= \frac{\text{Rs. 10,00,000} - \text{6,00,000}}{10,00,000}
\]

\[
= \frac{\text{Rs. 4,00,000}}{10,00,000}
\]

\[
= 40\%
\]

The P/V ratio helps in knowing the effect on income of a firm due to increase or decrease in sales volume. For instance, in the example above, a business enterprise may be interested in studying the effect of having additional sales of Rs. 4,00,00 on the income of the firm. Multiplying the P/V ratio (40%) by the change in sales volume (Rs. 4,00,00) indicates an increase in operating income by Rs. 1,60,000 if additional sales is possible. The total income will be Rs. 2,60,000 as is clear from the following computation:

<table>
<thead>
<tr>
<th>PARTICULARS</th>
<th>AMOUNT (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>14,00,000</td>
</tr>
<tr>
<td>Less: Variable costs (14,00,000 * 60%)</td>
<td>8,40,000</td>
</tr>
<tr>
<td>Contribution margin (14,00,000 * 40%)</td>
<td>5,60,000</td>
</tr>
<tr>
<td>Less: Fixed costs</td>
<td>3,00,000</td>
</tr>
<tr>
<td>Net income</td>
<td>2,60,000</td>
</tr>
</tbody>
</table>

It is clear from above example, variable costs is as percentage are 60% of sales (100% - P/V ratio which is 40%). Thus, variable cost as a percentage of sales is always equal to 100% minus the P/V ratio.
The P/V ratio is useful to management in deciding whether to increase sales volume. For example, if the P/V ratio of a business enterprise is large and the enterprise is operating at less than 100% capacity, it will be advantageous for the firm to go for increase in sales volume as net income will go up because of higher sales volume.

On the other hand, a firm with a small P/V ratio will not find profitable to have increase in sales volume much profitable. In fact enterprises having a lower P/V ratio should aim at reducing costs and expenses before thinking of increasing the sales volume.

The use of P/V ratio in a specific analysis is based on the assumption that except sales volume, other factors such as the unit selling price, percentage of variable cost to sales, amount of fixed costs remain constant. If there are any of these factors the effect of such change should be considered in making the analysis involving P/V ratio.

**BREAK-EVEN ANALYSIS**

Break-even analysis stresses the relationship and the factors affecting profit. A break-even analysis indicates at what level cost and revenue are in equilibrium. It is a simple and easily understandable method of presenting to management the effect of changes in volume on profits.

**BREAK-EVEN POINT**

The break-even point can be defined as the point or sales level at which losses cease and profits begin or vice-versa. Or it can be described as that level of sales at which profits are zero and there is no loss. The break-even point serves as a base indicating how many units of product must be sold if a company is to operate without loss.

At the break-even point profit being zero, contribution (sales- variable cost) is equal to the fixed cost. If the actual volume of sales is higher than the break-even volume, there will be a profit. The break-even point is reached when the fixed costs have been fully met, beyond the break-even point, all the marginal contribution represents income.

Assume that a company manufactures and sells a single product as follows:

Selling price per unit = Rs. 20
Variable cost per unit = Rs. 10
Total fixed cost = Rs. 1,00,000

The break-even sales to cover fixed costs will be 10,000 units.

Selling price per unit = Rs. 20
Variable cost per unit = Rs. 10
Contribution = Rs. 10

Break-even volume = Rs. 1,00,000 fixed cost/ Rs. 10 contribution margin
= 10,000 units.

If the company can sell more than 10,000 units, it will earn profits because fixed costs remain constant. If less than 10,000 units are sold, a loss will be incurred. The profits will be equal to the number of units sold in excess of 10,000 units multiplied by the unit contribution margin. For example, if 25,000 units are sold, the company will be operating at 15000 units above its break-even point and will earn a profit of Rs. 1,50,000 (15,000 units * Rs. 10 contribution margin).

