MULTI–CRITERIA FEASIBILITY ASSESSMENT OF THE MONORAIL TRANSPORTATION SYSTEM IN METU CAMPUS

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ABSTRACT

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The overall objective of this thesis is to assess the financial, technical and social feasibility of investing in modern Automated People Movers (APM) transportation systems, generally known as monorails, in METU campus which presents a unique opportunity to fulfill the modern-day transportation needs of METU campus. This study complements the Presidency Office's long term goal to integrate environmental, social and economic sustainability into the policies, practices and culture of the university and ultimately reduce the consumption of all resources on campus and traffic congestion and accidents.

In this context, the consequent cost-benefit effects of the proposed monorail system on campus life were quantified in monetary expressions and the corresponding multi-criteria feasibility assessment including: Break-even Analysis, Cost Effectiveness Assessments and Cost Benefit Analysis have been done successfully. According to these analyses the overall capital cost of system is $46.5 million which covers the 24 months project construction period, and an additional annual operating and maintenance cost of $2 million will span the 30 year project life time. Three different scenarios were proposed for financing the project and relevant break-even points were determined for each of the scenarios. Eventually, it appears that based on the evaluations, constructing such a transit system in METU campus will be cost effective and will certainly enhance the transportation, and will contribute to the institutional improvements and environmental preservation schemes of METU campus.

Key words: Feasibility Analysis, Cost-Benefit Analysis, Monorail, METU campus, Mass transportation

ÖZ

ODTÜ KAMPUSÜNDE BİR TEKRAYLI ULAŞIM SİSTEMİ İÇİN
ÇOK-KRİTERLİ OLURLUK DEĞERLENDİRMESİ

Tarighi, Amin
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Bu tezin genel amacı, genel olarak Monoray olarak adlandırılan Otomatikleştirilmiş İnsan Taşıyıcı(OİT) sistemlere yatırım yapmanın ODTÜ kampusunun günlük ulaşım ihtiyacını özgün bir şekilde karşına yönelik finansal teknik ve sosyal yapılabilirliğini değerlendirmektir. Bu çalışma üniversite yönetiminin uzun süreli hedeflerinden biri olan çevresel, sosyal ve ekonomik sürdürülebilirliği sağlamayı amaclıyan üniversitenin politikalarıyla, uygulamalarıyla ve kültürüyle bütünleştirmek ve böylelikle kampusun toplam kaynak kullanımını trafik yoğunluğunu ve kazaları azaltmak amacını tamamlamaktadır.

Bu bağlamda, önerilen monoray siteminin kampus yaşamı üzerindeki maliyet-kazanç etkileri finansal ifadelerle sayısallaştırılmış ve Başabaş Analizi, Maliyet Verimliliği Değerlendirmesi ve Maliyet Kazanç Analizi gibi analizleri de içeren çok-kriterli fizibilite değerlendirmelerinden uygun olanlar yapılmıştır. Bu analizlere göre sistemin toplam maliyeti 24 aylık proje inşa periyodunu da kapsayan 46,5 milyon USD dir. Buna ilave olarak 2 milyon USD olan yıllık işletme ve bakım maliyetleri 30 yıllık proje ömrüne yayılacaktır. Projeyi finanse etmek için uç farklı senaryo sunulmuştur ve her senaryo için ilgili başabaş noktaları belirlenmiştir. Sonuç olarak, ODTÜ kampusuna böyle bir sistem kurmanın maliyet açısından etkin olduğu anlaşılmıştır, ODTÜ nün ulaşımsal, kurumsal ve çevresel politikalarını gerçekleştirmeye katkı sağlayacağı beklenmektedir.

Anahtar Sözcükler: Fizibilite Analizi, Maliyet-Fayda Analizi, Monoray, ODTÜ kampusu, Toplu taşıma

To My Parents

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CHAPTER 1

INTRODUCTION

Contemporary societies heavily depend on transportation and modern social life is possible only if people have mobility on a daily basis—the ability to move around so that they can do what they have to do or like to do (Grava, 2004). The problem of how to accommodate inexorably rising travel demands in cities around the world is one of the most difficult of all for planners. On the one hand, high personal mobility and the lifestyle choices are features of modern societies but costs and constraints involved in meeting this demand threaten communities in important ways via financial impositions; increases in pollution and greenhouse effects and reduction of local amenity; promotion of dispersed development and the take up of farm or bush land; and depletion of scarce fossil fuel reserves (Searle, 1999). Cities respond to this dilemma in various ways considering different factors; geographic coverage and grain of access, carrying capacity, speed, reliability, safety and security, conservation of the natural environment and fuel, technological applicability, costs and civic image as it is extensively accepted, university campuses[1] share key transportation characteristics with other urban communities (Balsas 2002) and any.

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[1] the scope of inquiry of this research is definitely directed to North America and Australia Integrated type of campuses

university that is attempting to make the transition toward sustainability must confront the issue of transportation (Havlick, 2004). To this end, the scope of this study encompasses research from a broad overview of various public transportation modes to specific applicable choices in the context of the Middle East Technical University (METU) campus.

1.1 Problem

Middle East Technical University (METU) was founded in a government provided 4250 hectare land piece in South West of Ankara City Centrum in 1960, which is now roughly surrounded by Eskişehir Blv. in North, Mevlana Blv. and 100.Yil district in East, İncek Blv. in South and Bilkent Blv. in West. In a competition for METU architecture plan, the winning project proposed a "*redburn*" system for vehicle transportation (a service ring and cul de sacs) and an alley for pedestrian transportation. In this structure, a pedestrian can walk around the campus without being hindered by any obstacles (Erpi, 1999; Gökbulut, 2003). Nowadays [almost half a century after METU establishment] automobiles not only are the focus of transportation systems but they very often push the planning decision making processes (Newman and Kenworthy, 1999). By recent population growth of university and spatial extensions during the last decades which is due to a number of factors including:

1. Development of new graduate and undergraduate programs which draw more students and require more faculties,
2. Physical expansion along with the economic growth of the Technology Park on campus (METU Teknokent), and

3. New constructions especially in western area of campus; ODTÜ–Kent Residential Zone, Faculty of Education, Faculty of Information Systems, METU Elementary and High school, and Demiray dormitories.

There are some serious problems with pedestrian accessibility and motorized traffic load in campus. In other words, these factors have required the expansion of the land used to house the buildings and programs, requiring students and faculty to travel longer distances on campus. Any successful campus transit systems include factors such as careful planning, understanding user preferences, efficient design of system services, and coordination with existing city transit service. In this context, it seems necessary to recognize the changes in transit facilities as an effective mode for meeting campus mobility and to revise transit systems to serve the upcoming needs of METU campus in the light of emerging modern alternative transportation modes.

1.2 Methodology

Addressing these problems, the 'system thinking' approach will be applied to conduct this research. In other words, the methodology of this study primarily based upon considering the whole campus of METU as a dynamic system. This system, like the other human communities (Figure 1.1, Newman, 1999), actively interacts with its environment and processes various resources according to its priorities, to create livability (educational goals and objectives of METU) and gives off wastes. In this approach problems are viewed as parts of the overall system, rather than reacting to specific part, outcomes or events and potentially contributing to further development of unintended consequences (Wikipedia E., 2010). Hence, the efficiency and feasibility of proposed Monorail system will be analyzed through different aspects of effects on the whole system in the context of relationships of system components with each other, and the system's interaction with its environment. In this framework, this study will not only focus on financial aspects of feasibility of nominated system, but also evaluates on campus environmental, organizational and social advantages.

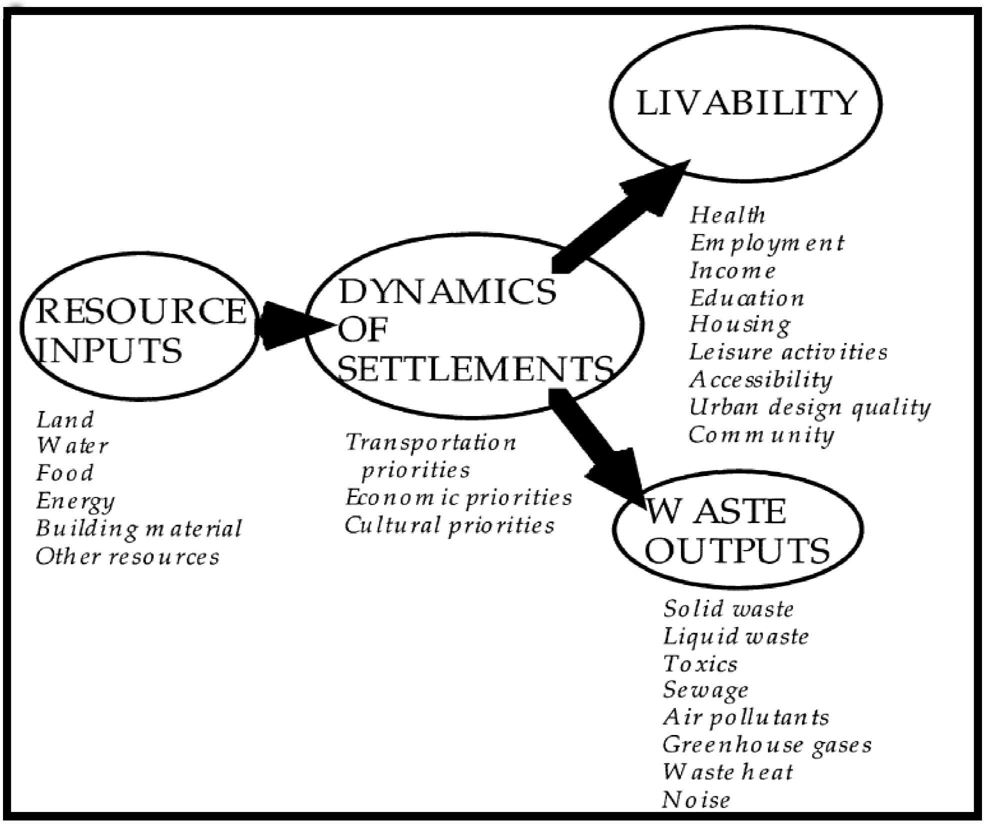


Figure1.1: Extended metabolism model of human settlements

1.3 Objective

The overall objective of this thesis is to assess the financial feasibility of investing in modern public transportation mode choices at METU campus which presents a unique opportunity for METU to assume a leadership role in such a venture in Turkey. In order to mollify the inefficiency in the transportation on and around METU campus, a system must be installed that will provide the following:

- ✓ An economical and consistent system that links the university campus and its surroundings to other parts of the Ankara city
- ✓ Access to a daily high frequency transportation services with minimal traffic lag time and construction delays
    - o Increase use of the system by students, staff, and
    - o General commuters who arriving by private car who park far from the main buildings
- ✓ Enhance the limited mobility inside the campus, because of the long walking distances with slightly sharp slopes
- ✓ Minimal toll to ride the transport system
- ✓ Leisurely and scenic trip around town that will attract tourist and prospective students

1.4 Scope

The study complements the University Headcounters Office's long term goal to integrate environmental, social and economic sustainability into the policies, practices and culture of the University and ultimately reduce the consumption of all resources on campus. To perform this study, after reviewing some of the innovated modern approaches have been conducted in university campuses to provide economical, environment friendly, efficient and effective transportation services to university populations, the extent and context of transportation services at METU Campus was clarified through an examination of data provided by Municipality of Ankara City, Campus Departmental data, planning documents, and campus maps.

This thesis is composed of five chapters; secondary relevant literature review was the first methodological step in the research. This process allowed me to consolidate available information and determine the case studies to be used for the primary research (Chapter 2). An investigation into the current Monorail system features along with the present state of transportation services at METU and demand analysis of the campus is the subject of Chapter 3. Consequent financial and environmental feasibility studies through Cost Benefit Analysis and Cost Effectiveness Assessments, for proposed Monorail system in METU campus is covered in Chapter 4 and in Chapter 5 (conclusion) all these data will lead to the selection of a Monorail system as the preferred public transit system for METU campus.

CHAPTER 2

TRANSPORTAION ON UNIVERSITY CAMPUSES

Community is a process of people acting collectively with others who share some common concern, whether on the basis of a place where they live, of interests or interest groups that are similar, or of relationships that have some cohesion or continuity (Checkoway, 1997) and university campuses are very distinct communities (Baslas,2002). University communities and student populations typically possess many of the characteristics that make the use of alternative modes of transportation both convenient and essential. Unlike other parts of modern communities, a densely populated residential area where a large portion of student, and even faculty and staff, reside generally surrounds universities. Various forms of commercial development may also locate close to campus to serve the university population's needs. This density of population presents challenges and opportunities for both the university and the community's transportation systems. Traffic congestion, accidents, high parking demand, and modal conflict are among the many transportation problems that are manifested in this type of environment. In fact, transportation planners often see a degradation of the automobile level of service when universities reach a certain population threshold and density. A number of universities and institutional communities have tried, with varying degrees of success, to address these problems through innovative ways of providing and financing mobility services on and around university campuses.

This chapter examines a number of the approaches have been conducted in university campuses to provide economical, environment friendly, efficient and effective transportation services to university populations.

2.1 Environment Preservation and Sustainable Transportation on Campuses

In many communities, college campuses are very often among the area's largest employers. They have their own energy plants and water treatment facilities. Besides energy, water and waste, college campuses are also major traffic generators, which require extensive parking areas (Baslas, 2002), and the major environmental impacts of transportation on college campuses include disturbance to teaching, loss of natural environment and greenery, despoliation of the visual environment by parking provision, and health effects on staff and students (Tolley, 1996).

In an attempt to reduce both the demand for parking and the environmental impacts of commuting, universities around the world are implementing strategies to reduce dependence on private vehicles and increase the use of alternative modes of transport (Shannon et al., 2005). A sustainable transportation system has been defined as one that satisfies current transport and mobility needs without compromising the ability of future generations to meet their own (Black, 1997; Richardson, 1999). On campus grounds sustainable transportation planning can be seen as providing incentives for walking, bicycling, taking mass transit, ridesharing, discouraging the use of single-occupancy cars by passing on the full costs of parking to drivers, and linking transportation planning to land-use planning (Baslas,2002).

2.2 Sustainable Transportation Systems: Starting Out From Campuses

The university campus is a microcosm of the city, at once interdependent yet distinct from its surroundings. Its transportation patterns are monitored and managed by municipal policy as they impact the functioning of surrounding neighborhoods and the city's transportation infrastructure. One aspect often overlooked by campus administrators and planners is the college's potential to affect not only the transportation behavior of the campus population in the present but also the transportation habits and the environmental awareness that students can develop in the long term, as "they will progress to occupy influential roles in government, companies or other organizations" (Tolley, 1996). In this way, innovative transportation approaches are likely to diffuse from higher education to other parts of society. One of the main problems is that campus planners and administrators were trained when the 'automobile was king' and 'are reluctant to embrace change' (Poinsatte and Toor, 2001). However, since students are more open-minded and have the potential to become 'movers and shakers' if properly motivated, they can become powerful forces for the establishment of bicycle and pedestrian friendly communities (Weerts, 1992).

In this context, the most widely implemented solutions are parking management, car sharing, park and ride schemes, mass transit, vehicle technology and alternative fuels, and the use of the internet and video to provide online classes and transportation information (Markowitz and Estrella, 1998). The partial replacement of university fleets with alternative fuel vehicles and technologies such as compressed natural gas on campus buses or electricity (monorail, trolley-bus, etc) is also being attempted by a growing number of universities (Keniry, 1995). In the forthcoming sections, some brief explanations including advantages and disadvantages of each popular private and public transportation modes on university campuses; automobiles, walking and bicycling, buses, minibuses, trolleybuses, light rails and monorails – will be reviewed and case studies of successful applications of each mode on campus communities will be given in brief.

2.3 Alternative Modes of Transportation on Campuses

2.3.1 Automobiles

Automobiles dominate the transportation picture today, both inside and outside cities. They have given an unprecedented level of mobility to the larger part of this society, but they also threaten to choke our center cities, and they consume resources at a disproportionate rate (Grava, 2004). Whereas, the daily movement of people back and forth to campus in automobiles burning fossil fuels is one of largest impacts a typical educational institution imposes on the life of the planet (Havlick, 2004).

Car-based transportation has many hidden costs (Balsas, 2001). It is expensive and inefficient over short distances and is a major contributor to global warming. The environmental, financial, and social pressures exerted by current levels of automobile dependence include greenhouse gas emissions, rapid land consumption, air quality and public health degradation, and deteriorating overall welfare and quality of life of urban populations (Hatzopoulou & Miller, 2008). However, the major problem with automobility is the amount of parking it requires (Dober, 2000). Parking pricing is a crucial issue for university administrators not only for reasons such as faculty and staff recruitment but also because of the very high cost of constructing and maintaining parking (Poinsatte and Toor, 1999). Universities can expect to pay between $15,000 and $30,000 per net new parking space constructed on campus, a figure that is independent of the cost for ongoing operations and maintenance (Toor, 2003).

2.3.1.1 Handling the Problems with Automobiles

Institutions of higher education have recently begun to implement increasingly more aggressive strategies for reducing vehicle emissions and enhancing opportunities for campus access by modes other than single-occupant vehicles (SOVs). For example, many campuses have begun to switch to cleaner fuels such as biodiesel, which can be used in existing diesel burning vehicles (Toor 2003). Other types of alternative fuels as well as hybrid vehicles offer promise. Others have begun to implement campus-owned vehicle programs (for institutional use) or car-sharing programs (for all uses, including personal use).

it seems that a balance between price and supply will result in a more efficient use of available facilities, since commuters with good alternatives available will switch if the price to park becomes sufficiently high. The cost to park, therefore, has a strong influence on the overall transportation network. Moreover, pricing parking to reflect the real cost to build and maintain parking means that drivers more closely pay for what they use. Some of the parking management strategies universities can employ (in addition to basic price-increase strategies) are regulatory measures, including parking bans for certain groups such as freshmen or other class years and on campus car share and campus car rental programs. Others are economic incentives: financial incentives for affiliates to drive less, such as parking cash-outs, or to drive more efficiently, such as preferential/lower-cost carpool and vanpool parking; and transportation demand management measures, such as enhancements to facilities for other modes of travel or subsidy of transit (Poinsatte and Toor 1999; Toor 2003). These programs act as a way not only to enhance transportation as an end in itself, but also to enhance the campus environment and increase livability, including people who cannot or do not wish to drive.

2.3.1.2 Travel Demand Management to Cutting down Parking Lots, University of California, Santa Cruz, California

The Santa Cruz campus is nested amidst a redwood forest with campus population of 17,000, but with only 5,000 parking spaces. Enrollment at UCSC has increased 30 percent since fall 2000, but average daily vehicle traffic on campus has remained about the same. Wes Scott, director of transportation and parking services (TAPS) at University of California-Santa Cruz, has implemented an array of TDM practices as an alternative to cutting down redwoods for car lots and as an economically wise decision.

The UC-Santa Cruz implemented tools include carpools – Hybrid vehicles may be available to further promote the University's sustainability efforts – that carry 300 people per day, vanpools transporting 100 per day, a transit pass system that moves 525 students each day, and a differential pricing system for parking permits. The TAPS parking permit for close-in parking costs $684 per year and the remote lots cost $384 annually. Freshmen and sophomores are not permitted to have cars on campus. Scott reports, "we stack vehicles in the aisles of remote parking lots and have created 400 new 'Virtual' parking place." Like many other progressive campuses, Santa Cruz has a comprehensive web page that displays all the alternative mode options, parking regulation, and penalties. Because there is a buffer zone between the scenic campus and the city, there is not an aggregated condition of campus overspill.

Biking is heavily prompted in the Santa Cruz tools portfolio and bike paths are abundant on the campus and in the town. To make the bicycle a favorite mode, TAPS has created a bike shuttle service. Cyclists load their bikes on a trailer, jump on the van, and are taken to related drop off pints on the Santa Cruz campus. One hundred faculty, staff and students use this bike shuttle service daily (Toor & Havlick, 2004).

Table 2.1: Automobiles: Reasons to support VS exercise causation

AUTOMOBILES[2]			
Reasons to support	**Loosening the geographic constraints:** - *Not to being constrained by the limited range of walking distances or the alignment of transit services* - *Great extension of the radius of daily operations* - *Potential availability of all job locations and all service nodes and entertainment /cultural centers within a metropolitan*	**Reasons to exercise caution**	**Excluded population:** - *Not everybody has access to a car, can drive a vehicle* **Congestion and space consumption:** - *Traffic congestion and loosing time and fuel* - *Parking problems*
	Freedom from schedules: - *Any travel for any purpose can be done at any time (at least theoretically)* - *Travel times are become shorter because there is no waiting time, no delays due to transfers, and no stops to accommodate fellow travelers*		**Air pollution:** - *Approximately one third of greenhouse gas emission in industrial countries is by private automobiles (dot, 2004)* - *Automobiles mostly are source of seven toxic ingredients in urban areas: ozone (o3), carbon monoxide (co), nitrous oxides (nox), sulfur dioxide (so2), lead (pb), volatile organic compounds (vocs), and particulate matter (particularly microscopic particles, pm10).*

[2] This Table is adapted from chapter 5 of "Urban Transportation Systems written by S. Grava, 2004"

Table 2.1 (continued)

Reasons to support	**Privacy:** - *The car is an exclusive and private capsule that requires no sharing of space with strangers* - *It has extra privacy and security benefits (listening to music, adjusting the thermostat, or smoking!*	**Reasons to exercise caution**	**Sound pollution:** - *Automobiles and other motor vehicles are source of various noise and sound pollution problem in cities* **Accidents:** - *Property damage, personal injury, and fatalities are among the most common problems*
	Social status: *- Known as an opportunity to express one's individuality or level of achievement*		**Depletion of petroleum resources:** - *Valuable and finite oil supply that has been generated through slow natural processes over millions of years in underground strata are refined to petroleum and gasoline used in motor vehicles* **Disposal problem:** - *Every year tens of millions of motor vehicles have to be scrapped in the world.*

2.3.2 Walking and Bicycling

We are all pedestrians; any trip by any means includes at least a small distance covered on foot at the beginning and end of each journey. Walking is efficient, healthful, and natural and it is the basic urban transportation mode that has allowed settlements and cities to operate for thousands of years (Grava, 2004). Walking is the primary mode of transportation for many people, although few of us may realize how it is a big part of our trip (Blomberg et al., 2000). Walking is fast, direct, and has no costs involved. And, bicycles are the most efficient form of transportation (with energy consumption of about 0.15 cal/g.km), with the lowest energy input and lowest output of pollutants and greenhouse gases. Apparently, the mechanical assemblage of pedals, a chain, and wheels, in combination with the powerful thigh muscles of the human body, is the best arrangement to achieve forward motion. It beats a salmon swimming, a jet plane or seagull flying, or a train or a horse running (Grava, 2004). Besides, the bicycle offers riders speed and flexibility over short distances, it produces no pollution, uses no energy, is silent, can be accommodated with relatively little space, is fast and cheap, and is also accessible to many people who cannot drive, especially the young (Tolley, 1996). In a broader view, active transportation – bicycling and walking– can also contribute to the health of the campus population (Toor, 2003).

However, regarding bicycling and walking, many college campuses lack proper and adequate facilities, including bicycle and pedestrian paths and lanes, intersection treatments, signage and parking (Dober, 2000). Many times a destination on campus is out of walking access ranges and bicycling on campus can be dangerous. Accidents can occur because of speeding, mixing types of traffic, poor right-of-way design, and college-age youth’s propensity to ride outside the routes designated for bicycles and to ignore traffic rules and regulations.

Table 2.2: Walking: Reasons to support vs. reasons to exercise causation

WALKING[3]			
Reasons to support	**Economy:** - *Involves very little expense, either public or private* - *The paths themselves, are usually built together with normal street construction, and the specific expense is rather minimal*	Reasons to exercise caution	**Distance:** - *A quarter mile (1320 ft; 400 m) is a range within which just about everybody will walk* - *eighty percent of walking trips are less than 3000 ft (0.9 km)*
	Health: - *Walking the most basic and natural form of exercise*		**Speed:** - *A regular walking speed is just 4 or 3 mph (6.4 or 4.8 kmph).*
	Availability: - *the mode is always present and ready for use* - *No need to wait for a transit vehicle or to turn on the ignition*		**Change in elevation:** - *People are reluctant to change elevations, because we know instinctively that this involves significant energy expenditure*
	Cognition : - *the act of walking is automatic and does not require deliberate attention or even too much care to avoid obstacles and dangers*		**Weather conditions** - *Adverse weather, whether it is rain, snow, high wind, or broiling* - *Sun, will significantly reduce considerably any propensity for walking*

* This Table is adapted from chapters 2 of “Urban Transportation Systems written by S. Grava, 2004”[3]

Table 2.2 (continued)

Reasons to support		**Reasons to exercise caution**	**Carrying goods:** - *pedestrians have limitations, including how much weight they are able or willing to carry with them*
	Environmental protection: - *walking is the ultimate environmentally friendly transportation mode*		**Impaired personal mobility:** - *any community has a certain percentage of people who have larger or smaller disabilities that will reduce the extent of their participation in the walking mode*
			Safety and security: - *Usually pedestrians are victims of pedestrian–vehicle conflict!*

2.3.2.1 The Future of Walking and Bicycling on Campuses

Having dealt with providing fair and sustainable transportation services on campuses, a growing number of campuses in addition to investing in modern transit services, are now focusing on enhanced infrastructure for pedestrian and bicycle travel. At a growing number of schools, biking is deeply rooted in local culture and transportation to, from, and around campus is programmed comprehensively with recognition of the benefits of accommodating different means of access (Poinsatte and Toor 1999). Some schools, such as the University of California at Davis, employ a full-time bicycle and pedestrian coordinator (Balsas 2003). In this context, the most important priority for any campus is the separation of vehicles and pedestrians. The presence of a dedicated staff person and modal advisory committees, argues Balsas, increases opportunities for consideration during the campus planning process. A bicycle infrastructure can range from basic provision of safe routes and bicycle racks, to refined amenities such as grade-separated crossings, covered bicycle parking, bicycle signals at intersections, and programs such as free bicycle check out to students and employees.

2.3.2.2 University of Washington Brings e-Bikes to Campus, Seattle

The University of Washington's (UW) U-PASS program encompasses a broad suite of TDM programs, of which the unlimited transit pass is just one component. Although the school has made significant strides in reducing SOV commute mode share to campus, for some drivers, having a car on campus means having the mobility at midday to complete errands, attend meetings, or go out for lunch. To address this critical barrier to achieving further reduced vehicle trips, UW has recently announced that a self-service electric bicycle rental program for its Seattle campus will be launched in autumn of 2008. The program, funded primarily by a performance-based grant from the Washington State Department of Transportation (WSDOT), will bring 40 electric bikes to campus at 10 station locations. These "pedal-assist" cycles supplement the rider's own pedaling with electric assistance, a particularly useful feature on Seattle's hilly terrain. Bicycles are unlocked from the station using a personal key fob called a GoKey™ (in combination with a typed personal security code) and can be returned to the same station from which they were rented or to another station location. Each station has five extra slots to accommodate an excess of bikes in one place. The per-hour fee is yet to be determined, but is likely to be in the range of about \$5/h, with a \$1/h discount for U-PASS holders; partial-hour fees will also be available.

The system is operated in partnership with Intrago Mobility Corporation, the vendor who will provide the bicycles and station facilities. UW and Intrago Mobility partnered to write the grant application and were awarded up to \$225,000 to establish the system, a figure that will be supplemented with in-kind operations and administration contributions from the university. Fifty percent of the funding (\$112,500) is available immediately for infrastructure investments, while the remaining 50% is paid based on the number of commute trips reduced. WSDOT defines a commute trip reduction as one round-trip commute no longer made by an SOV, 5 days per week, for a period of 1 year, and values a commute trip reduction at \$375. The total goal for the project is the reduction of 534 SOV commute trips (as defined by WSDOT). With the first 50% of the funding used for infrastructure costs, WSDOT will begin paying from the remainder of the award when the number of commute trips reduced exceeds 267. WSDOT bases the goals for this grant program, called the Trip Reduction Performance Program, on a 1-year timeline.

The program is available for all university faculty, staff, and students, who must register directly with Intrago Mobility; eligibility verification is provided by UW, but the relationship is between the client and the vendor. To start service, riders watch a training video and pick up a member packet that includes the key fob. When it launches, the pilot program will be the first self-rental electric bicycle system in the world. Some operational aspects are still in the planning phases:

Since the system permits one-way rentals, periodic rebalancing of the bikes to keep even numbers at each station is necessary; initially, this will take place daily at the end of the day. Additional rebalancing will be done as needed. Intrago subcontracts to a local scooter rental company, Scoot About, for routine vehicle maintenance as well as the rebalancing.

Riders must supply their own helmets in accordance with Seattle safety law. UW had initially considered providing helmets as a part of the rental, but found that concerns over sanitation and the possibility of imperceptible damage to the helmets that could compromise safety were significant barriers.

Users will not be able to make a reservation to rent the bikes; this first-come first-serve policy may be modified at a later date. (Kruger et al – TCRP Report, 2008: 26)

Table 2.3: Bicycling: Reasons to support vs. reasons to exercise causation

BICYCLING[4]			
Reasons to support	**Direct access** - *Except for walking, bicycles, because of their small size and weight, can provide the most direct door-to-door service compared* *To all other mechanical modes*	Reasons to exercise caution	**Traffic compatibility:** - *Bicycles are quite different from motor vehicles in their size, speed and there may be constant friction and occasional danger, mostly to the unprotected cyclist* - *Bicycles are even less compatible with pedestrians*
	Low energy consumption: - *It is the most efficient manmade machine in the world (35 calories / passenger mile)*		**Human capabilities and attitudes:** - *To pedal a bicycle requires a certain amount of strength, stamina, and agility, which are not possessed in equal amounts by all people*
	Low private expense: - *A reasonable buy price range ($100 - $500)* - *No fuel to buy or tolls to pay*		**Official attitude:** - *Cycling, particularly for commuting to work, is not among the normal patterns of operation in most communities*
	Healthful exercise: - *Cycling is a sport and also a healthful exercise*		**The natural environment:** - *Any street with a gradient steeper than 3 to 5 percent will bother most regular riders* - *Dteep downgrades present a potential safety problem.* - *Climate is a concern as well*

[4]This Table is adapted from chapter 3 of "Urban Transportation Systems written by S. Grava, 2004"

Table 2.3 (continued)

Reasons to support	**Space conservation:** - *It occupies just about 22 ft2 (2 m2) when standing and 55 ft2 (5 m2) when in motion (about one tenth of a normal automobile)*	Reasons to exercise caution	**Reach and speed:** - *For a normal person any distance below 5 mi (8 km) can be considered a comfortable distance and 10 mi (16 km) is the ultimate range.* - *While almost all cyclists can maintain a 12-mph speed over extended distances, many will usually ride at 6 mph (10 km/h)*
	Low public investment: - *Even under the most elaborate plans, a bike system is a low capital investment.* - *There could be right-of-way acquisition, but in most cases recreational bike trails would be fitted into already designated open spaces*		**Storage place:** - *Space to store equipment may not exist or be very inconvenient.*

2.3.3 Buses

Buses are without question the workhorses of the transit world. There are a great many places where they are the only public service mode offered; to the best of the author's knowledge, no city that has transit operates without a bus component. Nevertheless, buses provide the base service in most places, they can carry considerable passenger loads, and the service can be significantly expedited if proper attention is paid. No advanced engineering or special skills are required to run them, they are economical. Buses are one of the available options to decrease on campus traffic congestion problems and to maintain efficiency and availability of fair transportation services. In the last decade of 20^{th} century, many universities have started to establish and develop services under different named such as " Student Bus Pass" or "U-PASS" programs as a response to student demand, local community concerns with regards to traffic, parking and pollution problems and increasing pressures with the high cost of parking structures (Toor, 2004). These programs offer students access to local transportation services but also includes unlimited access to regional services around campuses. The Student Bus Pass program is a mandatory universal pass which is paid for as a part of a student's tuition (Toor & Havlick, 2009). Though having some deficiencies concerning the nature of bus-based transportation systems – limited work hours, air and sound pollutions, etc – these kinds of transportation systems are still among the most successful transportation management programs in heavily clogged university campuses.

2.3.3.1 Investing in Bus Shuttle Transit, Not Parking, Stanford University, Palo Alto, California

In the late 1980s, Stanford University set out to expand the campus by 25%—or over 2 million sq ft of new development. Stanford's host community, Palo Alto, was very concerned about the potential traffic impacts and was prepared to delay build-out through a detailed

Environmental Impact Report process for each new building. So in 1989, Stanford agreed to abide by a General Use Permit for the campus that allowed 2.4 million additional sq ft on the condition that no new automobile commute trips would be produced. Stanford began a detailed annual monitoring program.

To meet this goal, Stanford undertook a unique and simple calculation. To displace surface parking for new buildings and build replacement parking structures, the university realized that each new garage space added costs of over $150 per month, every single month for the 40-year useful lifetime of each parking structure. With land valued at $1 million per acre, building new surface lots wasn't much cheaper and had greater environmental impacts. Instead, Stanford followed four main strategies to avoid replacing the parking supply: adding transit, adding housing, adding bicycles, and most importantly, just paying people not to drive—a "parking cash-out."

Stanford expanded its Marguerite shuttle from a small commute- hour shuttle to a free, all-day transit system, running every 12 to 15 min with over 100 timed transfers to commuter rail trains every day. Its budget increased 70% to almost $1 million per year. However, Stanford realized that the subsidy of $2 per commuter per day on the shuttle was far less than the average cost of $7 per commuter per day to build and operate parking garages. Marguerite shuttle ridership quintupled in 10 years from 700 per day to 3,500 per day. Stanford's savings on parking construction enabled the university to build other transit amenities including a new transit mall, which runs for 1-1/2 mi through the heart of the campus. Over 5 mi of campus streets were closed to cars. (Kruger et al – TCRP Report, 2008: 23)

Table 2.4: Buses: Reasons to support vs. reasons to exercise causation

BUSES[5]			
Reasons to support	**Ready availability:** - *Buses do not depend on advanced technology, and they can be (and are) produced by numerous manufacturers in many countries*	Reasons to exercise caution	**Labor-intensive operations:** - *The ratio between operating personnel and number of passengers carried is considerably for buses than for those modes that depend on large units and automation.*
	No research and development required: - *Technical improvements and introducing new elements for buses are relatively slow* - *No evolutionary process, with no major breakthroughs anticipated or sought in the near future*		**Pollution:** - *Gasoline and diesel internal combustion* *Engines can seriously damage the urban environment.*
	No special workforce or skills required: - *The bus and the diesel engine have been around for a long time* - *Any truck mechanic who understands engines can take care of buses with little additional training* - *Anyone who has a regular driver's license can learn to operate a bus with a little training and practice*		**Street congestion:** - *Buses get caught in street congestion, and they contribute substantially to it in turn.* - *Street congestion makes bus service slow and unreliable in such instances, sometimes destroying its viability entirely.*

[5] This Table is adapted from chapter 8 of "Urban Transportation Systems written by S. Grava, 2004"

Table 2.4 (continued)

Reasons to support	**Low investment:** - *Since buses almost always use existing city streets, there is no additional construction expense for the transit channel.*	Reasons to exercise caution	**Slow service:** - *In addition to the congestion problem, the smooth operation of buses can be seriously retarded by fare collection practices.*
	Energy consumption: - *The bus offers significant fuel-saving opportunities compared to other modes, due to the efficiency of the power plant and the relatively light weight of the vehicle*		**Public image:** - *Buses appear to have a negative public image; many people seem to believe that their social status would be impaired if they were to be seen using a bus.*
	Flexible operations: - *Since the vehicles are not tied to a track or a guide-way of any kind, buses can move on any solid street surface.*		**lower capacity:** - *Each bus unit is considerably smaller than any rail vehicle.* - *Street conditions and loading demands do not allow running them as a continuous chain.*
	Line-haul ability: - *Buses can make frequent stops to pick up and discharge passengers,* - *But they can also move relatively fast without stops.*		**Comfort and ride quality:** - *Transit users have an instinctive preference for rail-based modes as compared to buses.* - *Rail provides a stable and steady ride,* - *The bus wobbles, shakes, and sometimes hits potholes or uneven pavement.*
	Maneuverability: - *While buses are large vehicles, they can negotiate almost all street configurations with narrow rights-of-way and tight turns*		
	Temporary diversions unlike : - *Rail vehicles& buses have the ability to avoid temporary obstacles that may appear on city streets and to bypass a disabled bus in front*		

2.3.4 Para Transit (Dolmuş)

Mobility will not be denied to people who need transportation services if they have some resources to spend or if the society in which they live recognizes its obligations. A way will be found everywhere, except in places in the most desperate economic state, to move urban residents, even if the systems have to be improvised and generated through local entrepreneurship.

If city buses do not or cannot reach all districts, or if the service is very sparse, neighbors will start running their own cars along obvious routes and offer rides to others (for an affordable fee). If low-wage, but essential, employees cannot reach job places by themselves, employers will have to pick them up with their own vehicles.

All this is *paratransit*—a service that is not quite full public transit and that has some of the convenience features of private automobile operations. It is most often smaller in scale than real transit, utilizing smaller vehicles, and it can be legal or illegal as defined by local rules and regulations. In many respects there is nothing much new about paratransit. Names such as *shuttle service, minibus, jitney, domuş* and *downtown circulator* describe operations that are quite well known and have been around for some time.

2.3.4.1 Meeting Community Needs through Private Transit, MASCO, Boston, Massachusetts

The Longwood Medical Area (LMA) of Boston has long been a dense community of private medical and academic institutions, but it is situated about 3 mi from downtown Boston and the hub of most regional transit services. Access has long been an issue. In 1972, five major LMA hospitals and the Harvard University Medical School jointly asked MASCO to provide joint support and planning services—chief among them was bus and minibus service to remote park-and-ride lots for employees and faculty. Harvard also sought to connect its Medical School to the main Harvard campus across the Charles River in Cambridge, and MASCO began running the first "LMA Bus and Minibus Shuttle." This route, the M2, was an instant success as it provided a critical cross-town express connection that was not available through the regional transit provider, the Massachusetts Bay Transit Authority (the "T"). Over the years, the M2 has evolved into a commuter shuttle for university staff, faculty, and students that is also open to the public for a fare (currently $2.35), operating frequent peak and daily service with up to six 40- and 60-passenger buses and minibuses. MASCO's commuter mission has grown over the years with the addition of similar successful commuter shuttles to the Ruggles Orange Line "T" stop and most recently to the JFK Station "T" stop.

MASCO's operates over 2,700 remote spaces serving 22 member institutions in the LMA, comprising over 37,000 employees and 13,000 students. MASCO operates 29 minibuses and buses on 8 routes with a $5.3M annual budget that is financed by $325 per-space-per-month member fees to park in its lots and institutional contributions for the commuter shuttles based on their percentage of ridership. Members fully recognize the value of the shuttle services and continue to approve annual parking rate increases of approximately $25 per year.

Over the years, other academic institutions have become a part of MASCO and benefit from its transit station commuter shuttles and TDM programs, including Emmanuel College, Massachusetts College of Art, Massachusetts College of Pharmacy and Health Sciences, Simmons College, Wentworth Institute of Technology, Wheelock College, and the Windsor School (Kruger et al – TCRP Report, 2008: 27-28).

Table 2.5: Para Transit: Reasons to support vs. reasons to exercise causation

PARATRANSITS(DOLMUŞ)[6]			
Reasons to support	**Communal transportation:** - *Without parastansits streets would be completely overwhelmed by single occupancy automobiles.* - *This saves space, conserves fuel, reduces air-quality impact, and gives more choices in individual mobility.*	**Reasons to exercise caution**	**Cost considerations:** - *Each small vehicle carrying few passengers requires a drive ,and support staff.* - *Generally, private jitneys can't compete with subsidized buses in the same route.*
	Mobility for all: - *Paratransit services is to accommodate all those members of society who do not, cannot, or do not wish to drive.*		**Use of motor vehicles:** - *Problems with street congestion, safety, and air quality concerns accident rates can be very high if driver behavior is not well controlled*

[6] This Table is adapted from chapter 6 of "Urban Transportation Systems written by S. Grava, 2004"

Table 2.5 (continued)

Reasons to support	**Ease of implementation:** - *The start of a paratransit service does not require large initial lumpy investments.*	**Reasons to exercise caution**	**Driver behavior:** - *If the driver's income depends on the number of fares that are collected, there is a natural inclination to hustle and cut corners.*
	Agility: - *Because the vehicles carry few passengers and make stops only on demand, any comparable trip duration will be less than on regularly scheduled transit.*		**Profit motivation:** - *There simply is no natural incentive for an operator to run services where the income does not cover costs, or to do it during low-demand hours.*
	Service quality: - *Jitneys offer a service at least one comfort level higher than conventional transit.* *This is due to the smaller vehicles used, the frequency, the quality of the vehicles themselves, and the relationship of the driver to passengers.*		**Institutional issues:** - *In some cases there may be not enough control on the drivers attitudes (i.e., strife) by municipality or local governments.*

2.3.5 Trolleybuses

The trolleybus (or trolley coach or trackless trolley) as an electrically powered transit mode running on streets has several interesting features, but it has never reached the top ranks among service choices. It is a cross between a bus and a streetcar, and not necessarily only the best characteristics of those two are to be found in the resulting vehicle. It looks and acts almost like a bus, except that it is tied to an overhead network of wires for power supply; it operates somewhat like a streetcar, but the reach of the power pickup poles allows it to move across several lanes. Figure 2.1 shows a newly operated electric trolleybus vehicle in Bologna, Italy using modern physical, electromagnetic, and optical guidance systems protect the vehicles from scratches and make the bus systems more accessible and attractive.

Figure 2.1: Electric Trolleybus Vehicle, Bologna, Italy (picture gotten from tbus.org.uk last accessed on 12/04/2010)

Table 2.6: Trolleybus: Reasons to support vs. reasons to exercise causation

TROLLEYBUSES[7]			
Reasons to support	**No exhaust:** - *By the electrical motor no exhaust is emitted, and thus no air pollution is generated directly by the vehicle (excluding power plan).*	Reasons to exercise caution	**Unsightliness:** - *Is the most often cited problem in public evaluations of this mode, as expressed by the overhead wires.*
	Quiet running : - *Trolleybus operates by pneumatic tires and electrical motors, which are not noisy even when surge power demands are placed upon*		**Not flexible:** - *The vehicles are tied to the lines without much flexibility in selecting a path.*
	Acceleration: - *Acceleration is quick because of the traction of rubber tires, and there are sufficient power reserves to climb steep grades, (beyond the capabilities normally shown by regular buses).*		**Wires:** - *The wires may be obstacles to other activities, such as vehicles with high loads, fire ladders, parades, etc.*
	Durability and ease of maintenance: - *Claims are being made that standard trolleybuses are durable and easy to maintain because of the simplicity of the components.*		**Power pickup:** - *The power pickup shoes frequently lose contact since there is little to keep them in place except a groove and the pressure of a spring on the pole.*

Table 2.6 (continued)

[7]This Table is adapted from chapter 10 of "Urban Transportation Systems written by S. Grava, 2004"

	Energy resource preservation: - *Petroleum-derived fuels are not used and thus the scarcer energy resources are conserved.*		**High vehicle price:** - *The purchase price of a trolleybus is high as compared to a regular bus.(almost as double as a normal bus with same capacity)*
			Costly infrastructure: - *Including overhead wires, poles, feeders, substations, etc.* - *This could be readily adapted in the early days. It is, however, a major consideration if a new network has to be created.*

2.3.6 Light Rail Transit (LRT)

The defining images of the modern city in the early twentieth century were traffic-choked streets where the streetcar offered the only real promise of mobility and blossoming suburban enclaves that were accessible only because a trolley line was in operation. There never was any question about the technical quality of this mode (as was the case with cable cars) or any doubts about its environmental characteristics (as was the case with coal-burning steam locomotives) or its carrying capacity (as is the case with automobiles today). Actually, the development of light rail systems toward the end of the twentieth century in our communities is being judged a major success and much constructive activity has taken place.

2.3.6.1 A Modern Central Corridor LRT system on The Twin Cities Campus of University of Minnesota

The University of Minnesota is working with the Metropolitan Council and other agencies to bring to life a light rail transit line that will service the Twin Cities campus. The Metropolitan Council started first round of road construction on the East Bank campus to accommodate the Central Corridor light rail line in preparation for construction of the line and to prepare alternate routes in and around campus in lieu of Washington Avenue, which will be closed to auto traffic beginning in Spring 2011 and In May 2010, construction on the Central Corridor light rail transit main line is scheduled to begin.

The University of Minnesota is strongly committed to transportation alternatives and it has invested heavily to enhance service and accessibility where 20,300 University students and 2,000 faculty and staff use discounted bus passes, 68 percent of students, staff, and faculty use transportation alternatives to get to campus each day and the university is the largest user of E85 (ethanol) in the United States. In fact, the University of Minnesota–Twin Cities was selected as one of the "Best Workplaces for Commuters" by the Environmental Protection Agency and the U.S. Department of Transportation.

The project has an estimated cost of $914.8 million, with the FTA funding 50 percent of the capital costs. The other 50 percent will be paid with state and county funds: the metro county transit sales tax will provide 30 percent of the cost, the state will provide 10 percent, Ramsey will provide 7 percent and the remaining 3 percent will be provided by Hennepin County. The Central Corridor line will run along Washington and University Avenues attracting 80,000 people on a typical day and will link three of the greatest traffic generators in the region: downtown Minneapolis, the University of Minnesota, and downtown St. Paul. Washington Avenue is the hub for University residence halls, Coffman Memorial Union, the graduate and professional schools, the Institute of Technology, the Academic Health Center, the University libraries, and dozens of heavily used class rooms. Vital research also takes place along the corridor, with over 80 University labs in nearby 17 buildings. Tim Mulcahy, the U's Vice-President for research, tells viewers: "We've been working with the light rail project now for a number of months to try to identify adequate solutions that will allow a win-win outcome - protect our research while preserving the opportunity to put the light rail line along Washington Avenue." (lightrail.umn.edu)

Table 2.7: LRT: Reasons to support vs. reasons to exercise causation

LIGHT RAIL TRANSIT[8]			
Reasons to support	**Flexibility in design and implementation:** - *There are reasonable shortcuts that can be taken in structuring a system* - *There are opportunities for cost saving since standards are flexible*	Reasons to exercise caution	**Fixed character:** - *Any rail system is fixed in place and any major modifications are unlikely unless drastic changes in land use and activity distribution occur.*
	Mechanical efficiency and power conservation: - *As a rail mode, LRT preserves the capability of moving considerable weight with relatively little power consumption* - *Petroleum-based fuel is not consumed, and the necessary electrical power can be produced at remote locations relying on a variety of energy sources.*		**Interference with street traffic:** - *Experience shows that motorists are fully aware that reserving lanes for exclusive or partial LRT use* - *This will reduce vehicular capacity and constrain automobile use.*
	Reliability and safety of operations: - *The track gives stability and control of movement, and, consequently, the chances for collision and running "off the road" are minimized.*		**Overhead wires:** - *It has some sort of visual concern about the appearance of LRT system*

[8] This Table is adapted from chapter 11 of "Urban Transportation Systems written by S. Grava, 2004"

Table 2.7 (continued)

Reasons to support		Reasons to exercise caution	
	Labor productivity: - *Each light rail vehicle, no matter how large, requires only one person to operate it.* - *Maintenance tasks are not difficult or too complicated*		**Maintenance attention:** - *This visual concern appears to be a matter of first, LRT operators have to exercise continuous vigilance to ensure uninterrupted service*
	Quality and attractiveness of ride: - *On a well-maintained track, with good vehicles having resilient wheels and advanced suspension systems, the movement is smooth and without vibrations.*		**Feasibility thresholds:** - *It has been suggested by urban analysts and transit system planners at various times and in different places that LRT is appropriate for communities starting with a population size of 250,000 (preferably 500,000)*
	Environmental characteristics and capacity and cost: - *No local air pollution,* - *Under heavy and large capacities usage it is so cost effective*		

2.3.7 APM Systems (Monorails)

With increased population and congestion, we have a corresponding increase in the need for fine-grained, high-quality systems of circulation within major activity centers and for connections between these centers and longer-distance modes. Automated People Movers – APMs – are well suited for this purpose; their exclusive rights-of-way and driverless operation allow unimpeded, frequent service on an around-the-clock basis, attributes that vastly enhance their attractiveness to riders. There are many variations among monorail type APMs, but their one common element, of course, is a single rail, beam, or channel that supports or carries the passenger container. The vehicle may be large—comparable to a subway car—or small—a cabin for a few passengers. The principal difference is whether the passenger compartment hangs from an overhead beam or channel, representing a *suspended* monorail, or sits atop a single horizontal beam, representing a *straddling* monorail (Grava, 2004).