BREAK-EVEN FORMULA

The break-even point can be obtained directly by a mathematical formula. The basic formula to find out the break-even point is:

Break-even sales (units) = fixed costs/contribution margin per unit

Break-even sales (volume) = fixed costs/C/S ratio (also known as P/V ratio)
OR
= total fixed expenses/1-(total variable expenses/total sales)

BREAK-EVEN CHART

Total revenues and total costs at different sales volume can be estimated and plotted on a break-even chart. This chart is constructed as follows:
1. A horizontal base line, the x-axis, is drawn and spaced into equal distances representing plant capacity, sales volume or number of units. A physical index of output (units of product) is preferable because it is not influenced by changes in selling price, but when many products are involved a sales value index may be selected.

2. A vertical line, the y-axis is drawn on the left side of the chart and also spaced into equal parts. This line indicates sales revenue and also costs.

3. A line parallel to the horizontal line (x-axis) is drawn for fixed costs.

4. A total cost line is drawn starting at the y-axis fixed cost point and moving to the right. This total cost line represents at each point the total of all items of cost, fixed and variable.

5. The sales line is drawn starting at the zero point on the vertical axis and ending at the top on the right side.

6. The total cost line intersects the sales line at a point which is known as the break-even point.

7. The area to the left of the break-even point between the total cost line and the sales line is the loss area: the profit area lies to the right of the break-even point, above the total cost line.

It can be observed from the chart that the break-even point occurs when sales are 10,000 units at Rs. 2,00,000.
MARGIN OF SAFETY

This is the difference between sales and the break-even point. If the distance is relatively short, it indicates that a small drop in production or sales will reduce profit considerably. If the distance is long it means that the business can still make profits even after a serious drop in production. It is important that there should be a reasonable margin of safety, otherwise a reduced level of production may prove dangerous. The margin of safety can be found by using the following formula:

\[
\text{Margin of safety} = \frac{\text{Profit}}{\text{P/V ratio}}
\]

OR

\[
\text{Margin of safety} = \text{profit} \times \text{sales} / \text{sales-variable cost}
\]

ANGLE OF INCIDENCE

This is the angle at which the sales line cuts the total cost line. Management’s aim will be to have as large an angle of incidence as possible because a large angle of incidence shows a high rate of profit. A narrow angle
would show that even fixed overheads are absorbed and profit accrues at a relatively low rate of return, indicating that variable costs form a large part of cost of sales.

**SALES FORMULA**

Often, it is necessary to know what level of sales is required to satisfy certain conditions of costs, contributions, etc. The desired sales can be expressed in various ways:

\[
\text{Sales} = \text{Fixed cost} + \text{Variable cost} + \text{Profit}
\]

OR

\[
\text{Sales} = \frac{(\text{Profit} + \text{Fixed cost})}{P/V \text{ ratio}}
\]

**PROFIT VOLUME (P/V) ANALYSIS**

A P/V graph is sometimes used in place of or along with a break-even chart. Profits and losses are given on a vertical scale, and units of products, sales revenue or percentage of activity are given on a horizontal line. The horizontal line is drawn on the graph to separate profits from losses. The profits and losses at various levels are plotted and connected by the profit line. The break-even point is measured at the point where the profit line intersects the horizontal line. The P/V graph may be preferred to the break-even chart because profit and losses at any point can be read directly from the vertical scale, but the P/V graph does not clearly show how costs vary with activity.

**LIMITATIONS OF CVP ANALYSIS**

CVP analysis is a useful planning and decision making device, usually in the form of a chart, showing how revenue, costs, and profit fluctuate with volume. The CVP technique is useful to management in areas of budgeting, cost control and decision making. Budgeting makes use of CVP to forecast profits. Further, CVP is used to evaluate the profit impact of alternative decisions. In spite of CVP being a useful technique, it suffers from some limitations.

- Because of the many assumptions, CVP is only an approximation at best. CVP analysis needs estimates and approximation in assembling necessary data and thus lacks accuracy and precision.
- In CVP analysis, it is assumed that total sales and total costs are linear and can be represented by straight lines.
- CVP analysis is performed within a relevant range of operating activity and it is assumed that productivity and efficiency of operations will remain constant. This assumption may not be valid.
CVP analysis assumes that costs can be accurately divided into fixed and variable categories. Such categorisation is sometimes difficult in practise.

CVP analysis assumes no change in the inventory quantities, during the period. That is, opening inventory units equal the closing inventory units. This also means that units produced during the period are equal to units sold. When changes take place in inventory level, CVP analysis becomes more complex.