APM technology has, over the past 40 years, already proven its merit at many airports and amusement centers, health care complexes and universities (Warren, 2002). In Japan, the first APM system, Tokyo Monorail, was put into operation in 1964. Also the first commercial APM in USA was constructed in 1971 for Tampa International Airport. Today there are almost 100 transportation systems around the world supplied with electronic mechanisms that allow them to be fully automated. Half of those systems are in airports and leisure areas. One quarter are providing mass transit. Institutions such as hospitals, retail malls, universities, special districts and others use the rest (Dunning et al, 2003).

2.3.7.1 Morgantown Personal Rapid Transit, West Virginia University, USA

Morgantown is a small city with a population of about 30,000 permanent residents and the WVU adding another 28,000 seasonally. West Virginia University's campuses - Downtown, Evansdale, and Health Sciences are distributed so, the Personal Rapid Transit system, was built to link them.

Boeing began construction on the Personal Rapid Transit (PRT) system with original estimates of $15 to $20 million. But there were large cost overruns during the initial development of the system and The "Phase I" system consisted of 5.2 miles (8.4 km) of guideway, 45 vehicles, 3 stations and a maintenance/control facility and cost $62 million began operations in 1975, four times over the estimate. The expansion, "Phase II" during the 1978–1979 school year, expanded the system to 71 vehicles, 8.65 miles (13.92 km) of guideway, and 5 stations. One station was expanded and a second maintenance facility was added as well bringing the total for the entire system to $130 million.

Although the system was massively over-budget, it proved itself to be what its designers had claimed: a reliable system of automated transit that was inexpensive to operate. In the years since construction, the system has had no injuries and offered on-time service rates far surpassing the bus services it replaced while eliminating the gridlock that had locked up the city center. From July 2005 to June 2006, about 2.25 million rides were taken on the PRT. As of November 2007, the PRT transports about 16,000 riders per day. The record for most riders in a day is 31,280, set on 21 August 2006. Students currently pay $60 for four months of service, which provides PRT with 50 to 60 percent of its total operating costs.

The unique aspect that makes the system "personal" is that a rider can tell the system which station is the destination and then he/she will be directed to a car that is bound only for that station. The PRT cars are painted in the school colors (blue with gold trim) and feature the University name and logo on the front. Inside, the seats are light beige fiberglass and the carpeting is blue. Each car has eight seats with an overall capacity of 20 people, including standing room.

The National Society of Professional Engineers named the WVU PRT one of the top 10 engineering achievements of 1972, and in 1998 The New Electric Railway Journal picked the WVU PRT as the best people mover. In 2006, the U.S. Department of Transportation and U.S. Environmental Protection Agency dubbed WVU one of the best workplaces for commuters. (Wikipedia, E. 2010)

Figure 2.2: Disneyland straddling Monorail Red, Anaheim, CA, USA

Figure 2.3: Airport suspended Skytrain Monorail, Düsseldorf, Germany

Table 2.8: Monorails: Reasons to support vs. reasons to exercise causation

MONORAILS[9]			
Reasons to support	**Monorails are nonpolluting, quiet, andnand automated:** - *All these characteristics are approximately the same for any electrically powered modern transport system on a guide- way or rails.*	Reasons to exercise caution	**Switching is cumbersome:** - *While vehicles can certainly be switched from one line to another, an entire section of the supporting beam has to be moved to accomplish each maneuver.*
	Safety: - *The record has been extremely good, with serious operational accidents not yet encountered.* - *Personal safety has also been exceptional, and systems operate in controlled environments, and extensive surveillance programs done by monitors and safety personnel are in place.*		**Fragility of system:** - *Automated types of monorails are characterized by highly advanced technology with components that can be somewhat delicate.* **Monorails can only operate in an elevated configuration:** - *The lines can't be placed on surface, because cross traffic can't be accommodated on same level.*
	Suitability for constrained spaces: - *All the dimensions of AGT elements are measurably smaller than those of conventional transit* - *Little noise or vibration is generated*		**The vehicles more expensive** *The suspension or straddling mechanisms are more complex than regular bogies or truck sunder standard rail cars (while the passenger compartments can be identical to those of any other rail car,)*

[9] This Table is adapted from chapter 12 and 15 of "Urban Transportation Systems written by S. Grava, 2004"

Table 2.8 (continued)

Reasons to suppose	- *Placed in tunnels), so there is no interference with traffic on already overloaded surface streets.* - *There are better opportunities to thread lines through intensely developed districts, and even buildings can be penetrated.*	**Reasons to exercise caution**	
	Vehicles are not likely to derail: - *It is practically impossible for the vehicle to leave the beam or channel, although other mechanical problems are not precluded.* - *Suspended monorails claim to be weatherproof because rain and snow cannot enter the guide way channel.*		**Evacuation of a stalled or disabled train is a problem:** - *Since the slender beam or channel does not provide for any walkway, the safe accommodation of passengers along the elevated structure under emergency conditions will require special arrangements and catwalks.*
	Advanced technology image: - *Monorails are associated in the public mind with technological advancement and visionary concepts.* - *This may be a considerable positive force, possibly generating considerable public and civic support for implementation.*		**Cost factors:** - *Capital investments will be considerable because a completely new exclusive guideway has to be created,* - *Advanced-technology vehicles have to be acquired, and sophisticated maintenance facilities have to be made available which are considerably expensive.*
	Low labor input: - *Since there are no drivers or conductors on the vehicles, and passengers may not see any employee of the operating agency, there is considerable savings on the personnel side of the ledger.*		

CHAPTER 3

APM SYSTEMS: The Modern and Smart Solutions

Recently, there are encouraging examples in which public transportation is helping to generate new vitality like never before. Beautiful, walkable town squares combine residential, retail, office, recreation and public transportation features to make community living easy. New Automated People Movers (APMs) and light rail extensions improve mobility and ease congestion. Along with easing congestion and improving air quality, the benefits of enhancing modern public transit facilities are enormous.

APMs can be defined as a light to medium scale rail transit system using small, light weight rolling stock running on rubber tires on a dedicated guide-way that is usually elevated. Unmanned APM trains are controlled by computers which help reducing staff costs. At present there are about 130 APM installations in operation around the world moving about five million passengers daily. As shown in Table 3.1, about 30 percent of them are within and around airports, and the rest are mostly around dense urban centers (i.e. central business districts). About one third of them are mass public transport of one form or another - driverless metros and district circulators. The rest are in universities, private leisure and institutional settings. (Yigitcanlar et al, 2008). In the forthcoming sections first, various features and capabilities of monorail systems as one of the most applicable APM technologies on contemporary campuses will be studied and then, different characteristics of METU campus will be evaluated to apply such a progressive transportation system.

Table 3.1: Operating APM world statistics (Fabian, 2007)

Airport	Daily Ridership (Thousand People)
Atlanta	240
Cincinnati	35
Dallas-Ft Worth	25
Denver	58
Detroit	50
Frankfurt	35
Hong Kong	45
Houston- WED	11
Houston-Adtranz	35
Kuala Lumpur	25
Las Vegas	50
London-Gatwick	24
London-Stansted	18
Madrid	25
Mexico City	25
Miami	9
Minneapolis	7
Orlando	100
Osaka-Kansai	40
Paris-CDG-LISA	50
Pittsburgh	50
Rome	25
Seattle-Tacoma	50
Singapore	19
Tampa	71
Taipei	25
Tokyo-Narita	40
Toronto	25
Zurich	30
TOTAL	**1242**
Air Front	
Birmingham (UK)	10
Chicago	45
Dusseldorf (Germ)	4
Minneapolis	10
NY JFK AirTrain	35
Newark	30
Paris-CDG-Line 1	50
Paris OrlyVAL	8
San Francisco	22
Tampa-parking	8
TOTAL	**222**
Leisure	
Abu Dhabu Museum	1
Aichi HSST	10
Arosa, Switz.	1
Bronx Zoo, NYC	2
CalExpo	2
Chester Zoo, UK	2
Circus-Circus, LV	4
Circus-Circus, LV Reno	6
Hersheypark, PA	8
Helsinki-Lin.Park	3
Hong Kong Disney	20
Jakarta Cult.Park	8
LotteWorld, Korea	5
Magdeburg, Germ.	5
Magic Mt, CA	8
Mandalay Bay, LV	75
Manila Dreamland	5
Memphis-Mudd Isl.	2
Miami Zoo, FL	1
Minn. Zoo, MN	1
Mirage-Tr Isl, LV	5
Primm UniTrak, NV	5
ShenzhuenPk, China	5
Shenzhuen City	10
Sun City, So. Africa	2
Tokyo Disneyland	60
Whiskey Pete, NV	5
York, UK	1
TOTAL	262

Line Transit	Daily Ridership (Thousand People)
-- Attended --	
Ankara, Turkey	170
Chiba, Japan	60
Hiroshima, Japan	40
Ina (Omiya), Japan	27
Kita Kyushu, Japan	35
Wuhan, China	50
-- Driverless Metros --	
Chongqing, China	30
Copenhagen	61
Kuala Lumpur	160
Lille- 1, France	200
Lille- 2, France	115
Lyon- D, France	250
Paris Meteor	190
Perugia, Italy	30
Rennes, France	95
Singapore-NE Line	200
Taipei-Brown, Taiwan	250
Tokyo Yukarinome, Jap.	94
Toulouse, France	140
Turin, Italy	40
Vancouver SkyTrain,Can	150
Vancouver Millennium	60
Yokohama, Japan	45
TOTAL	**2492**
Institutional	
Belfast Mall, UK	1
ClarHeath -Indianapolis	1
Dortmund Univ, Germ.	6
Duke Hosp.- Raleigh, NC	2
Getty Center- LA, CA	15
Huntsville Hospital	2
Las Colinas, Dallas	1
Las Vegas Monorail	22
Milan- San Raffaele	5
Morgantown PRT, WV	20
London Docklands	210
Moscow Monorail	5
Oerias (Lisbon, Port.)	1
Pearlridge, Honolulu	3
Rio-Bara Shopping, Braz.	7
Senate Subway, DC	14
Shanghai Shuttle	8
Taejon, Korea	5
Villepinte, Paris, Fr.	3
Ziegenhain Hosp, Germ.	1
TOTAL	**332**
Local Transit	
Bukit Panjang,Singapore	40
Detroit DPM, MI	3
Haifa Incline, Israel	5
Hiroshima Skyrail	20
Hong Kong Penny Bay	25
Jacksonville Skyway	3
Kobe Portliner, Jap.	65
Kobe Rokkoliner, Jap.	30
Laon, France	3
Miami Metromover, FL	28
Nagoya HSST	10
Osaka New Tram, Japan	65
Ponggol, Singapore	6
Scarboro (Tor), Can.	35
Sengkang, Singapore	17
Serfaus, Austria	6
Sydney HarbLink, Aust'l.	13
Tokadai(Nagoya),Jap.	5
Yukarigoaka, Japan	5
TOTAL	**384**
GRAND TOTAL	**4934**

Note: Excludes urban gondolas, inclines and funiculars.

3.1 Monorail as an APM System

3.1.1 Basic description

Among the various types of APM systems, Monorail are one the most efficient and applicable systems on university campuses, public and private leisure and institutional settings. They can be divided into straddle type, in which the vehicle sits astride the rail, and the suspended type, in which the vehicle is suspended from the rail and both types use rubber tires and air springs for their bogie suspension to reduce vibration and noise. Most modern urban monorails are equipped with VVVF (Variable Voltage, Variable Frequency) drives, composite or aluminum body shell and ATO (Automatic Train Operation) system. In addition, because of the special structure of the monorail system, there is no danger of derailment. The monorail can withstand severe weather conditions, such as strong winds, ice and snow.

Monorail Railways are a complex combination of various Electrical and Mechanical (E&M) systems including the trains, track, track switches, substations, substation supervising system, signals, communication systems, operation control systems, etc. World's famous monorail manufactures – such as Hitachi, Bombardier, Mitsubishi, and Siemens – supplying all of these E&M products individually and as a fully integrated monorail system to meet the demands of urban environments.

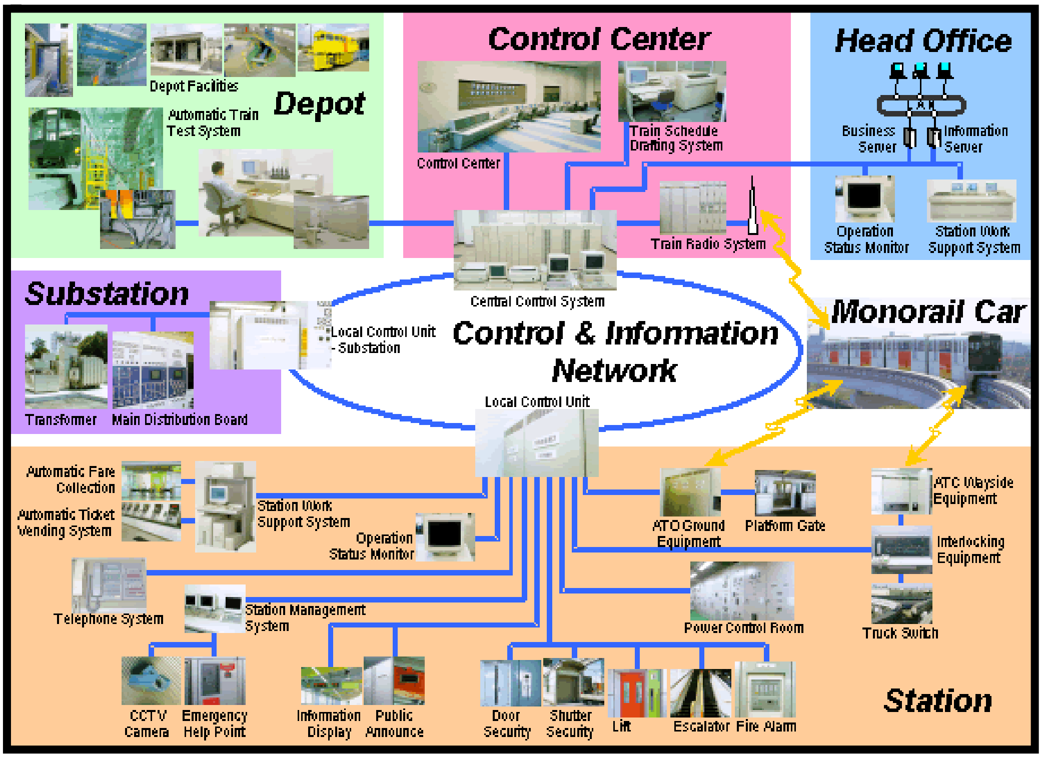


Figure 3.1: Schematic view of a monorail control and maintenance system

3.1.2 Straddle Type of Monorails: Capacity and Body Outline

The straddle type uses a high-strength concrete or steel girder as the rail. A bogie which is equipped with traveling wheels, guide wheels and stabilizer wheels—all made of rubber—sits astride the top and sides of the rail and the car-body is mounted on the bogie. The car body is made of composite or aluminum shell and they sit on top of square and round tubing-based truss assemblies (Figure 3.2).

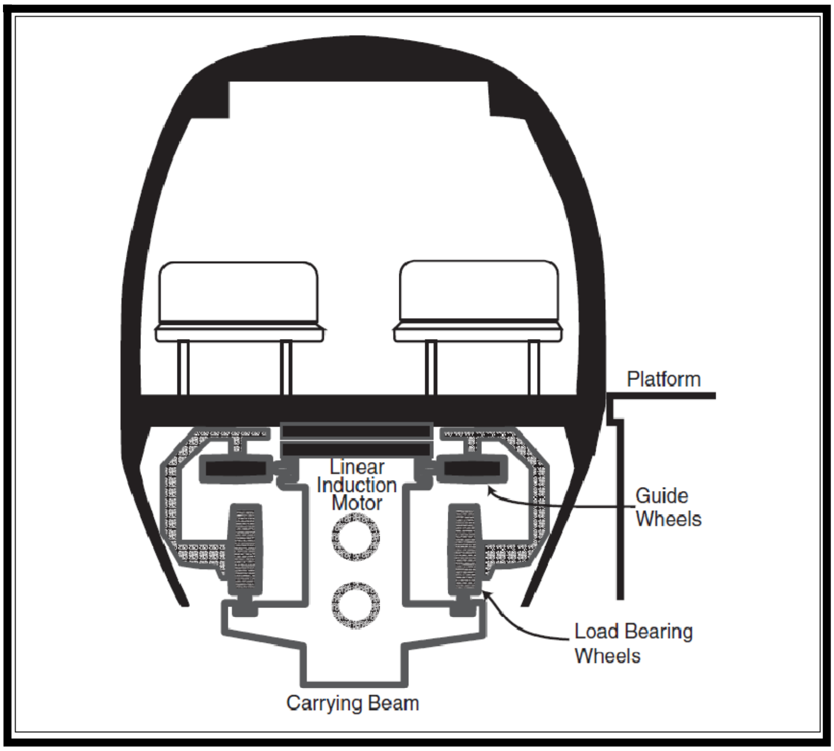


Figure 3.2: Support system of Straddle type monorail, (Grava, 2004)

Normally, each car has 4 doors, two on each side. The trains could be fully air conditioned on demand. Each car can carry 15-20 passengers seated and 40-50 passengers standing. Cab cars are 12-15 m long and intermediate cars are 9 – 11 m. Train sizes are various depending on the manufacturer and number of cars attached. Based on their size and number of cars affixed, trains are categorized in three main types; small types have two cars, medium types have three cars and large ones have four to six cars attached. Tables 3.2 to 3.4 shows outline characteristics for these common types. These tables' data were adapted from www.hitachi-rail.com, last accessed on 08/11/2010.

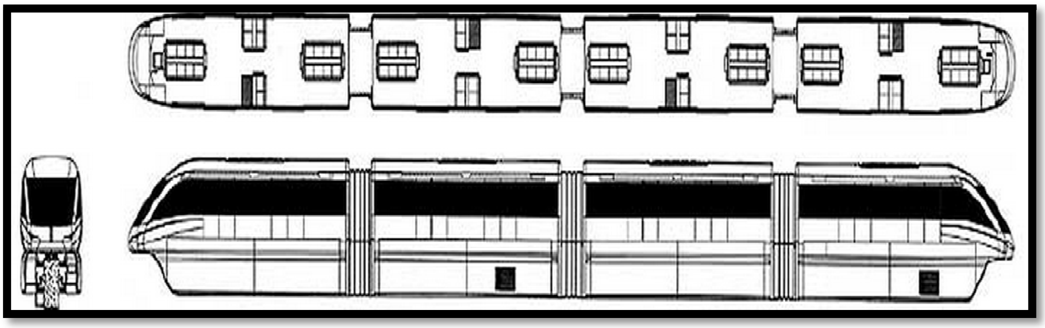


Figure 3.3: Four-car straddle monorail

Table 3.2: Small type straddle monorail train specifications

Small train	
Nominal capacity	100-120 passengers (~4 passengers / m2)
Full loaded capacity	130-150 passengers (~6 passengers/m2)
Train length (2-car consist)	22 - 26 m
Train width (maximum)	2.5 - 2.7 m
Train height (full)	3.5 - 4.8 m
Train height (Beam surface to top)	2.2 - 3.8 m
Minimum curve radius	60m (recommendable)

Table 3.3: Medium type straddle monorail train specifications

Medium train	
Nominal	370 - 400 passengers (~4 passengers/m2)
Full loaded	510 - 550 passengers (~6 passengers/m2)
Crush loaded	650 - 680 passengers (~8 passengers/m2)
Train length (3-car consist)	40 - 45 m
Train width (maximum)	2.5 - 2.9 m
Train height (full)	3.6 - 4.9 m
Train height (Beam surface to top)	2.2 - 3.8 m
Minimum curve radius	100m (recommendable)

Table 3.4: Large type straddle monorail train specifications

Large train	
Nominal	430 - 460 passengers (~4 passengers/m2)
Full loaded	590 - 620 passengers (~6 passengers/m2)
Crush loaded	750 -780 passengers (~8 passengers/m2)
Train length (4-6 car consist)	60 - 71 m
Train width (maximum)	2.5 - 3 m
Train height (full)	3.5 - 5.6 m
Train height (Beam to surface)	2.4 - 3.8 m
Minimum curve radius	100m (recommendable)

3.1.3 Suspended Type of Monorails: Capacity and Body Outline

The suspended type uses a steel track girder with an open bottom. The car body is suspended from a bogie which is equipped with traveling and guide wheels made of rubber. The bogie ran inside a hollow box girder on the lower face of which was a slot through which the suspension gear passed. The system enjoyed the same type of quiet, rapid acceleration and braking as did the straddle type. The cars were hung on a pendulum type suspension with pneumatic springs, giving stability and comfort even at high speeds. The complete enclosure of the bogies inside the box protected them from the weather, so the system was unaffected by rain, frost or snow. Operation was electric from a third rail also enclosed in the box, preventing accidental electrocution. The vertical support for the vehicle's passenger compartment is by two tubular steel hangars with a pair of hydraulic springs that are used to dampen the oscillation and permit banking in curves (Figure 3.4). Like straddle type, various manufacturers have different designed sizes of vehicles and guide ways but generally, the passenger cars have 60-70 seats and are 2.5 – 3.5 m wide, 16 – 19 m long, and 3 – 3.9 m high. An empty vehicle weighs about 25 to 30 tones. Maximum passenger capacity is 160 - 200 people; 60 - 70 seated and 100 - 130 standing. Construction is usually aircraft composite with composite transparent windows. The space below the floor contains a ladder that can be lowered in case an emergency evacuation is necessary. Minimum turning radius is about 20 meter; about a third of what is required in a conventional light rail system. Unlike the suspended type where all of the electrical and control systems are below the passenger compartment, in suspended type the equipments are located above the passenger compartment.

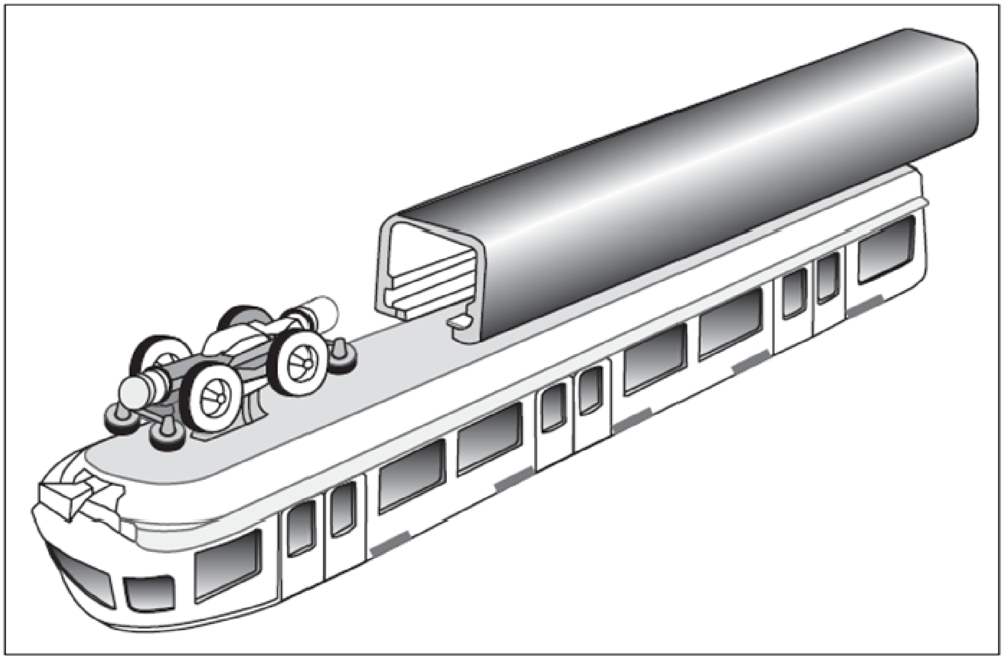


Figure 3.4: Suspended type monorail, (Grava, 2004)

This type of monorails began its service much longer than straddle types and the oldest monorail system in continuous service was a straddling type monorail named *"Schwebenbahn"* – Schweben in German means "to hang, to be suspended" – is constructed in Wuppertal, Germany. Opened in 1901, *Schwebebahn* designed to provide service for passengers of the entire city. This system is still in full operation today over a 13-km (8-mi) track with 19 stations, and it has been recently renovated with some completely rebuilt stations.

Figure 3.5: The oldest monorail in continuous service, in Wuppertal, Germany, (Grava, 2004)

Because of some of its improper visual effects, capacity limits and slightly high construction costs, most of the current monorail projects are straddle type and from now on, just straddle monorail systems' features and characteristics will be the matter of focus in this study.

3.1.4 Guide–way Structure

The supporting columns were set on top of appropriate foundations (cast-in-place, driven pile or spread foundations.) Most of the supporting structure consists of T-shaped reinforced concrete columns. The columns are depending on the context are 1 – 8 meter high, with about 1.5 m embedded into the ground.

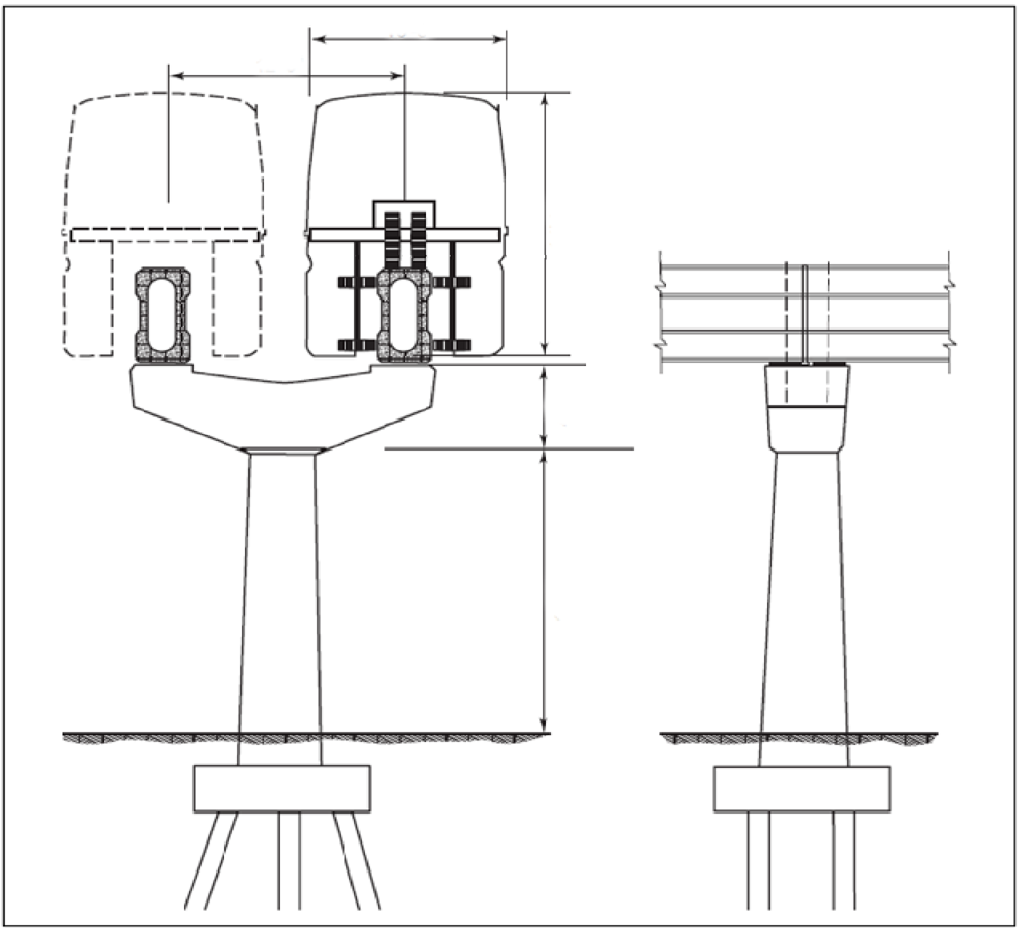


Figure 3.6: Typical straddle monorail structure, (Grava, 2004)

The beamway itself consists of prefabricated, pre-stressed concrete beams with or without steel shells. These were hollow girders approximately 1 m wide and 1.5 m high, with the approximate shape of an "I" beam. In a dual-beam environment, the distance between the beams is about 3 m on-center. Each of the 90-ft (27.4 m) straight beams weighs about 55 tons. The 77-ft (23.4) curved beams also weigh about 55 tons, since they have slightly thicker walls. Maximum span for straight beams is from 20 – 30 meters. Curved beams of 600+-ft (182.9 m) radius can span 75 feet (22.8 m), while curved beams of less than 300 feet (91.5 m) average 60 feet (18.3 m).The construction procedure was very simple. After the foundations were in place, one crane and one labor crew could set 12 columns per a day. Then, two cranes plus one labor crew could set 18 beams per a day.

Figure 3.7: Concrete and steel guideway structure, Palm-Jumeirah monorail train, Dubai, UAE

3.1.5 Vehicle Safety and Passenger Comfort

Monorails are categorized in Zero Accident or the safest public transpiration systems. Because of their elevated design, accidents with surface traffic are impossible. Zero accidents translates to no system down time, less liability suits and most importantly, no injuries or deaths where street rail systems with grade crossings (light rail, trams or trollies) can't offer this kind of safety. Also, passenger safety is a primary consideration in the design of modern monorail system. Various manufacturers are trying to produce vehicles satisfying the latest transportation safety standards to ensure passengers safety and comfort during their trips. These kind of modern cars benefited recent interior design techniques and modern convenience features such as fully automated air conditioning systems, the vehicles' air spring suspension and unobstructed passageways to bring an open atmosphere to the passengers, and to provide a pleasant time for passengers rather than a time feeling boxed in, as they feel like having fun walking in the air.

The straddle design provides stability as the vehicle rides along the guideway. Passenger comfort is enhanced by and use of the latest power traction technology to drive rubber-tired wheels offering a sure-footed, significantly quieter and more comfortable ride compared to steel wheeled transit vehicles. And also rubber tire system makes running vehicles less noisy and protecting the neighborhood communities from noise pollution with a virtually silent track system.

Figure 3.8: Interior view of a straddle monorail train

(www.bombardier.com, last accessed 10/10/2010)

3.1.6 Propulsion System, Grade and Traction

The propulsion equipment usually uses Variable Voltage, Variable Frequency (VVVF) inverters with a high power/weight ratio motors with an average power of 100 hp for each motor, using 600 – 1500 VDC voltage. These motors also act as brakes by turning the motors into generators and dissipating the power into resistor banks between each car. This is called regenerative braking. The system also provides high reliability and safety features including safe-off state interlock with the braking system. It is also equipped with dual media redundant network interfaced to the Vehicle Management System.

The drive motors/controllers are current technology Pulse-width modulation (PWM) AC Drive with Dynamic Braking. These are fine tuned for smooth acceleration/deceleration and high standards of passenger comfort. They have high torque and duty cycles as well. Besides the motors, the brake system comprises the latest generation of electro pneumatic systems currently available. Functions include emergency braking, service braking, security braking, and power braking. The brake system also controls compressors and communicates with the train management system, as well as Automated Train Operation (ATO) or Automated Train Protection (ATP) equipment if present. Compared to ATP, which only controls braking, ATO controls all phases of train operation from acceleration to precise stopping. Currently, ATO is installed mostly in monorails and linear metro. Combined with the Platform Gates, ATO helps the train operators to realize driverless operation. In ATO system the train's location as it travels between stations is detected using passive balises (passive tags). Two-way transmission using active balises at specified station-stop positions provides station-code information and information to enable interlocking control of platform gates. And then the onboard equipment is mounted at one end of the train, reducing installation costs. This system provides supervisory control, monitoring, and diagnostic systems. Train status information is graphically displayed to the operator via the HMI panel and allows the operator to quickly respond to and understand all train systems' status. This system annunciates the train system status and abnormal conditions are categorized and displayed in real time. It also acts as a "flight data recorder" for further data analysis.

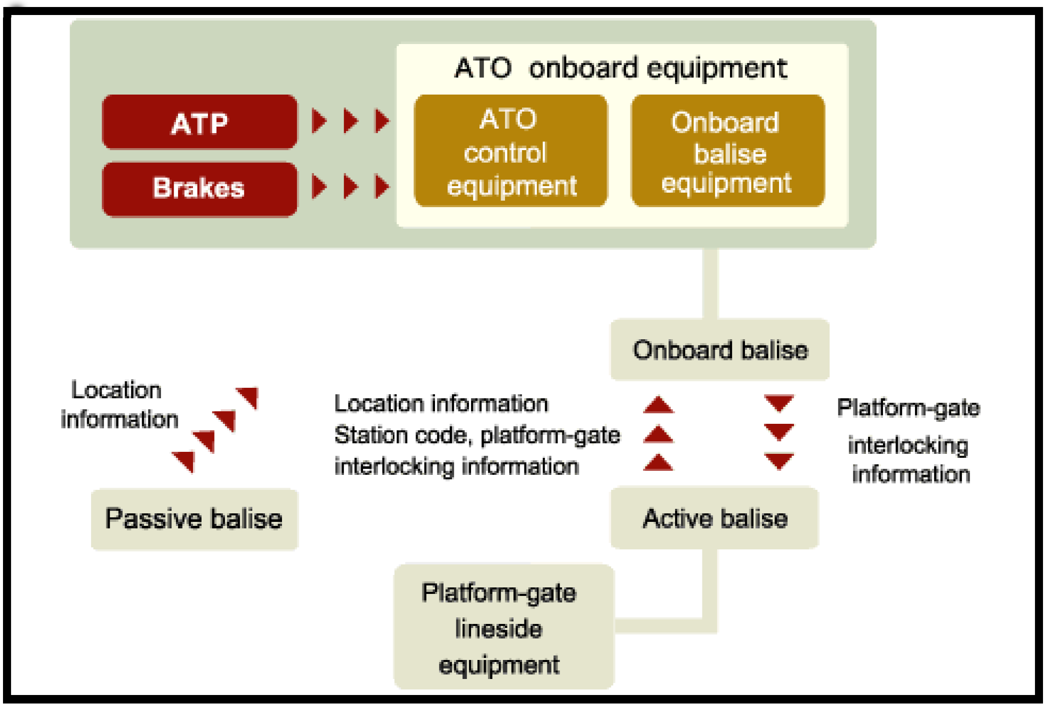


Figure 3.9: ATO vehicle management system configuration

(www.hitachi-rail.com, last accessed on 10/10/2010)

3.1.7 Switching and Steering

Track switches are critical to the successful operation of any train based transit system and must be highly reliable. There are three types of switches: traverser, straight beam, and flexible beam. A traverser consists of steel or reinforced-concrete parallel beams, each as long as a train and spaced far enough apart to have a train on each one. The straight beam is a switch capable of serving 3 monorail tracks. The other 3 supports are movable carriages which travel laterally with the beam. Switching time is about 9-12 seconds. The flexible switch (first invented by Hitachi) is used in high-speed installations. This type of switch operates in about 7 seconds.

Hitachi's monorail track flexible switch design has an unsurpassed record of accident free service from 1964 at the Tokyo Monorail, which is Japan's first urban transit monorail system, and have been installed at all other Hitachi urban transit monorail systems in operation. Utilizing a section of the track beam itself, this kind of track switch provides a smooth transition between lines (Figure 3.10).

Also, there are four steering tires per train, 2 on the front cab car and 2 on the rear cab car (Figure 3.11). As it was mentioned before, monorail benefited rubber tires instead of steel ones which makes the riding more comfortable and steerable and produces less noise.

Figure 3.10: Flexible monorail switching system in three different situations (www.hitachi-rail.com, last accessed on 10/10/2010)

Figure 3.11: monorail's load tires (left) and steering guide tires (right).

3.1.8 Control, Reliability, Related Information

The operation of safe, efficient and cost-effective monorail systems is directly depends upon an advanced rail control and signaling system. Today, monorail manufacturers offer a comprehensive portfolio of rail systems including:

- ✓ Autonomous integrated control systems
- ✓ Computer and relay based interlocking systems
- ✓ Automatic train protection and train operation systems
- ✓ Radio based rail control and signaling systems
- ✓ Wayside equipment

These systems are the key to increased availability, line capacity and operational line speeds to meet the requirements of every railway operator. They are paramount to the effective, efficient and profitable operation of monorail systems of the future. Improvements through enhanced safety, increased reliability and experienced comprehensive support systems and processes are the vital demands from mass transit operators and passengers.

Figure 3.12: An ultra-modern control room allows technicians to monitor all aspects of operations,Kuala lumpur Monorail, Malaysia

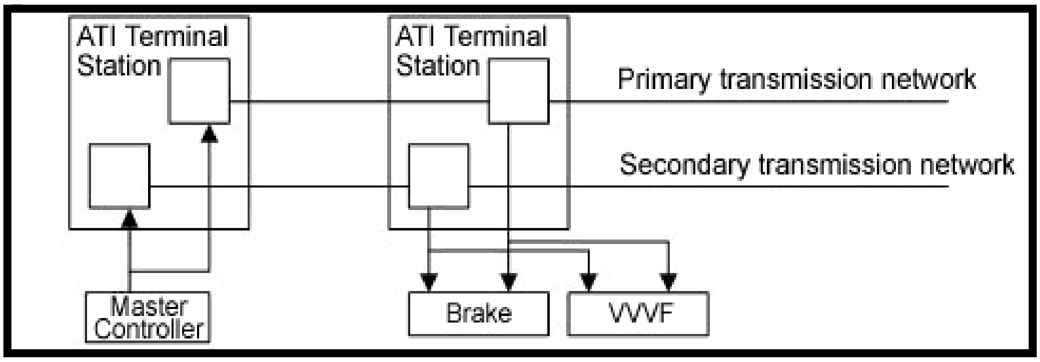


Figure 3.13: Dual transmission network system applied for train operation control command signal (www.hitachi-rail.com, last accessed 10/10/2010)

By the advancement of microcomputer and data transmission technologies integrated control systems act as a spinal chord of a train. Autonomous Integrated Control (ATI) system is a type of digital information exchange system that integrates the information collected from the ground equipment and the on-board devices for train control which makes train under a live and dynamic control. Also, to retain the fail-safe transmission functions without the increase of delay time of command signal transmission, even if a failure occurs in the primary transmission network. The transmission system of command signals becomes dual system, then the transmission system of monitoring signals also become dual system at the same time.

3.1.9 Environment and Energy Issues

3.1.9.1 No Emissions

Monorails are completely electric and produce zero emissions and, as means of transpiration, monorails aid in the removal of large amount of various motor vehicle traffics and reduced emissions by tons of carbon monoxide (CO), volatile organic compounds (VOC) and nitrogen oxides (NOx) over the course of the year. Figure 3.14 shows Las Vegas Monorail removes 2.7 million vehicle miles from Southern Nevada's major roadways in 2009, reducing 48 tons of greenhouse gases emissions annually.

3.1.9.2 Greenery along Route

The alignment space needed for monorail is small but is big enough for landscaping. Shown here is some of the lush landscaping that enhances the route of the Kitakyushu City Monorail in Japan. You can't plant this much vegetation on a street level light rail route without gobbling up more traffic lanes. Figure 3.15 shows Kitakyushu Monorail in Japan includes a heavy dose of landscaping below the guideway.

3.1.9.3 Friendly to the Natural Environment

Environmentalists have long sought to be rid of pollution and congestion caused by auto traffic in every preserved natural area. There are several examples of green monorail track through jungle areas. Since most monorail trains run above the surface, wildlife and humans would be safer, noise levels would be lower, and pollution would be greatly reduced.

Figure 3.14: Las Vegas Monorail, Nevada, USA

Figure 3.15: Kitakyushu Monorail, Fukuoka, Japan

Figure 3.16: The Green monorail at Disneyland, Florida, USA

3.2 Monorail: The Smart APM Systems on Campuses

University campuses have unique transportation requirements that may be characterized with a high concentration of trips during multiple peak periods (i.e., morning, lunch, and afternoon). These campuses are often the largest employers in small-to-medium size cities and it is therefore critical to coordinate modern campus mobility needs with the overall transportation system. New APM technologies offer promise to enhance the operation of transit on campuses and in communities with a campus. These APM systems are a top issue for transit systems that are looking both at ways to improve the efficiency and cost effectiveness, as well as to transition transit from a mode that has historically frequently been marginalized as a second class mode of travel. Moreover, systems hope to appeal strongly to college students, who are often more tech-savvy and are also more likely to use transit to get around than other groups, and who are perceived as the "next generation" of riders that transit systems aim to attract to habitual use (Miller, 2008).

3.3 METU Campus Monorail System

3.3.1 Site Characteristics

The potential site proposed is the METU Campus, including connections between ODTÜ and Bilkent stations of Ankara metro, dormitories and residential regions, Teknokent region and various on campus facilities and buildings.

3.3.2 Urban and Mobility Context

Middle East Technical University (METU) was founded in a government provided 4250 hectare piece of land in South West of Ankara City Centrum in 1960. In the original plan, all of the academic and administrative facilities and residential buildings, covering about only 65 hectare land, were sited on the northern part of the campus land (Güllüoğlu, 2005). According to Current Master Development Plan of the METU campus in year 2025 – approved by the Metropolitan Municipality of Ankara (ABB) on 07.02.1994 (ABB, 1994) – 418 hectare land was allocated as the gross settlement and development area of the campus (only 220 hectare was in use by 2009) and the remaining forests and bare lands, covering about 3,800 hectare, will be preserved as natural areas. The development plan of the campus proposes a gross expansion of 90 % on the western side of the campus; comprising METU Foundation Primary and High School on the northwest, METU Teknokent on the west and METU Residences (ODTÜ Kent) on the southwest. Thus, main development direction of the campus is determined westwards according to the plan.

At present, Ankara is the capital city and second largest city of Turkey with about 4,500,000 habitants and the campus is now roughly surrounded by Eskişehir Blv. in North, Mevlana Blv. and 100.Yil district in East, İncek Blv. in South and Bilkent Blv. in West. METU campus is connected to the other parts of Ankara mostly by buses, as part of the urban bus network provided by Ankara municipality (EGO Buses) and private operated urban minibus services (Dolmuş) on prescribed routes (similar to those of the buses). Ankara Metro is planning to start its service on A1 and A2 university entrances in 2012. Also the two radio taxi stations in the campus region provide good services. In addition, METU provides organized shuttle bus services (morning and afternoon) to the staff.

Figure 3.17: Location of the METU Campus in Ankara (Google Earth©2010)

Approximately 9,000 vehicles a day enter the Campus, 8,200 out of them are private cars and taxi. (A total number of 7.688 METU entrance cards were in use the end of 2009 where 2,959 of them were academic and staff users). The remaining 800 vehicles are mainly pickups, minibuses and buses. Figure 3.17 presents a schematic map of METU campus.

Campus vehicular road schema can be figured with two adjacent loops. First loop, based on the original campus plan, encircles core campus and main pedestrian alley and most of the public buildings serving the METU community are located along or close to it. Second loop is adjacent to the first loop and passes through the Teknokent and western residential and dormitories region and shares a segment of faculties' road. These two loops have vital importance for the vehicular traffic in campus. These loops are linked to campus gates; A1 and A2 gates on the north, A4 gate on the east and A7 gate on the west. However, gate A2 is only used for service purposes.

Campus ring services are operated for providing the circulation in campus through working hours (from 08:25 to 16:45) on both of the mentioned campus loops. METU District services are operated between campus and 46 different districts of Ankara; in morning rush hours (between 06:20 & 07:55, from districts) and in the evening peak (at 17:45, to districts). Unlike campus ring services, free for everyone; METU district services are only available for METU staff due to limited fleet capacity. In 2009, campus ring services were reorganized and four different ring routes were determined. Two of them (blue and orange routes) depart from west dormitories zone at 08:25 and others (red and routes) are available from the ring stops through working hours, between 09:00 and 16:45. There are also other ring services as; dormitories ring service, operating between west (new) and east (old) dormitories zones after 18:45 until 23:30 in weekdays during academic year.

3.3.3 Campus Facilities and Population

According to a study conducted by the presidency office in 2003, the whole campus is divided into nine zones (Gökbulut, 2004). In this study, Faculty Buildings, Library, Presidency Office and Student Affairs are located along the so-called zone A's central alley and each of the Zones B to I are respectively include; Zone B: Cultural Center and Cafeteria, Zone C: Shopping Center, Zone D: Eastern Housing units, Zone E: Dormitories No.1 to No. 9 and 3 private student housing units, Zone F: Teknokent Residencies, Zone G: METU Primary and High schools, Zone H: University Support Units (Telecommunication, Electrical Works, etc), office of Constructions and Technical Works and Zone I: Teknokent Business and Research Center (Figure 3.18).

Examining this study, in consideration of the temporarily dense areas, such as Congress Center, Stadium, it is seen that the population is concentrated mostly in the area where the Faculty of Physics and the Presidency Office are located. The population of the largest and densest zone A has increased from 15,681 in 1997 to 17,157 in 2003 to about 20,000 in 2009.

According to Presidency Statistics, in the year 2009 METU has a total population of 30,100 persons. The detailed population figures are 24,760 students (undergraduate, graduate, postgraduate), 1,100 faculty members, 4,300 academic and administrative staff, 1,660 Teknokent staff, 2,100 METU primary and high school and 1,300 others (campus residents, participants in various courses, general visitors, etc).