If prices, unit costs, sales-mix, operating efficiency, or other relevant factors change, then the overall CVP analysis and relationships also must be modified. Because of these assumptions cost data are of limited significance.

Furthermore, a number of problems arise while making a multi-product analysis under CVP analysis. The first problem is identifying the facilities which are shared by unrelated products. If fixed expenses and facility usages can be identified directly with individual products, the analysis will be satisfactory. A second problem occurs if there is a non-linear relationship in the units of measurement. Different products typically yield different contribution margins and are produced in various volumes with differing costs. As a result neither the revenue curve nor the cost curve is necessarily straight and the break-even point is difficult to find. A third problem lies in the assumption of certainty in demand projections. Most analyses performed by accountants and managers are deterministic, certainty is assumed although uncertainty is the environment of operation. A fourth problem is the complexity of analysis where several products are concerned.

Therefore, while preparing or interpreting cost-volume-profit analysis all assumptions and limitations should be carefully considered. A series of CVP analysis based on different sets of assumptions and circumstances may be prepared to reflect situations prevailing in different business enterprises.
1.5.6 FACTOR ANALYSIS

Factor analysis is a multivariate statistical technique in which there is no distinction between dependent and independent variables. In factor analysis, all variables under investigation are analyzed together to extract the underlined factors. Factor analysis is a data reduction method. It is a very useful method to reduce a large number of variables resulting in data complexity to a few manageable factors. These factors explain most part of the variations of the original set of data.

A factor is a linear combination of variables. It is a construct that is not directly observable but that needs to be inferred from the input variables. The factors are statistically independent.

USES OF FACTOR ANALYSIS

The technique of factor analysis has multiple uses as discussed in the following situations:

1) SCALE CONSTRUCTION: Factor analysis could be used to develop concise multiple item scales for measuring various constructs. Factor analysis can reduce the set of statements to a concise instrument and at the same time, ensure that the retained statements adequately represent the critical aspects of the constructs being measured.

2) ESTABLISH ANTECEDENTS: This method reduces multiple input variables into grouped factors. Thus, the independent variables can be grouped into broad factors.

3) PSYCHOGRAPHIC PROFILING: Different independent variables are grouped to measure independent factors. These are then used for identifying personality types.

4) SEGMENTATION ANALYSIS: Factor analysis could also be used for segmentation. For example, there could be different sets of two-wheelers-customers owning two wheelers because of different importance they give to factors like prestige, economy consideration and functional features.

5) MARKETING STUDIES: The technique has extensive use in the field of marketing and can be successfully used for new product development; product acceptance research, developing of advertising copy, pricing studies and for branding studies.
CONDITIONS FOR A FACTOR ANALYSIS

Factor analysis requires some specific conditions that must be ensured before executing the technique.

1) Factor analysis exercise requires metric data. This means the data should be either interval or ratio scale in nature. The variables for factor analysis are identified through exploratory research which may be conducted by reviewing the literature on the subject. Generally in a survey research, a five or seven-point Likert scale or any other interval scales may be used.

2) As responses to different statements are obtained through different scales, all the responses need to be standardized. The standardization helps in comparison of different responses from such scales.

3) The size of the sample respondents should be at least four to five times more than the number of variables (number of statements).

4) The basic principle behind the application of factor analysis is that the initial set of variables should be highly correlated. If the correlation coefficients between all the variables are small, factor analysis may not be an appropriate technique. The hypothesis to be tested may be written as:

\[ H_0: \text{Correlation matrix is insignificant, i.e. the correlation matrix is an identity matrix where diagonal elements are one and off diagonal elements are zero.} \]

\[ H_1: \text{Correlation matrix is significant.} \]

The test is carried out by using a Bartlett test of sphericity, which takes the determinant of the correlation matrix into consideration. The significance of the correlation matrix ensures that a factor analysis exercise could be carried out.

5) Another condition which needs to be fulfilled before a factor analysis could be carried out is the value of Kaiser-Meyer-Olkin (KMO) statistics which takes a value between 0 & 1. For the application of factor analysis, the value of KMO statistics should be greater than 0.5. The KMO statistics compares the magnitude of observed correlation coefficients with the magnitude of partial correlation coefficients.