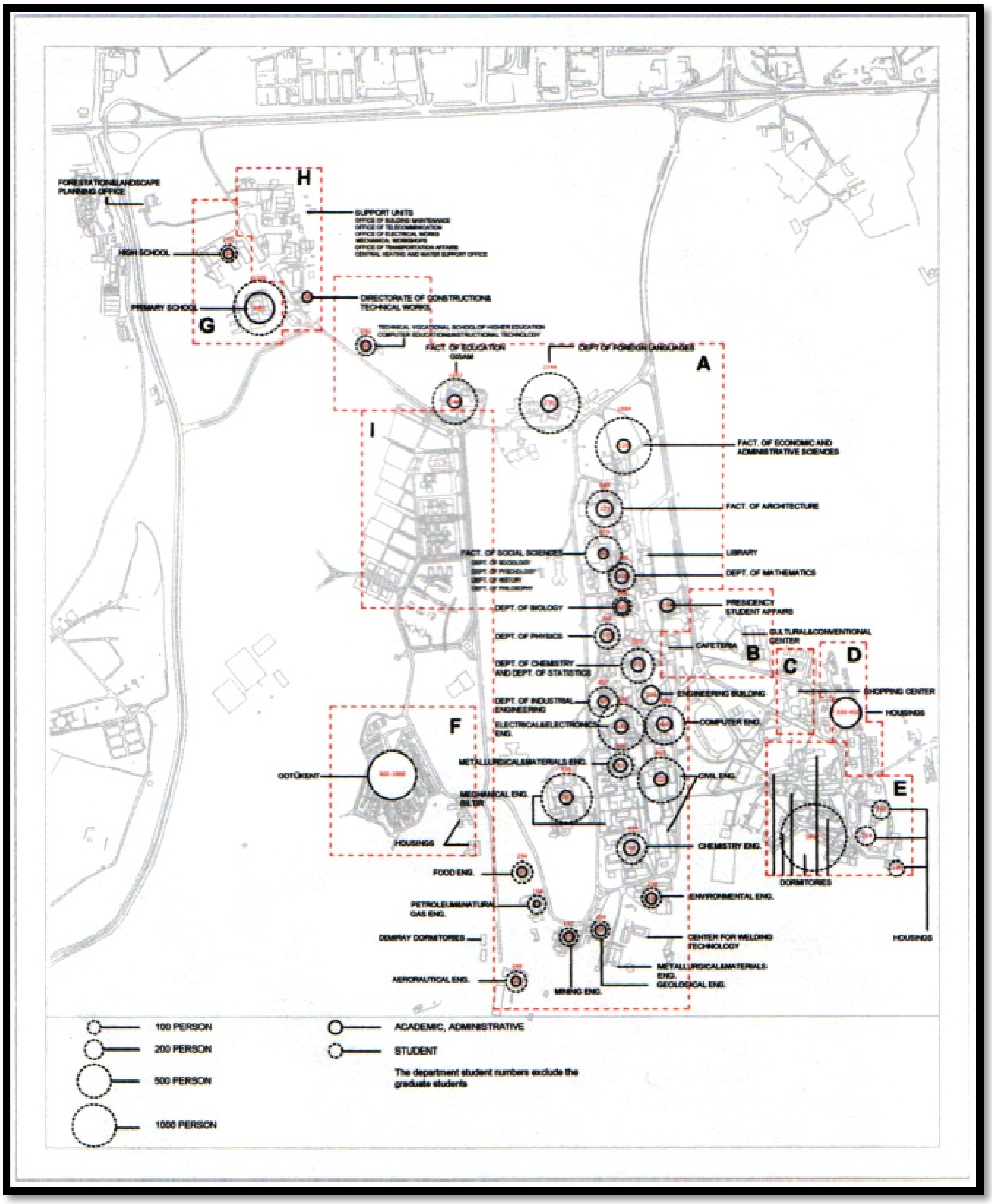


Figure 3.18: The nine population zones of METU campus (Gökbulut, 2004).

Besides, presidency of METU offers housing opportunities within the campus for its academic and administrative staff. In the year 2009, METU was offering totally 450 housing units and guest houses. 120 residences and a guest house are located on the eastern part of the campus. Besides, 330 houses are available in the ODTÜ-Kent residential zone, covering 9 hectare on the western side of the campus. At present from the mentioned 30,100 campus population, 6,600 students and 1,400 other residents are inhabited in above mentioned dormitories, guesthouses and residencies inside the campus.

3.3.4 Expected Demand

Campus trip demand can be figured as an aggregation of the following domains;

- Trips attracted from city to campus and trips generated from campus to city which is now served by EGO public services (via buses), private sector services (via buses and minibuses) and personal automobiles;
- The trip demand within the campus, arising from the trips attracted/generated between different zones of campus which is served by the campus ring services and, of course, by personal automobiles for long distances.

According to the last research done in METU, the automobile usage ratio reached from 7% in 1985 and 24% in 1996 to 39% in 2003 (Gökbulut, 2004). For the first phase assuming that, the demand will be derived only from students and staff who uses public transportation system to reach campus in the morning and to return home in the afternoon, we expect at least approximately a total of 5,000 passengers a day, based on the following assumption: approximately 3,000 undergrad students and about 1,000 graduate and post graduate and academic staff who will use the proposed system to reach campus, and about 1,000 students and habitants of campus who will use the system during the day to reach A1 gate and vice versa.

The peak hours are 8:00 to 10:00 AM and 16:00 to 18:00 PM. These are conservative assumptions, since they don't take into account the normal increase in METU population. According to METU Presidency Office provided campus population data, daily traffic and zonal interactions in different periods of working days are explored relative to the probable movements of different population groups in Table 3.6.

Table 3.5: Approximate travel demand of METU population groups (2009 ODTÜ Faaliyet Raporu)

Population Groups	Population	(08:00– 10:00) Morning Peak Hours	(10:00–16:00) During the Day	(16:00– 18:00) Afternoon Peak Hours	(18:00–08:00) Evening &Night	Estimated Demand
Preparatory School & Under Graduate Students	15,793	1 trip to campus	N/A	1 trip to home	N/A	~ 31,500
Graduate & Postgraduate Students	7,141	1 trip to campus (25%)	1 trip to campus (25%)	1 trip to home (50%)	N/A	~ 7,100
Academic & Administrative Staff	5,438	1 trip to campus	N/A	1 trip to home	N/A	~ 10,800
METU Residencies (Staff & Family)	1,421	1 in-campus/ 1 trip to city	1 city-campus round trip (25%)	1 in-campus / 1 trip to campus	1 city-campus round trip (25%)	~ 4,500
Eastern Dormitories (Students)	5,397	1 in-campus trip	N/A	1 in-campus trip	1 city-campus round trip (25%)	~ 13,000
Western Dormitories (Students)	1,925	1 in-campus trip	N/A	1 in-campus trip	1 city-campus round trip (25%)	~ 4,400
Teknokent Region & METU Primary/High School	3,795	1 trip to campus	N/A	1 trip to home	N/A	~ 7,500

CHAPTER 4

FEASIBILITY ANALYSIS OF METU MONORAIL TRANSPORTATION SYSTEM

4.1 Project Description

4.1.1 Project Summary

Project Type: A campus–wide Monorail System (monorail guide ways, passenger stations, pedestrian-bicycle corridors, public facilities, and public safety facilities)

Project Location: Middle East Technical University Campus – including: the connections between ODTU and Bilkent metro stations, dormitories and residential zones, campus facilities and buildings, and Teknokent region.

Turkish Governmental District: METU, Çankaya District, Ankara Metropolitan Area, TURKEY

Investors: Middle East Technical University Presidency Office

4.1.2 Historical Development of Project

In the original plan, academic and residential areas were arranged as near as possible to each other for 15,000 students, without preventing further spatial development. In this plan, the walking time between the academic and residential zone was planned as 20 minutes. A pedestrian was walking the campus area in 10 minutes (Gökbulut, 2004; Çinici, 1999). Today, as a result of the shifting of pedestrian transportation to automobile, the spatial structure of the campus has been transformed and has affected the walking time around the campus.

On the other hand, METU campus has limited parking (only about 1,000 parking spaces) available for students and visitors (more than 1700 of total 2700 on campus parking spaces are assigned to faculties and academic staff). The peripheral parking lots and also most of the student dormitories are located far from the campus center and main buildings, resulting in long walking distances (more than 1 km). In addition, there are quite steep slopes inside the Campus, in some cases more than 10%. Therefore, many students prefer to park in forbidden places, even at the risk of penalties (fine, suspension of entry rights, etc). Especially on special days when cultural activities are taking place, this problem is seen with the overflowing of cars to into main streets.

Also many students prefer not to wait for the shuttle when going to their destinations. In addition, there are some problems to reach campus from the city centre and vice versa in the evenings, when public transportation is very limited. An average of 8,000 students and academic staffs are living in on campus provided dormitories and residential buildings. Furthermore Ankara Metro plans to open two new stations at A1 and A2 entrances on

2011 as part of the city's Metro system development program, integrating campus to the current and planned heavy and light rail network of Ankara by connecting METU campus with the downtown (Kızılay) from METU station on A1 entrance and with the business and commerce area in Bilkent from the west entrance station. However, neither of these stations, at gates A1 and A2, is directly accessible by pedestrians from the built up area of campus. Furthermore, as the new rail route starts service, the number of EGO buses servicing METU is going to be reduced by the local government. As Gökbulut (2003) and Güllüoğlu (2005) also stated, sustainable solution to increase ODTÜ and Bilkent stations' service area, they should be connected to another public transport service operating within the campus.

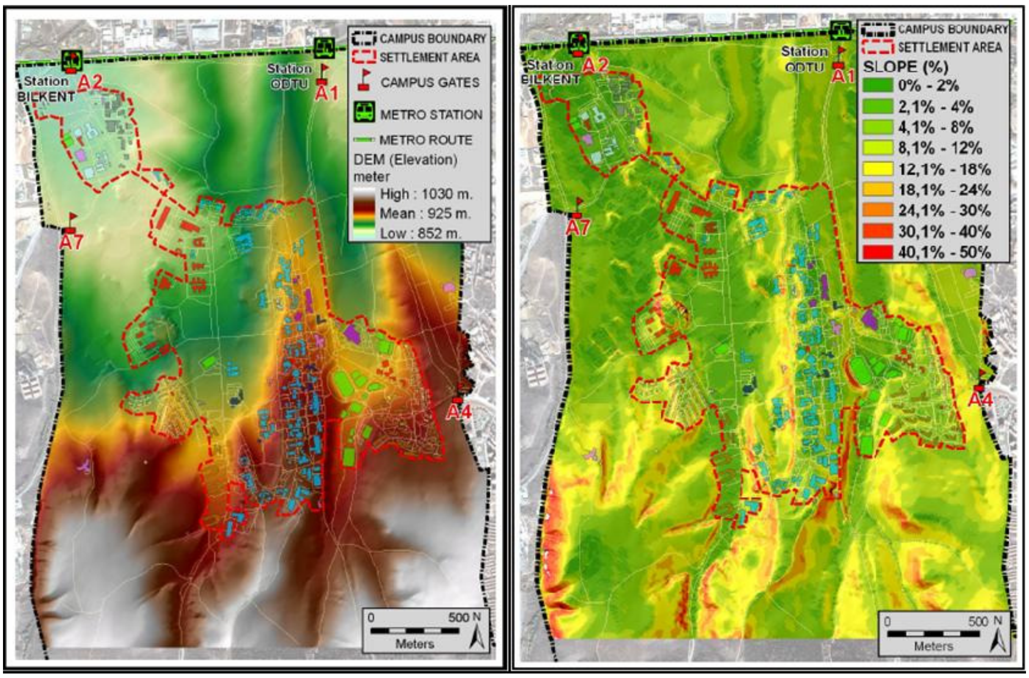


Figure 4.1 Digital elevation model (left) and Slope map of METU campus (right) (Güllüoğlu, 2005)

Considering these changes and forthcoming problems, METU presidency office accepted a project proposal by a Turkish private company to build a 1.5 km sample monorail line from A1 entrance to the Central library building in 2004 to test the cons and pros of such a system, thus a 300 meter guideway was built near the A1 entrance and a model vehicle was placed there but because of some internal problems the company quitted the project. This study, along with all previous efforts, studies the feasibility of constructing the METU monorail system as the essential need of a pioneer and sustainable transportation system for one of the most prestigious technical university in Turkey.

4.1.3 Necessity of Project Evaluation and Feasibility Study

The decision to implement any new project or program must be based on a thorough analysis of the current operation. So, the impact of implementation of this proposed project on the future operation of the campus transportation system must be evaluated. This feasibility study is based on extensive research on both the current practices and the proposed project and its impact on the campus transportation system operation. This study will contain data related to financial and operational impact and will include advantages and disadvantages of both the current situation and the proposed plan. It is conducted to assist the decision-makers in making the decision that will be in the best interest of the school foodservice operation. The extensive research, conducted in a non-biased manner, will provide data upon which to base a decision.

4.2 The Proposed Monorail System's Characteristics

4.2.1 An overview of the Current Transportation System

Ankara the capital city of Turkey, the fastest growing country in Europe region, with a population of over 4.5 million people is home to the campus of Middle East Technical University, one of the most prestigious and completive Turkish university, with an enrollment of approximately 24,700 students and employment of over 5,500. The campus, with an area of over 255 hectare, is approximately located 8 kilometers southwest of Ankara city center. The current transportation system of campus is consisted of the following services:

- Car dominates on campus and other regional travel patterns, with an estimated usage ratio of 50% in all campus–city trips. It takes approximately 15 minutes to drive from campus to downtown or vice versa.
- A range of public transport bus services are available. Characteristics of the services include regular short-distance bus services that provide hourly trip options to and from at least three regional centers: Kızılay, Sıhhiye, and the intercity bus terminal (AŞTİ).
- Privately operated minibus services (Dolmuş) are available during the day from three regional centers: Kızılay, Ulus, and Ayrancı and vice versa.
- Campus ring services are operated for providing the circulation in campus through working hours (from 08:25 to 16:45). Currently, campus ring services were reorganized and four

different ring routes were determined. Two of them (blue and orange routes) depart from west dormitories zone at 08:25 and others (red and routes) are available through the ring stops through working hours, between 09:00 and 16:45. There are also other ring services as; dormitories ring service, operating between west (new) and east (old) dormitories zones after 18:45 until 23:30 in weekdays during academic year.

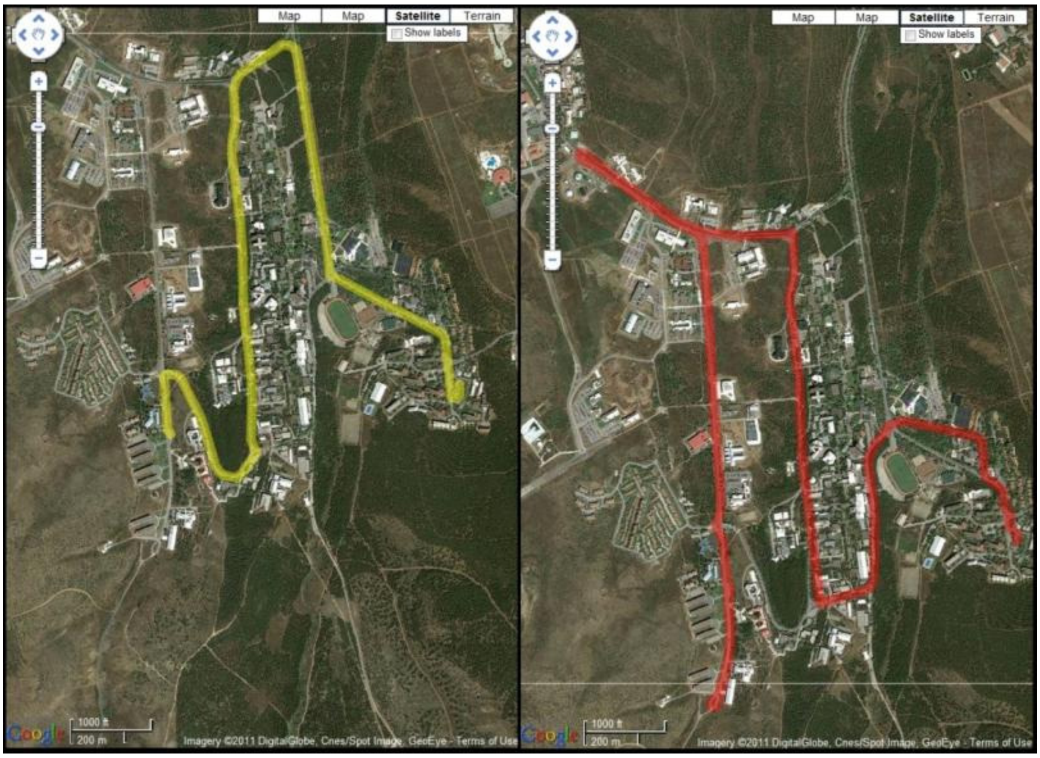


Figure 4.2: Yellow Campus Ring service path (right), Red Campus Ring service campus service path (left),

- Unlike campus ring services, free for everyone; METU has a fleet of district services, only available for METU staff due to limited capacity. METU District services are operated between campus and 46 different districts of Ankara; in morning rush hours (between 06:20 & 07:55, from districts) and in the evening peak (at 17:45, to districts).
- Two taxi stations on campus provide almost 24 hours relatively expensive services to different parts of the city.
- Ankara Metro is planning to start its service of Ankara Çayyolu line on A1 and A2 university entrances in 2012 (Figure 4.3).

Figure 4.3: Metro System, which will pass through to A1 and A2 gates, is under construction.

- An average of 7,000 students living on campus dormitories and residential facilities are walking, biking or using ring services daily to academic departments and other parts of the campus.

As it was mentioned on the previous chapters, there is a lack of public transportation services for many of the students living outside the campus during the day and also for dormitories' students for occasional trips to downtown in the evenings. There are some gaps in public transport supply and service effectiveness for basic requirements such as day return travel to campus, and the services that are provided are not always appropriately scheduled, accessible or adequately comfortable and have a limited ability to use public transport for inside the campus. Finally, there is a strong case on socio – economic over usage of personal automobiles on campus including: increasing parking demand, emission of greenhouse gases, traffic congestion in peak hours, sound pollution and different kinds of accidents.

4.2.2 General Features of the Monorail System

The proposed monorail transportation system would accommodate and link public and private transportation modes (intercity EGO bus services, on campus ring services, taxis, private para–transit services (Dolmuş), bicycle commuters, pedestrians, and the future Ankara city metro services) for the residents, students, facility and visitors of METU campus by providing the following:

- ✓ The new driverless monorail system will be substitute for the old bus ring transportation with limited service schedules and capabilities, to provide high-frequency and late-night transit services, seven days of the week.

- ✓ The proposed system will significantly reduce and bypass congestion during peak traffic hours; consequently, this will reduce the current limitation on usage of on campus parking spaces will be decrease for students and visitors.
- ✓ Campus residents in eastern and western dormitories and guesthouses will have the opportunity of a fair day and night access to any part of the campus and to Ankara city's public transportation system.
- ✓ With an at least 30 years of useful life time the proposed monorail system will guarantee an environmental friendly, sustainable and convenient service for the generations of students and faculties of METU.
- ✓ This system links the forthcoming two metro stations at A1 gate (ODTU station) and A2 gate (Bilkent station) to on campus facilities.
- ✓ Equipped with twelve to fifteen modern stations, bicycle carriage services on vehicles, the new pedestrian and bike paths to stations, and bike lockers at the stations, the new system will support of the new trends of biking to work culture and as an amenity extending the range of bicycle commuting and walking within the students and faculty members and academic staff of METU community.
- ✓ Due to its straddle-beam design it is safe and quiet, which hinders the prospect of derailment, high maintenance cost, and excessive frictional noise.

- ✓ Enhances and protects the existing green spaces and preserves the healthful natural environment of METU by reducing the amount of greenhouse gases emitted by on campus motor vehicles and consequent pollution and provide an energy efficient and environment friendly form of transit system

It will be fully air-conditioned or heated with handicap accessibility, and the passengers will enjoy a serene musical environment. It is perceived that the system will serve 1 million riders annually; as a result, this great incentive for tourism and increase in patrons and customers will encourage funding for this project by METU presidency office, City of Ankara, and other industrial businesses.

4.2.3 Route Alignment

Route alignment and locating passenger stations are among the first major concerns in design process of any transportation system. The proposed guide way network should connect points of heavy demand generation with areas of consumption through the shortest technical feasible alignment. To transit students to major academic departments, to link two of metro stations to on campus transportation loops, and finally the capability of future expansion should be considered carefully. Alignment should avoid steeper slopes, intersecting crossroads, and obstructing the vehicular and pedestrian traffic as far as possible. However, monorail trains can tolerate steeper slopes comparing normal light rail vehicles and besides, monorail guide ways can be elevated so they make fewer problems interrupting other vehicles traffic. Areas of predominant demand generation and consumption should be identified to generate streams of traffic and possible routes. As it was mentioned before, in this study demand areas are based on the 2003 study conducted by METU presidency which has been divided the whole campus into nine population zones (Gökbulut, 2004).

There are different hypothetical network routing systems but real-world route networks fall into one of the following major categories (Grava, 2004):

- Single line with one vehicle shuttling back and forth between terminals
- Single line with two vehicles operating simultaneously with a double track in the middle to allow bypassing of the cars
- Single one-direction loop with a series of stations. The loop should be relatively small, because otherwise movement between two nearby stations may require a long trip if the destination point is in the reverse direction.
- Double loop with two-directional movement and any number of stations. This system operates like regular fixed guide way service.
- A combination of any of these arrangements is possible, as would be a grid network for a larger system.
-

The first three classes are the simplest possible systems as they are found in various airports, shopping centers, recreation areas, between parking lots and destination points, and on campuses (Grava, 2004).

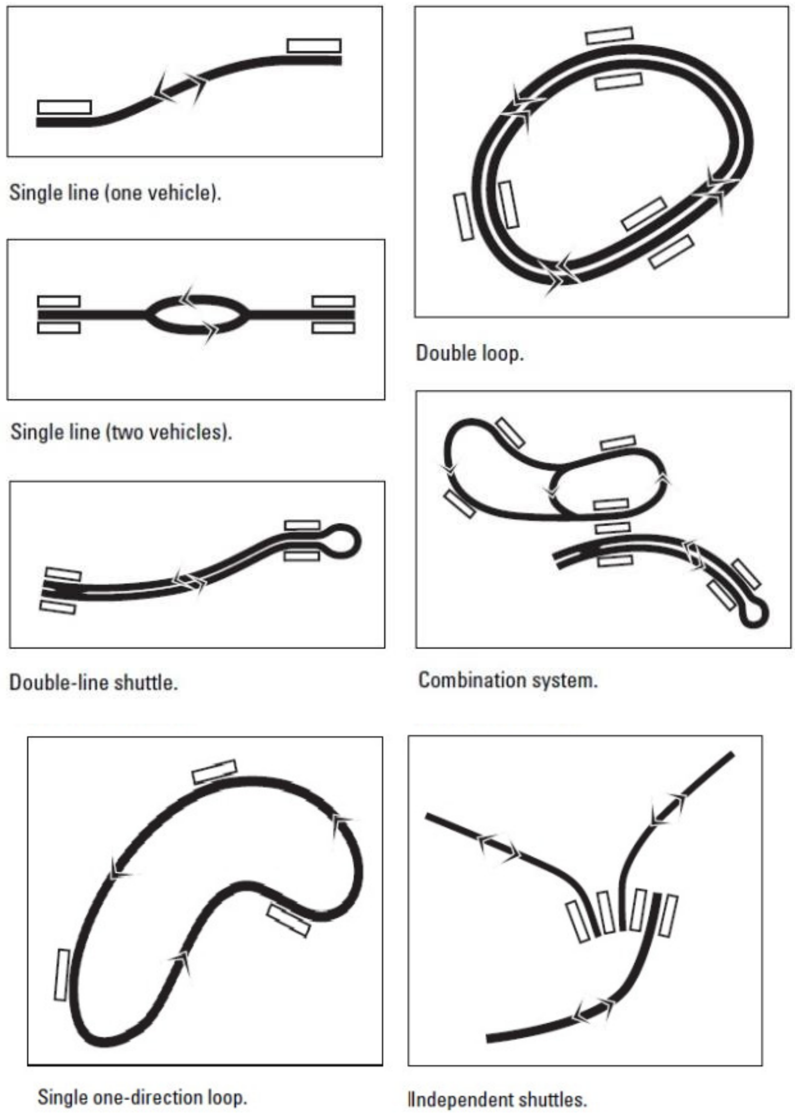


Figure 4.4: Various monorail network routing systems (Grava, 2004)

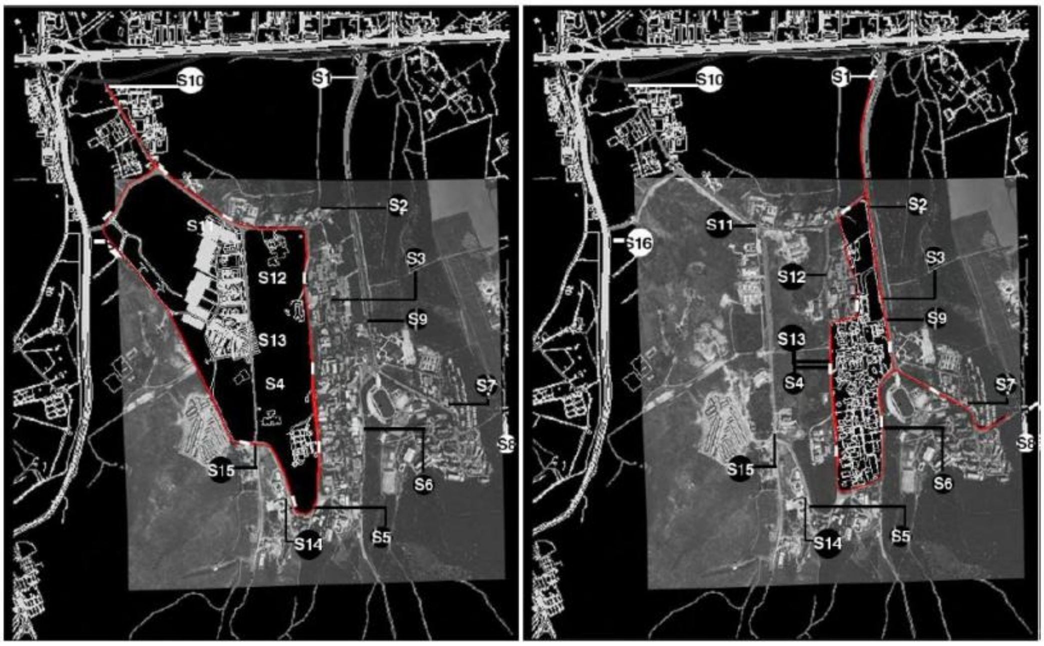


Figure 4.5: Proposed METU Monorail Guideway Path (Gökbulut, 2004)

After researching the different features of real network routes in urban and campus areas, and previously proposed networks for METU monorail systems, finally the proposed network by Gökbulut – 2004, is chosen because as she was said it is effective in terms of volume and capacity and be flexible for possible future growth.

This network (Figure 4.5) is a combination of two adjacent loops and three single lines connected to them. The first loop serves to the major academic and the most populated regions of campus – *The faculties, Library, Presidency Office, Cafeteria, Congress Centre, and Eastern Dormitories* – and the second loop serves Western part of the campus including*: Residential Units, West Dormitories, School of Foreign Language, Faculty of Education, High School, Elementary School, Teknokent region,* and the planned area for future expansion of campus. Each of the three branches was also designed to connect one of A1, A2, and A4 entrances to campus loops.

4.2.4 Technical Planning

The technical specifics of such a monorail will entail 15-second stops at various locations across the planned routes through the heart of campus and nearby communities. Monorail system will be installed around the campus and through the neighboring public transit terminals to provide commuters with an efficient and consistent mode of transportation. The monorail will have several different routes for the academic and educational faculties, sport centers, parking lots, shopping centre, residential areas, and nearby metro stations; and thus will cumulatively span a 9.5 km route. Furthermore, there are several other attractive reasons why METU campus should embrace this specific form of transportation. Firstly, the monorail is elevated above the ground, which will significantly reduce and bypass congestion during peak traffic hours. In addition, powerful electric engines installed on rubber wheels will propel the train, will reduce sound and air pollution and provide an energy efficient and environment friendly form of transit system. Furthermore, equipped with the latest vehicle online monitoring technology and advanced control systems, it will be unique experience of a safe, quiet and pleasing riding, which also hinders the prospect of derailment, high maintenance cost, and excessive frictional noise.

There will also be a special attraction, which will provide an extraordinary experience of visiting the whole campus and for its surrounding natural environment by modern monorails, for prospective students as well as tourists. Additionally, the monorail will have a fleet of five to eight individual cars: each car will run at 70 km/h, contain 50 to 60 seats and several bicycles, and have dimensions of 2.5 m wide by 6 to 8 m long. It will be fully air-conditioned or heated with handicap accessibility, and the passengers will enjoy a serene musical environment.

4.2.5 Facility Sustainability Features

A critical component of the modern transportation facilities would be their qualifications to reduce the operation region's greenhouse gas emissions and to reduce dependence on oil. Moreover, the facility technical design should tackle energy and environmental issues and challenges in a collaborative manner with sustainability and energy efficiency goals in the final operation stage. In this case design and subsequent energy performance during service time of the system provide a nexus between long term outcomes and immediate returns, demonstrating that the benefits of designing a transportation system with careful attention to life cycle costs provide immediate and ongoing benefits. Benefits that will be achieved in METU monorail system include:

4.2.5.1 Environment Friendly Mobility

Concerning CO_2 emission in passenger transport the rail transport (including light, heavy rail and monorails) is four times more efficient than the car and three times more than the plane on average (Figure 4.5); also because most of the modern light rail and monorail systems have electrical engines, the required energy is supplied by a stationary power supply system fed by the public power grid or a distant small size power plant. This means, the mentioned systems does not produce any local exhaust emissions.

In addition while these transit vehicles have electrical braking systems (based on the synchronous machine respectively the eddy current brake and a contactless levitation and propulsion system), they do not produce any kind of respirable dusts, normally produced by automobile brakes either.

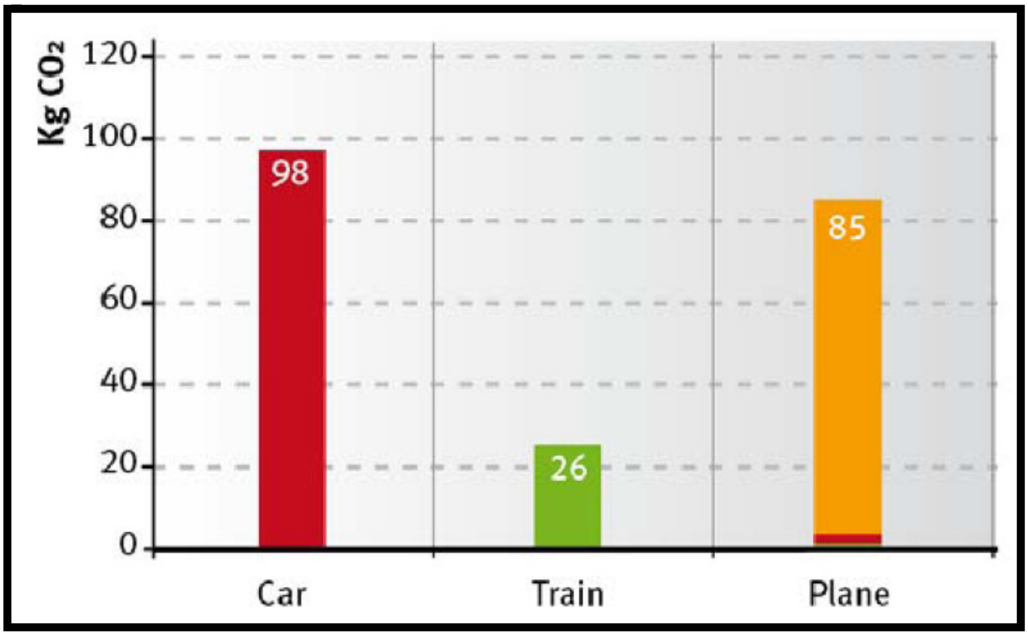


Figure 4.6: Passenger Transport CO_2 Comparison (Hellinger, 2009)

4.2.5.2 Reduced Noise Pollution

The proposed monorail involves 7 to 9 kms of elevated guideway. Even though much of this would run along current road rights of way, some would pass educational, commercial, and some residential areas. There will likely be opposition to this design approach because of probable sound pollutions. Actually, noise emissions of transport systems are unavoidable but as already explained regarding the aerodynamic resistance, monorail is designed with smooth surfaces. Compared with other light rail trains, monorail uses rubber tires monorail systems therefore it produces lower noise and monorail systems are satisfying the toughest European sound emission standards (Hellinger, 2009).

4.2.5.3 Efficient Land Use

Transport infrastructure has negative influence by the actual space requirement, as well as fragmentation and degradation of the natural or urban landscape. A comparison of capacities of urban transport modes show that rail has the highest capacity (Figure 4.7).

Besides, due to the maglev technology, monorail allows a high grade ability of up to 10%. This allows a flexible alignment with a lower number of tunnels and bridges (Figure 4.8). The monorail system can be aligned at-grade or elevated. Especially the elevated alignment has safety and environmental advantages: the safety advantages are no crossing traffic and no possibility for animals to climb the guideway; the evironmental advantage is the track is no barrier for water or animals.

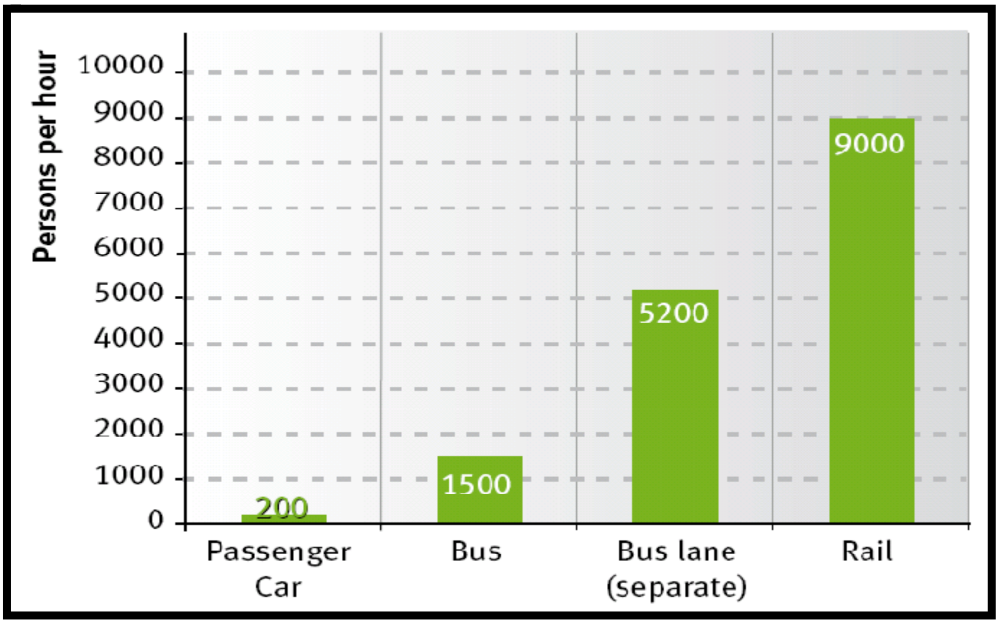


Figure 4.7: Comparison of maximum capacity of urban transportation modes per meter of infrastructures (Hellinger, 2009).

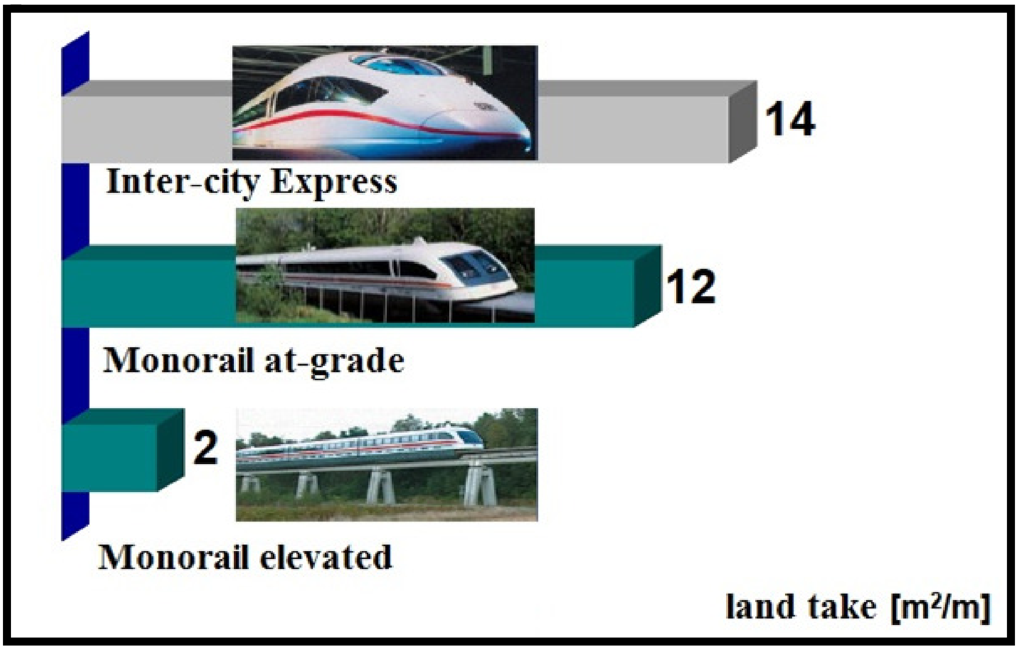


Figure 4.8: Land take of the guide way in m² per m track length (Hellinger,2009)

4.2.5.4 Higher Safety Features

An additional feature of the proposed system is increased safety. Cars, motorcycles, and trucks differ markedly in size, weight, maneuverability, and crash-worthiness. But traffic accidents caused by collisions almost always lead to damage, injury, and death. Every year, the traffic accidents kill more people than malaria : 1.2 million dead plus 50 million injured and traffic accidents will be the third biggest burden on global health by 2020, predicts the World Health Organization, with an 80 percent increase in casualties in low and middle-income countries (knowledge.allianz.com). On the other hand, according to an international research conducted in South Africa, in average cars caused damage costs of 33 Euro per 1000 passenger kilometers while this amount for rail transportation is only 3 Euro (Venter et al, 2001). In other words, rail transit is safer than car and causes much less incidents. According to on campus data, a total number of 459 traffic accidents occurred in the limits of METU campus during the period of 2003 and 2008. 432 of these accidents only lead to physical damages while other 23 accidents also caused some human injuries. In average 75.6 traffic accidents take place on METU campus annually where 78.8% of these accidents are multi-sided and 5% leaded to human injuries (Keskin et al, 2010).

4.2.5.5 Social and Academic Durability

Transport infrastructure development or change can have a range of social impacts which can occur at both the local and regional levels (AECOM, 2010). Social durability is where the character and quality of development supports and nurtures positive human interaction and healthy lifestyles, where a sense of community and neighborhood is promoted. Constructing monorail infrastructure in METU campus, also, can provide significant social on campus benefits including:

- ✓ Improved transit safety, accessibility and travel time savings;
- ✓ Coordinated transportation system that will link not only motorized but public transportation modes such as Ankara metro system with campus transit system allowing for easy connections and long term satisfaction of students, visitors, and local residents;
- ✓ Reducing movement barriers and linked pedestrian, cyclist, and disabled paths through residential and academic zones connecting with the fast growing, west side of campus;
- ✓ Assist university master planned strategies on prioritizing and developing academic and research facility construction within the west side of the campus; thereby, supporting its growing science and technology-based educational institution;
- ✓ Ability to act as the catalyst to development of the Teknokent Business District and bringing new life and services to campus residents and visitors;

4.3 Economic Effects of Proposed Monorail System

Assessment of the economic effects associated with the proposed monorail system has been divided into estimated cost values regarding construction period of the system and estimated benefit values associated with system services and consequent regional impact.

4.3.1 Estimated Cost Values

Cost values for APM systems like the other transportation systems are classified in two major categories:

- ✓ Capital and Construction Costs;
- ✓ Operating and Maintenance Costs;

4.3.1.1 Capital Costs

Monorail systems are not cheap. They cost much more than bus systems. However they usually cost less than light rail systems, considerably less than heavy rail commuter railroads, and much less than underground light rail or subway systems. Even though bus systems normally cost much less, in the case of true bus rapid transit where specially-designed buses run on grade separated bus-only roadways, the costs may exceed that of a monorail line. The figures in Table 4.1 are taken from an analysis by Shen et al, 2005.

Table 4.1: Costs of Various Line Haul Systems

Cost per route kilometers ($million 2005)			
System Type	**Low**	**Average**	**High**
Rapid Rail Transit Systems	$69.1	$126.2	$183.7
Light Rail Transit Systems	$15.9	$55.5	$122
High Capacity Urban APMs	$51.7	$71.2	$90.9
High Capacity Airport APMs	$30.5	$81.9	$148.1

Generally, there are many variables which influence the price of building a monorail system (and most forms of rail transit). Included Factors are as follow:

- ***Total length of the system:*** In many cases, costs can be reduced the longer a system is.
- ***Topography:*** Is the terrain flat or hilly, are there many roads or rivers to cross?
- ***Location:*** What is the access for construction equipment? Will there be heavy traffic or other impediments to construction?
- ***Utilities:*** Relocation of water mains, power lines, telephone lines, etc. can have a significant effect on cost increases.
- ***Land:*** What amount of land needs to be purchased or easements need to be acquired?
- ***Passenger requirements:*** What size and number of vehicles are required? How much time will they wait at stations?
- ***Speed:*** What are the speed requirements of the system? Are there long enough distances between stations so that a higher speed is desired?

- ***Number of Stations:*** Each additional station adds to the cost.
- ***Special Structures:*** Tunnels, bridges, overpass reconstruction or urban structures may be a cost factor?
- ***Geotechnical conditions:*** What are the subsurface conditions? They can have a major impact on foundation costs.
- ***Environmental Mitigation:*** Will restoration, wildlife protection or sound walls be required?

Table 4.2 and Table 4.3 show the cost figures of various APM type monorail systems built by the world's famous manufacturers in South East Asia, Middle East shows, North America, and Europe.

According to these data, by the recent progresses in modern electronics, and communication technologies and enhancement of automated guidance and Satellite Real-time Locating Systems, driverless monorail projects are now cheaper and more cost effective. The average figures from the present data [in Europe market] are $5.2million/km for the airport applications and $5.7 million/km for the non-airport, but $9.8million/km for the underground (Kerr et al, 2005).

Table 4.2: Cost figures of monorail systems (Asia, Middle East)

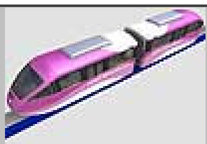
	System type	Cost/Year ($ million)	Info Source	System Status
	Hitachi	$15 / km 1964	Tokyo-Haneda Monorail	Operating
	Hitachi	$62 /km 1985	Kitakyushu Monorail	Operating
	Hitachi	$27 /km 2003	Okinawa Monorail	Operating
	Kuala Lumpur MTrans	$36 /km 2003	Kuala Lumpur Monorail	Operating
	Hitachi	$73.4 /km 2006	Palm Jumeirah , Dubai	Operating
	Metrail	$20 /km 2008	Dubai	Contracted
	Rowin/ Urbanaut	$10.3 /km 2008	Rowin, Korea	Constructio n (2008)
	Scomi	$27.25 /km 2008	Mumbai, India	Constructio n (2008)

Table 4.3: Cost figures of monorail systems (North America, Europe)

	System Type	Construction Year	Application	Length (km)	Capital Cost $million/km (2005)	Capital Cost $million/km (2010)	Guide-way Cost $million/km (2005)	System Status
	Lille VAL	1983-89	Urban At grade	25.3	85.9	99.7	26.2	Operating
	Vancouver Sky Train	1986-94	Urban Elevated	28.8	51.7	60.0	15.8	Operating
	London DLR	1987-93	Urban Elevated	27.0	56.0	65.0	17.1	Operating
	Miami Metromover	1986-94	Elevated	7.1	90.9	105.4	27.7	Operating
	Paris APM	1996	Airport	4.3	30.4	35.2	9.3	Operating

Table 4.3 (continued)

	Denver APM	1995	Airport Tunnel	2.9	67.4	78.2	20.6	Operating
	Newark APM	1995	Airport Elevated	3.1	148.1	171.8	45.2	Operating
	Seattle Monorail	2004	Urban Elevated	22.4	55.6	64.5	17.0	Operating
	Las Vegas Monorail	2004	Urban Elevated	5.0	68.1	79.0	20.8	Operating
	Average				**72.7**	**84.3**	**22.2**	

In this special case for METU campus, since this monorail system will cover the existing two main loops around several localities on campus area, the installation of Monorail System will not cause any relocations and reconstructions of facilities in the area. However dependant on the complete operation design of system it is estimated to construct 10 to 15 passenger stations all around the campus and also due to ample concrete supply in Ankara, and reasonably lower prices in Turkey, the construction cost of this monorail guide-way is estimated to be fairly low in comparison to other monorails. Additionally, capacity of the proposed system cannot be compared by above mentioned urban monorail systems which provide longer and heavier services at densely populated urban communities.

Furthermore as it was discussed in detail in the previous chapter, to ensure the safety and the effectiveness of the monorail at all time, a fair amount of budget should be allocated to mechanical and electrical specification of the project. This would include the hiring of technicians and engineers from certain professional consortiums to design and implement the mechanical and electrical components. The table below shows the estimated costs for various specifications of the monorail system.

As the table shows, costs include the capital costs for the infrastructure improvements, elevated stations constructions, electrification and communication equipments and the train prices. A two-year construction/implementation period has been assumed for those options involving capital works. The capital cost is divided equally between the two years preceding project opening.

Table 4.4: Justified present cost values of proposed monorail project[10]

Cost Categories	Estimated Present Value
Infrastructure: civil works, guide way structure and materials, construction and installation, rails	$24 million
Rolling Stock (Single Vehicles or Car Train) and stations	$7 million
Mechanical and Electrical: switches, electrification	$7 million
Land Acquisition: public and private	---
Engineering Design	$3 million
Project and Construction Management	$1 million
Facilities: line Stations, parking structures, maintenance facilities, traffic control centers	$2.2 million
Subsystems: safety, communications, traffic control, etc	$1.3 million
Special Structures: tunnels, bridges, overpass reconstruction, urban structures	$1 million
Total Costs	**$46.5 million**

[10] see Appendix C and Appendix D for typical cost breakdown figures for APM systems and Appendix B for relating interviewed persons

4.3.1.2 Operating Costs

Supporters of rail way technologies assert that *operating cost savings* are a major advantage and a major reason why these mode is such an attractive choice compared to various bus service alternatives. For moderate traffic as well as heavier passenger volumes it's believed that rail technologies tend to be much cheaper to operate than comparable bus service.

The major reasons why rail based technologies are cheaper to other modes are including (LR Progress, 2001):

- ✓ Train vehicles generally provide more passenger space, and in special cases the trains' length could be increased easily by adding more cars.
- ✓ The largest recurring cost in any enterprise are the salaries and benefits of the employees and the significant cost advantage for driverless APM's is that they do not need operator/driver and less other kind of employees, which wages make up about 70%-80% of ongoing operating costs.
- ✓ Especially in rush hour (or other peak periods, like special events) they can handle heavy passenger loads and accommodate and move much more rapidly and efficiently. (even when the trains operate on public arterials, there's significantly less conflict with other traffic than there would be if expensive fleets of buses were used instead)
- ✓ Elevated APM's never mix with traffic, which makes them safer and more reliable. This also means the system can be automated, which will allow it to operate with little or no ongoing subsidy

Table 4.5, show passenger-mile costs for some light rail systems and the counterpart bus system differences. Although these systems are all need drivers to move, costs are generally lower than bus systems.

Table 4.5: Operating cost comparison Bus, LRT (per passenger-mile)[11]

	Bus ($)	LRT ($)	Difference (%)
San Diego	$0.38	$0.17	-55%
St Louis	$0.66	$0.20	-70%
Los Angeles	$0.48	$0.30	-38%
Portland	$0.51	$0.35	-31%
Sacramento	$0.53	$0.38	-28%
Dallas	$0.74	$0.47	-36%
Baltimore	$0.53	$0.48	-9%
Denver	$0.53	$0.61	15%
San Jose	$0.72	$0.79	10%
Buffalo	$0.78	$0.86	10%

For APMs cases applying driverless systems along with the most advanced engineering technologies, recurrent costs are much lower to LRT technologies. Comparing other modes of transportation, three major advantage factors which decrease energy demand for monorails and APMs are:

- ✓ Aerodynamic Drag
- ✓ Mechanical Fiction
- ✓ Acceleration & Deceleration

[11] Totals based on vehicle/train miles for equal number of passengers

Table 4.6 shows relative operating indexes of mentioned factors for LRT, heavy duty monorail, and small monorails.

Table 4.6: Energy demand factor relative comparison (Urbanaut, 2009)

	Light Rail	Straddle Monorail (Heavy)	Straddle Monorail (Light)
Aerodynamic Drag	1.3	0.8	0.60
Mechanical Fiction	1.5	0.65	0.65
Acceleration & Deceleration	1.4	0.85	0.60

In general, automated rail technologies including APMs and driverless monorails are superior in cost efficiency to other choices. Where bus systems are need relatively lower capital investment, they are so costly to operate especially in periods of longer than 10 years. Though for LRT technologies, driver operating cost is lower than bus, still the automated driving problem seems unsolved. So among the current urban transportation technologies APMs are the best choice in heavy and moderate passenger load cases (Table 4.7).

Table 4.7: Comparison recurrent costs summary for Bus, LRT, Monorail

Operating Cost Elements	HOV/Bus	At-Grade LRT	Elevated Monorail
Cost per Revenue Vehicle Km	\$2.85 (Diesel) \$2.70 (CNG)	\$6.95	\$1.55
Cost per Revenue Vehicle Hour	\$56.00 (Diesel) \$55.30 (CNG)	\$150.00	\$38.00
Cost per Place Km	\$0.04 (Diesel/CNG)	\$0.07	\$0.08
Total Average Annual Cost	\$8,830,000(Diesel) \$8,350,000(CNG)	\$12,621,150	\$4,000,000

To this end and according to operating context and applied technologies, the annual infrastructure maintenance costs and the justified estimation annual costs of operating the service options are equal to \$2 million[12] (3 million TLs) each year which are applicable for the 30 year operation period of the system.

12 See Appendix B for list of relating interviewed persons

4.3.2 Estimated Benefit Values

Generally benefits of improved monorail transport services on METU campus include:

- ✓ Benefits to passengers transferring from existing bus/minibus services;
- ✓ Benefits to new users (transferring from other modes, or those making trips not made previously);
- ✓ Non-user benefits, such as reductions in road crash costs and environmental externalities; and
- ✓ Residual values of rail assets

4.3.2.1 Benefits to Passengers Transferring From Existing Services

This includes travel time savings, avoidance of transfers, and an amount that recognizes people's preference to travel by metro-monorail rather than bus or minibus services. This system will decrease dramatically time and money consumption for 30% of university population who use current bus and minibus public transport to travel between home and school. By opening the two Metro stations, it is estimated that each daily round trip will be shorten by 30 to 40 percent. Including waiting time and travel time this will lead to at least 45 minutes time saving each day or by a standard value of time of $5/hour it will $3.15 million saving each year. In this case most of the students and staff may find the new metro-monorail services more frequent and thus more convenient for when they want to travel than any of the existing service times. This potential benefit has not been valued.

4.3.2.2 Benefits to New Users

Benefits to new public transport users include the same set of benefits as those received by passengers diverting from existing services, however they are calculated as half the average benefit gained by existing users based on the “rule of a half” (Kenneth A., 2007). The theory behind this is that some of the new rail service users at the margin will be indifferent about using the service and are assumed to obtain a negligible benefit. At the other margin there are users who were indifferent about using the existing public service before the re-introduction of the monorail but who will value the benefits of the monorail compared with existing at the full value experienced by existing users. Other new users are assumed to be distributed on a straight line between these two extremes and so the average benefit for new users is half the benefit for existing users (AECOM, 2010). Users who transfer from car will benefit from savings in their vehicle operating costs.

An additional benefit in the case of new users arises from the “producer surplus”. This is the benefit gained by the train service provider as a result of the new users. The producer surplus earned by METU University as service provider (revenues minus costs) is an economic benefit in the same way that consumer surplus is for the passengers. Revenues are mainly consisting of travel service sales. There are several strategies of service sales. The most widely used and also the oldest method is selling ticket for each trip, but according to various studies in USA and Canada it is not an efficient strategy in institutional organizations like universities and huge organizations. Because in these kind of organizations the most important purpose of offering such services are encouraging students and employees to use public transport services instead of personal cars and paying for

each trip is a big obstacle for this purpose because for most of the users using personal automobile the differences in prices are negligible.
Selling the mandatory university transportation pass (U-PASS) to students, faculty, and staff each semester with an unlimited right of access to monorail and metro services during the semester. This will cause the people to use the services more frequent and actually besides the undoubted economic benefits for students, it is a kind of incentive for automobile owner to use public transportation more frequent and guarantees the annual revenue resources of the monorail system for University administration. The proposed price for U-PASS cards for this system is 50 TL per person for each semester. This means net revenue of 3 million TL for each academic year for university only from service price.

4.3.2.3 Non-User External Benefits

The other benefits that have been valued and included in the evaluation comprise campus road user benefits such as reduced road traffic congestion and parking demand, road crash/incident cost savings and environmental benefits, including changes in greenhouse gas emissions and noise pollution indexes.
As it was discussed in previous sections new monorail services will result in palpable reduction in motor vehicle congestion and parking demand in campus area. Moreover, rail transit is ten times safer than car, but assessing in cash, these benefits are relatively small comparing the capital cost of monorail system. In this case it has been conservatively assumed that at least 15% of new users would otherwise have been car drivers because of factors such as students needing their vehicle at the end of the day or after

visiting school. The remaining 85% of new users are thus assumed to be entirely new trips which were previously not made.

Furthermore, this trend is also reflected in the environmental assessment. By ceasing the current costly campus ring services and reducing the city wide staff transit service which are based on a fleet of 56 Mercedes Benz O302 buses with average age of 35 years, will be a major saving source for the campus expenses and also will have a considerable effect in reduction of diesel fuel consumption and consequently the greenhouse gases emission. According to data received from METU Directorate of Vehicle Management by stopping the ring services and decreasing the city staff services by 20 percent, at least 156,000 liters of diesel fuel will be saved each year and CO_2 emission on campus area will be decreased by 421.2 tons per year (about $43/tC with 4% increase annually) and this excludes the reduction of fuel consumption and CO_2 emission caused by lower usage of personal automobiles in campus.

Table 4.8: Approximate Annual Costs of METU Bus services (2010 prices)[13]

Cost Categories	Campus Ring Service Costs (TL)	Citywide Staff Service Costs (TL)
Fuel Cost	320,000	1,280,000
Maintenance and operation Cost	600,000	2,400,000
Repair and Over-haul Cost	200,000	800,000

[13] Data provided by Mr. Cemal YAVUZ, Head of METU Directorate of Vehicle Management, last interview on 25.12.2010

4.3.2.4 Residual values

New rail infrastructure assets are assumed to have a design life of 50 years. Since the appraisal period is only 30 years, a residual value of the asset has been added as a benefit in the final year of the appraisal. Straight line depreciation has been assumed, such that the residual value is 20/50 years (or 40%) of the construction cost.

4.3.3 Potential Intangible Benefits Not Considered Directly

4.3.3.1 Social Equity

The full social equity issues are not directly captured within this analysis. Community feedback emphasized the appeal of train services compared to buses/minibus and this has been recognized in the economic evaluation, notwithstanding that high quality bus/minibus services may overcome many of the issues associated with current bus/minibus services (AECOM, 2010). In addition, the supply of public transport is itself a contributor to social equity because of its ability to enable travel that could not previously be undertaken or shortens the current travel time. When travel times diminish, people and specially students may increase the quality of their housing accommodation and living environment, by increasing their commuting journey length, without changing their commuting journey time (Elhorst, 2008).

4.3.3.2 Regional Business Growth and Academic Impacts

The introduction of monorail services could stimulate a higher business growth rate than would be expected otherwise, particularly in Teknoket region. Ultimately, the success of the monorail system in generating new jobs will depend on the new business opportunities developed in Teknokent business district and other campus research centers. Projections based on the reviewed studies in the same area in various countries in the world suggest that a fully operated monorail system merging Ankara metro services will add a permanent net increase of 200 professional jobs including at least 10 percent increase in Teknokent region employees and new research and shopping centre planned to construct in the western part of campus also 25 jobs directly related to maintenance and operation of monorail system. Having such a large influx of part-time and full-time jobs across the campus region will be a tremendous boost for university students, who work for companies in Teknokent region. While these jobs will not be high paying, they will help lead to high paying careers as these students graduate and enter full time employment.

4.3.3.3 Landscape Related Benefits and Tourism Impacts

Monorails with stylish and innovative designs are usually perceived as signs of the future, high tech transportation. Along with numerous direct and indirect economic advantages, constructing such a facility according to the latest modern industrial design techniques will enhance the landscape architectural and visual perspective of METU campus as the pioneer technical university in Turkey and will certainly increase the attraction of private sector companies to make further investments in the region. Impacts on tourism, as a direct result of the introduction of monorail on METU campus, are difficult to estimate. However, it is possible that introduction of the rail service, combined with targeted marketing including tourism packages such as scientific tours for high school students and etc, will significantly encourage tourism development in the area.

Table 4.9: Estimated benefits of monorail project (11% discount rate)

Benefit Stream	Estimated Present Values[1]
User Benefits	
Travel time saving – existing passengers (diverted from existing public services)	$19.98 million
Travel time (Car vehicle operating cost) saving – new trips (diverted from personal cars)	$4.04 million
Total user Benefits	**$24.02 million**
Non-user Benefits	
Crash/incident cost savings	$0.0083
Environmental externality benefits (Greenhouse gases emission)	$0.0895
Bus Services Fuel cost savings	$2.43 million
Bus Services Operation and maintenance cost saving	$6.07 million
Total Non-user Benefits	**$ 8.5978 million**
Fare revenue from Transit Pass Sales	**$12.47 million**
Residual Value of Monorail Assets (End of 2043)	**$0.597 million**
Total Benefits	**$58.6248 million**
Intangible Benefits	
Social Equity	
Regional Business and Academic Impacts	
Landscape and Tourism Impacts	

[1] **Values discounted at 11% to 2010 over 30 years from (2014 to 2043)**

Table 4.10: Estimated benefit Value of monorail project (7% discount rate)

Benefit Stream	Estimated Present Values[1]
User Benefits	
Travel time saving – existing passengers (diverted from existing public services)	$31.9 million
Travel time (Car vehicle operating cost) saving – new trips (diverted from personal cars)	$6.45 million
Total user Benefits	**$38.35 million**
Non-user Benefits	
Crash/incident cost savings	$0.0106
Environmental externality benefits (Greenhouse gases emission)	$0.123
Bus Services Fuel cost savings	$3.87 million
Bus Services Operation and maintenance cost saving	$9.67 million
Total Non-user Benefits	**$ 13.6736 million**
Fare revenue from Transit Pass Sales	**$40.43 million**
Residual Value of Monorail Assets (End of 2043)	**$2.00 million**
Total Benefits	**$94.4536 million**
Intangible Benefits	
Social Equity	
Regional Business and Academic Impacts	
Landscape Benefits and Tourism Impacts	

[1] **Values discounted at 7% to 2010 over 30 years from (2014 to 2043)**

4.4 Cost Benefit Analysis

Cost benefit analysis is a term that refers both to:

- Helping to appraise, or assess, the case for a project, program or policy proposal;
- An approach to making economic decisions of any kind;

Under both definitions the process involves, whether explicitly or implicitly, weighing the total expected costs against the total expected benefits of one or more actions in order to choose the best or most profitable option (Wikipedia E., 2010)

4.4.1 Underlying Economic Concepts and backgrounds

4.4.1.1 The Concept of Consumer Surplus [44]

Persons and households demand goods and services to increase their happiness. For the purposes of this discussion, consider the case of tram journeys. The price of the tram journey (or other transport trips) is described by transport economists as the 'Generalized Cost of Travel'. The curve representing the demand for a half-hour tram trip will be a downward sloping curve of generalized cost against the number of trips demanded, as shown in the graph below. A few people will be prepared to pay a great deal, say $100, for a tram trip, as it gives them such happiness not to drive, or to park or pay for parking, that they would be prepared to hire a chauffeur or a limousine if a tram were not available. Others will be prepared to pay nothing, as they prefer to walk or cycle or drive their car. Most will be prepared to pay several dollars for the tram trip. The lower this generalized cost of the tram trip, the more people will want to travel by tram.

The first three classes are the simplest possible systems as they are found in various airports, shopping centers, recreation areas, between parking lots and destination points, and on campuses (Grava, 2004).

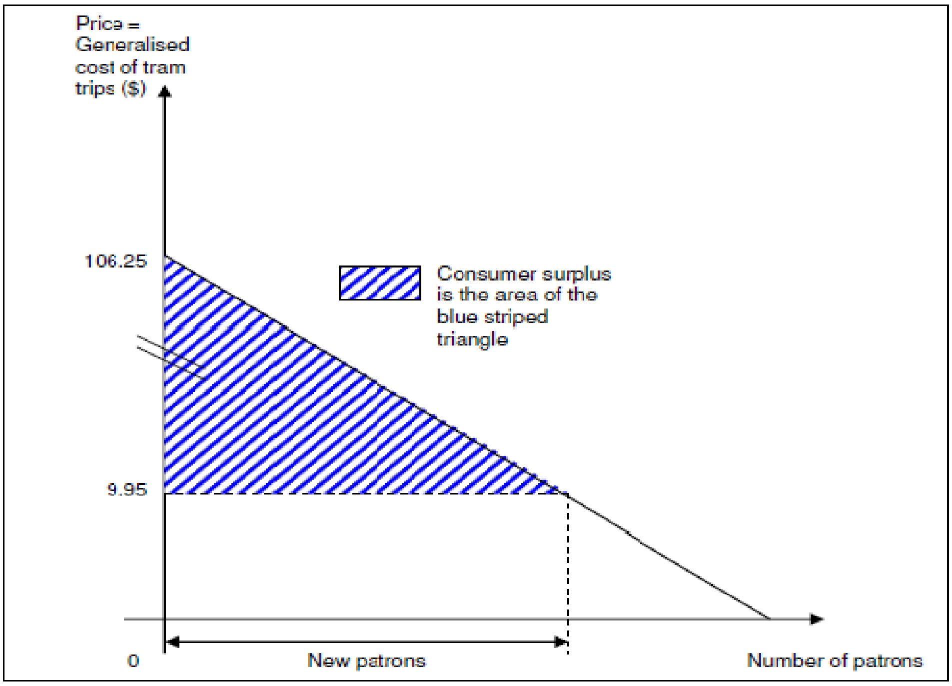


Figure 4.9: Hypothetical demand for a half-hour tram trip

The consumer surplus for new patrons attracted to a half-hour tram ride is shown by the blue striped triangle. The minimum generalised cost (the price of travel) that will be incurred by travellers is composed as follows:

Table 4.11: Hypothetical price of travel

Tram fare, 2 hour - Zone 1 (as at 1 Jan 2010)	$3.70
30 minutes of travel time at $12.50 per hour for non-business purposes, but including journey to and from work	$6.25
Total	**$9.95**

4.4.1.2 Changes in Consumer Surplus [44]

The consumer surplus will increase if the tram can travel more quickly, as patrons will save travel time and therefore benefit from a reduction in price (expressed as generalized cost). A benefit such as a saving in travel time usually requires capital expenditure, such as reprogramming the road traffic lights to give trams greater priority.

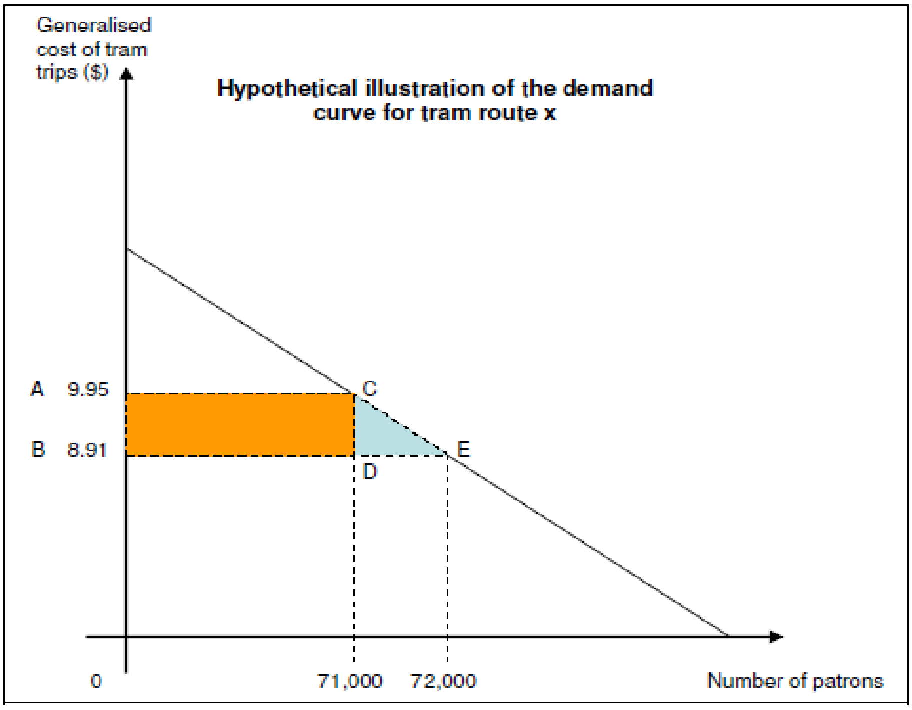


Figure 4.10: Hypothetical illustration of the demand curve for tram route

The following chart shows the increase in consumer surplus due to cutting the 30 minute trips down to 25 minutes – a saving in the generalized cost of $1.04 per trip, being a twelfth (five minutes) of the Value of Travel Time (VoTT) for a non-working trip of about $12.50/hour. The existing 71,000 patrons each working day will gain a total benefit of $73,840, the area of the orange rectangle ABDC. An additional thousand new patrons induced or attracted by the quicker service value their benefit at $520, the area of the light blue triangle CDE.

4.4.2 The Key Steps of Cost Benefit Analysis

Generally, eight major steps are used in a CBA process (Victoria SDT, 2010):

1. Identify the problems to be addressed and objectives to be achieved. Policy objectives should be established in terms of specific and measurable outcomes;
2. Develop options, including a base case or no policy change scenario. Consider any engineering possibilities in the project options;
3. Determine the standing or basis of the CBA. Whose benefits and costs should be counted? Is the analysis to be conducted on a global, national, regional or local scale?
4. Catalogue the physical impacts (inputs, outputs and externalities) associated with Steps 1 and 2 and the appropriate units of measurement.
5. Predict the incremental physical impacts quantitatively over the life of the project.
6. Monetize (attach monetary values to) all impacts. This is commonly done using present day domestic prices.
7. Discount the future benefits and costs obtained in Step 5 to present day values.
8. Two major measures are commonly used to assess overall value:
    - NPV = Present value of benefits – Present value of costs
    - BCR measures the ratio of the present value of benefits to the present value of costs of a project

The measures of NPV (net present value) and BCR (benefit-cost ratio) have particular applications in assessing the overall value of a project, as discussed below.

NPV*[14]*:

$$NPV = \sum_{t=0}^{n} \frac{\left(\mathrm{B} - (\mathrm{C} + \mathrm{O})\right)_{\mathrm{t}}}{(1 + \mathrm{r})^{\mathrm{t}}}$$

- If the estimated NPV > 0, then the estimated total benefit exceeds total cost, and provides a net social benefit given a selected discount rate, r.
- The project or option with the highest NPV would be the most socially beneficial.
- The NPV measure does not have a project (capital expenditure) size bias, unlike the IRR and BCR.

[14] B = benefits, C = capital costs, O = operating or recurrent costs, r = the selected discount rate

BCR*[15]*:

$$BCR = \frac{\sum_{t=0}^{n} \frac{(\mathrm{B} - \mathrm{O})_\mathrm{t}}{(1 + \mathrm{r})^\mathrm{t}}}{\sum_{t=0}^{n} \frac{\mathrm{C}_\mathrm{t}}{(1 + \mathrm{r})^\mathrm{t}}}$$

Or, alternatively:

$$BCR = \frac{\sum_{t=0}^{n} \frac{\mathrm{B}_\mathrm{t}}{(1 + \mathrm{r})^\mathrm{t}}}{\sum_{t=0}^{n} \frac{(\mathrm{C} + \mathrm{O})_\mathrm{t}}{(1 + \mathrm{r})^\mathrm{t}}}$$

- The top BCR formula only contains the present value of capital expenditure in the denominator. This is appropriate if the purpose is to estimate the return on capital expenditure.
- If the BCR > 1 then the NPV > 0 and vice versa.
- The BCR is useful for decision making if capital is constrained which is usually the case. The proponent should proceed with projects in order of BCR (highest to lowest) to maximize the gains (NPV) from the use of scarce capital.

4.4.3 METU Monorail Cost Benefit Analysis

Cost Benefit Analysis (CBA) is an approach and set of procedures for defining and comparing the benefits and costs. For transport projects, Cost Benefit Analysis is premised on the concept of maximizing social or

[15] [15] B = benefits, C = capital costs, O = operating or recurrent costs, r = the selected discount rate

community welfare, and the full range of benefits and costs considered are sometimes referred to as 'social benefits' and 'social costs'.

This section covers the cost benefit and economic analysis of the METU monorail service. The evaluation was carried out using "*standard cost benefit analysis*" methodology which assumes that the relevant benefits and costs can be described as continuous functions (Small, 2007). The evaluation has been undertaken using a 30-year evaluation period from project opening and depending on future situations, two different discount rates of 11% and 7%. The estimation of costs and benefits of this system is covered in previous sections of this article (Table 4.4, Table 4.9 and Table 4.10).

For 11% annual discount rate (1.0264% quarter base, Table 4.9), the benefits include gained value by reductions in travel time ($19.98 million) , vehicle operating costs and crashes ($4.04 million), and also environmental benefits such as lower emissions of noxious and greenhouse gases from vehicles and reduced noise emissions($0.0895 million). As it was mentioned some benefits (such as improved transport choice or access to public transport services) are difficult to quantify and were classified as intangible benefits. According to these estimations constructing and operating cost of the monorail is $49.24 million (in 2010 dollars and the exchange rate of 1.5 Liras for each dollar). This includes a total capital cost of $36.34 million and a total discounted stream of operating costs of $12.9 million ($2 million per year), using the same discount rate (11%). Operating costs were discounted over a span of 30 years, from 2013 through 2042.

For conservative estimation of 11% discount rates, the table results show a ***BCR of 1.19,*** and ***NPV of $9.38 million for 30 year period.*** The main contributors to the present value of benefits are the travel time savings to existing passengers diverting from existing services, and the fare revenue from new users.

For 7 % annual discount rate (1.017% quarter base, Table 4.10), the benefits include values by reductions in travel time ($31.9 million) , vehicle operating costs and crashes ($6.45 million), and also environmental benefits such as lower emissions of noxious and greenhouse gases from vehicles and reduced noise emissions($0.123 million). As it was mentioned some benefits (such as improved transport choice or access to public transport services) are difficult to quantify and were classified as intangible benefits. According to these estimations constructing and operating the monorail is $60.07 million (in 2010 dollars and the exchange rate of 1.5 Liras for each dollar). This includes a total capital cost of $39.62 million and a total discounted stream of operating costs of $20.45 million ($2 million per year), using the same discount rate (7%). Operating costs were discounted over a span of 30 years, from 2013 through 2042.

In the case of progressive estimation of 7% discount rates, the table results show a ***BCR of 1.57,*** with the ***NPV over 30 years $37.38 million***. Same as the previous option, the main contributors to the present value of benefits are the travel time savings to existing passengers diverting from existing services, and the fare revenue from new users.

Table 4.12: Cost Benet Analysis Results

	Discount Rate = 11%	Discount Rate = 7%
Present Value of Benefits	$58.62 million	$94.45 million
Present Value of Costs	$49.24 million	$60.07 million
Net Present Value (NPV)	$9.38 million	$37.38 million
Benefit to Cost Ration (BCR)	1.19	1.57

Table 4.13: Cost Benefit Analysis for Monorail Project (11% discount rate)

	2012				2013				2014				2015			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.60	0.60	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.18	0.24	0.24	0.24	0.24
Fare Revenue From New Users	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.97**	**1.97**	**0.97**	**2.29**	**1.29**	**2.29**	**1.29**
Costs																
Capital Investment	0.00	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	**0.00**	**5.81**	**5.81**	**5.81**	**5.81**	**5.81**	**5.81**	**5.81**	**5.81**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**
Present Value of Total Benefits	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.67**	**1.33**	**0.64**	**1.47**	**0.80**	**1.39**	**0.76**
Present Value of Capital Costs	**0.00**	**4.97**	**4.84**	**4.72**	**4.59**	**4.48**	**4.36**	**4.25**	**4.14**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Present Value of N-Capital Costs	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.35**	**0.34**	**0.33**	**0.32**	**0.31**	**0.30**	**0.30**

Table 4.13 (continued)

	2016				2017				2018				2019			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	1.90	0.72	1.80	0.69	1.71	0.65	1.63	0.62	1.54	0.59	1.47	0.56	1.39	0.53	1.32	0.50
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.29	0.28	0.27	0.27	0.26	0.25	0.25	0.24	0.23	0.23	0.22	0.22	0.21	0.21	0.20	0.20

Table 4.13 (continued)

	2020				2021				2022				2023			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	1.25	0.48	1.19	0.45	1.13	0.43	1.07	0.41	1.02	0.39	0.97	0.37	0.92	0.35	0.87	0.33
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.19	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13

Table 4.13 (continued)

	2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.83	0.31	0.78	0.30	0.74	0.28	0.71	0.27	0.67	0.26	0.64	0.24	0.60	0.23	0.57	0.22
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.08

Table 4.13 (continued)

	2028				2029				2030				2031			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.54	0.21	0.52	0.20	0.49	0.19	0.47	0.18	0.44	0.17	0.42	0.16	0.40	0.15	0.38	0.14
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06

Table 4.13 (continued)

	2032				2033				2034				2035			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.36	0.14	0.34	0.13	0.32	0.12	0.31	0.12	0.29	0.11	0.28	0.11	0.26	0.10	0.25	0.09
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table 4.13 (continued)

	2036				2037				2038				2039			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.24	0.09	0.22	0.09	0.21	0.08	0.20	0.08	0.19	0.07	0.18	0.07	0.17	0.07	0.16	0.06
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02

Table 4.13 (continued)

	2040				2041				2042				2043			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.60
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	19.89
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.16	0.06	0.15	0.06	0.14	0.05	0.13	0.05	0.13	0.05	0.12	0.05	0.11	0.04	0.11	0.79
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Table 4.14: Cost Benefit Analysis for Monorail Project (7% discount rate)

	2012				2013				2014				2015			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.60	0.60	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.18	0.24	0.24	0.24	0.24
Fare Revenue From New Users	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	2.97	0.97	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.00	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	2.31	0.74	2.47	0.95	2.38	0.92
Present Value of Capital Costs	0.00	5.25	5.16	5.08	4.99	4.91	4.83	4.74	4.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.39	0.38	0.38	0.37	0.36	0.36

Table 4.14 (continued)

	2016				2017				2018				2019			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	2.31	0.89	2.23	0.86	2.16	0.83	2.08	0.80	2.02	0.78	1.95	0.75	1.88	0.72	1.82	0.70
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.35	0.35	0.34	0.33	0.33	0.32	0.32	0.31	0.31	0.30	0.30	0.29	0.29	0.28	0.28	0.27

Table 4.14 (continued)

	2020				2021				2022				2023			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	1.76	0.68	1.70	0.66	1.65	0.63	1.59	0.61	1.54	0.59	1.49	0.57	1.44	0.55	1.39	0.54
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.27	0.26	0.26	0.25	0.25	0.25	0.24	0.24	0.23	0.23	0.23	0.22	0.22	0.22	0.21	0.21

Table 4.14 (continued)

	2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	1.34	0.52	1.30	0.50	1.26	0.48	1.22	0.47	1.17	0.45	1.14	0.44	1.10	0.42	1.06	0.41
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.20	0.20	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.16	0.16	0.16

Table 4.14 (continued)

	2028				2029				2030				2031			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	1.03	0.40	0.99	0.38	0.96	0.37	0.93	0.36	0.90	0.35	0.87	0.33	0.84	0.32	0.81	0.31
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.16	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12

Table 4.14 (continued)

	2032				2033				2034				2035			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.78	0.30	0.76	0.29	0.73	0.28	0.71	0.27	0.69	0.26	0.66	0.25	0.64	0.25	0.62	0.24
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09

Table 4.14 (continued)

	2036				2037				2038				2039			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.60	0.23	0.58	0.22	0.56	0.22	0.54	0.21	0.52	0.20	0.51	0.19	0.49	0.19	0.47	0.18
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07

Table 4.14 (continued)

	2040				2041				2042				2043			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Benefits																
Travel Time Saving	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Car Operating Cost Saving	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Bus Services Fuel Cost Savings	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bus Recurrent Cost Saving	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Fare Revenue From New Users	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Residual Values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.60
Total Benefits	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	1.29	3.29	19.89
Costs																
Capital Investment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recurrent/Operation Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total Costs	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Present Value of Total Benefits	0.46	0.18	0.44	0.17	0.43	0.16	0.41	0.16	0.40	0.15	0.39	0.15	0.37	0.14	0.36	2.46
Present Value of Capital Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Present Value of N-Capital Costs	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06

4.5 Cost Effectiveness Assessment

In public projects where it is difficult to arrive at monetized measures of the benefits from a project, the standard decision criteria of a CBA (e.g. Net Present Value) can be biased since the present value of the benefits is likely to be understated relative to the present value of costs. Another used approach to economic analysis of projects is typically employed where this is the case, known as cost-effectiveness analysis (AECOM, 2010).

Cost-effectiveness analysis differs from CBA in that benefits are expressed in physical rather than monetary terms. For example, since there are numerous issues relating to putting a monetary value on a life, the benefits from health projects are usually expressed as lives saved. As a result, cost-effectiveness analysis compares alternatives in terms of their effectiveness in achieving an outcome and their cost to do so. In the case of this study, a number of unique elements of the study have meant that it has been difficult to arrive at monetary measures of the benefits from travelling by each of the alternative modes of transport. Given that the monetary value of the benefits is likely to be understated, we have also employed cost-effectiveness analysis to assess the economic impact.

In order for the approach to be valid, it is important that each alternative delivers equally effective outcomes. With 'lumpy' investments such as public transport, it is often not feasible for each alternative to deliver equal outcomes. To overcome this limitation, the effectiveness of each alternative is defined in terms of reaching a set of minimum criteria. In this case, the minimum criteria to be satisfied in order for an alternative to be considered effective are:

- To be accessible to the wider range of students, staff and faculties: current bus and minibus services are not acceptable because, they pose a barrier to use because of limited space and amenity on board;
- Conveniently scheduled: the service is needed at a reasonable hour and the lack of departure options during the day, particularly from the western part of the campus, makes the existing services unfavorable;
- Have adequate luggage and bicycle space, conveniently available: people want to bring a reasonable amount of day-to-day luggage and other reasonable items like bicycles, without needing to make special arrangements."
- Comfort and Environmental issues: the service must provide a high standard of on board comfort befitting the journey time, along with compromising the international environmental friendly standard qualification;

The proposed monorail alternative identified in this study is considered to meet the above criteria for the facility. Some the applicable indexes in cost effectiveness analysis are as follow:

- Number of vehicles in maximum service: 4
- Total number of vehicles: 5
- Initial vehicles costs: $2,250,000
- Annual operational cost: $2 million
- Annual hours of service: more than 3,000 hours
- Annual passenger-trips: about 1 million passengers
- Approximate Cost per passenger-trip: $2

4.6 Project Business Plan

The Business Plans addresses the ownership, continuing control and/or legal requirements of the Turkish government grant funded project. METU Presidency office as the director and employer of the project may sign an agreement with second parties on issues such as, management, funding, revenues and expenses. As a public transportation projects, METU monorail needs huge amount of investments and a critical component of the project plan is ownership of the facility. For this purpose three different scenarios have been developed to finance the project:

- ✓ **Scenario A:** *The project will be completely financed by METU*
- ✓ **Scenario B:** *The project will be completely financed by the project partner company(s) resources*
- ✓ **Scenario C:** *A consortium including METU and partner company(s) will grant and operate the facility in a 50/50 sharing scheme*

4.6.1 Scenario A

In this scenario, it is assumed that METU presidency office will provide the whole $46.5 million investment money for monorail system construction in the period of approximately two years through its governmental or internal resources. The consequent available decision/management policies for this scenario are listed as follow:

- **Director of the project:** *METU Presidency Office*
- **Facility Ownership:** *METU Presidency Office as the grantee of the project*

- **Facility Management/Operations:** *the facility management and operation rights are exclusively will be belonged to Middle East Technical University.*
- **Land Ownership:** *Middle East Technical University will continue to possess the construction area lands.*

4.6.1.1 Break-Even Analysis

In economics & business, specifically cost accounting, the break-even point (BEP) is the point at which cost or expenses and revenue are equal: there is no net loss or gain, and one has "broken even". A profit or a loss has not been made, although opportunity costs have been paid, and capital has received the risk-adjusted, expected return (Wikipedia E., 2011). In this part calculations will be made to find the U-PASS selling price as the only available source of money to recover the estimated $2.0 million operating cost and to return of the total invested money in the period of 30 years.

In this scenario, since METU will provide the whole $46.5 million for system construction, the approximate $1.34 million annual saving caused by stopping the ring services and decreasing staff services by 20%, is counted as a source of return.

Minimum price for Monorail pass system with 11% discount rates to recover the total invested money in 30 years and also to provide the annual operating cost is $100.2 for each of the current 30,000 campus habitants, including: students, staff, faculties, etc in each two semester academic years (Figure 4.11). Also, in case of 7% discount rate the minimum ticket price is $73.5 in each year (Figure 4.12).

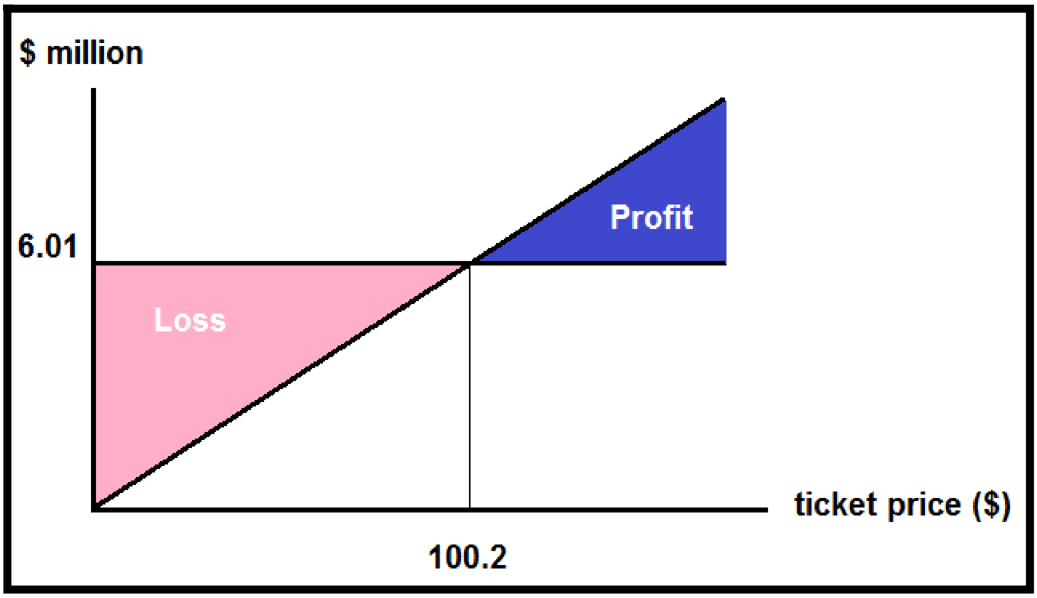


Figure 4.11: 30 years break-even point for Scenario A (11% discount rate)

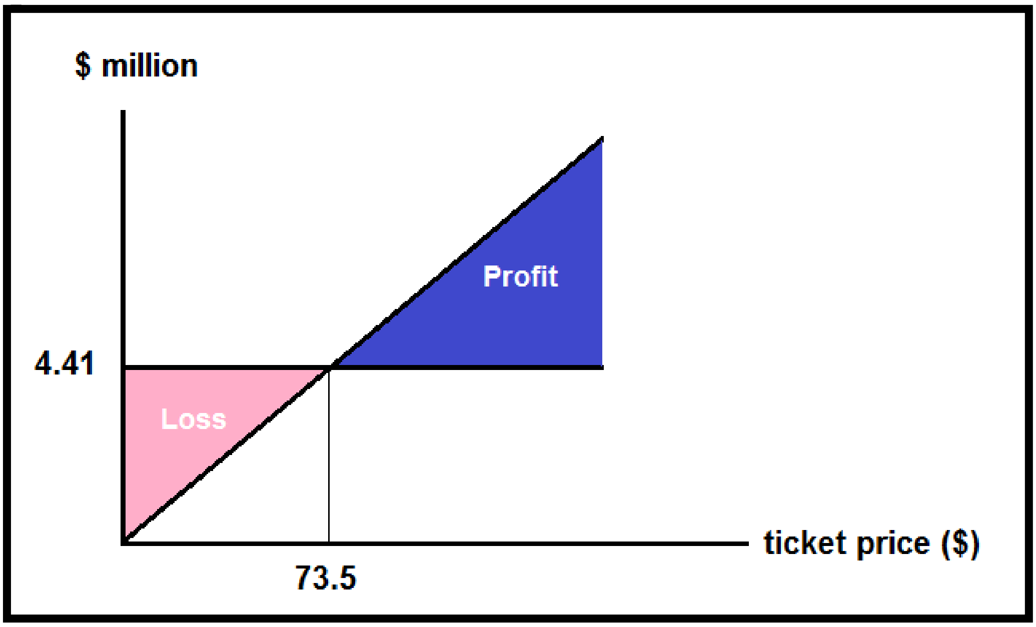


Figure 4.12: 30 years break-even point for Scenario A (7% discount rate)

4.6.2 Scenario B

In this option, the proposed project will be funded under a private company(s) and the company(s) will be the owner of facilities and METU will not interfere in management and operating issues. Responsibility of determining ticket prices and ticket selling policies are also goes to the project funder. This type of financing the projects is the most popular in public services and also in institutional contexts and most of the studied campuses apply this kind of approaches in their transportation systems, where a private company fund the project, construct it and operate it under an agreement with university administrators. Applicable decision/management policies for this scenario are including:

- **Director of the project:** *METU Presidency Office.*
- **Facility Ownership:** *The grantee company(s)*
- **Facility Management/Operations:** *Middle East Technical University abdicates its authority to the company(s) under an time limited agreement.*
- **Land Ownership:** *The land would be owned by Middle East Technical University and a long term lease agreement (approximately 50 years, the estimated life of the facility) would be established between the University and The Company(s).*

4.6.2.1 Break-Even Analysis

As it was mentioned above, riding right selling is the only way to recover the costs of the project. Advertisement in riding services and other choices are also available for this special scenario but cannot be considered as a source of dependable return. As like as previous case, operating cost of facility is $2 million per year for 30 years of operating period and total investment amount is $46.5 million.

As it is seen in Figure 4.13, the minimum price for annual riding right with 11% discount rate is $122.5, where adding a minimum 10% fare profit for the company, the final price is $134.75 for the second scenario. And considering 7% discount rate (Figure 4.14), minimum break-even price is $95.8 and minimum 10% fare price is $105.4.

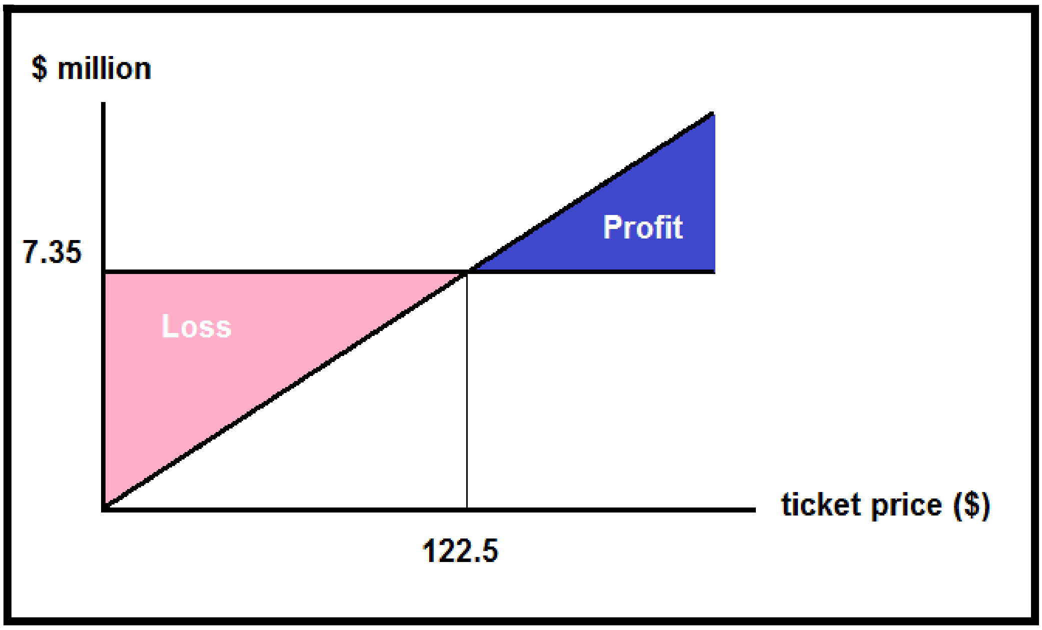


Figure 4.13: 30 years break-even point for Scenario B (11% discount rate)

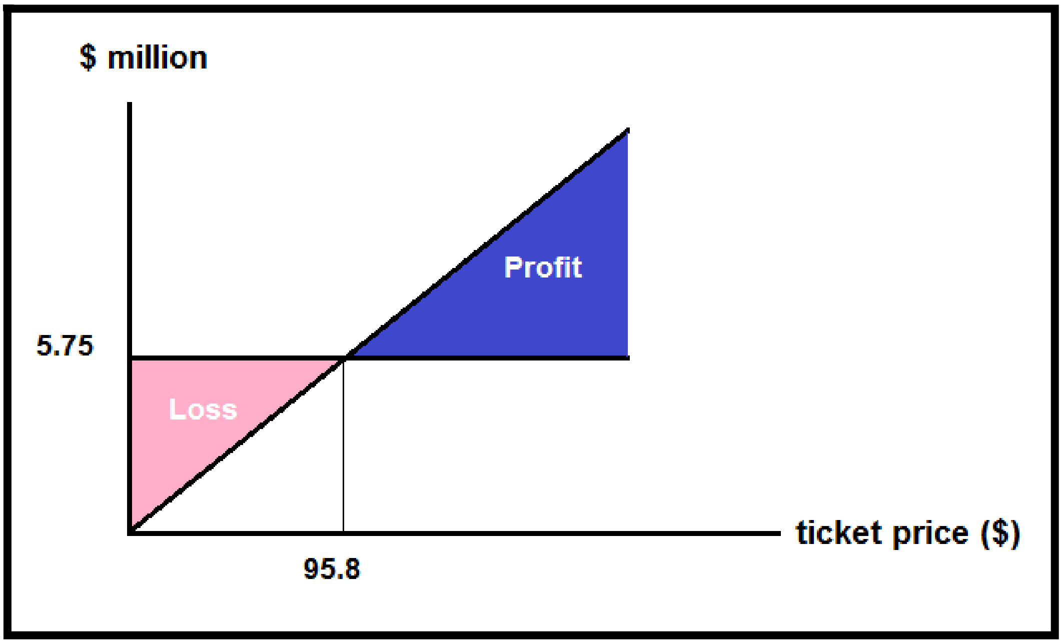


Figure 4.14: 30 years break-even point for Scenario B (7% discount rate)

4.6.3 Scenario C

In the last scenario, METU and partner company(s) will finance the facility in a 50/50 share. In this way, METU and partner(s) will grant $23.25 million in two years of construction period. And by opening the facility, METU will resign its right to project partner(s) and partner(s) will continue to operate and manage the system through the following 30 year period. General decisions/policies applicable in this case are as follow:

- **Director of the project:** *METU Presidency Office.*
- **Facility Ownership:** METU and *partner(s) in a 50/50 share*
- **Facility Management/Operations:** *The partner(s) will have the full authority under an agreement with, Middle East Technical University.*
- **Land Ownership:** *Middle East Technical University will continue to possess the lands during the construction and operating periods.*

4.6.2.1 Break-Even Analysis

In this context, project partner(s) and METU will continue to share the incomes granted by riding right selling. During the operating time, partner(s) will get the $2 million to recover the recurrent costs plus $2.675 million with 11% discount rate assumptions or $1.875 million otherwise. METU will continue to recover its investment through the annual $1.34 million saving from reducing bus services plus $1.335 million (11% discount) or $0.535 million with 7% discount rate.

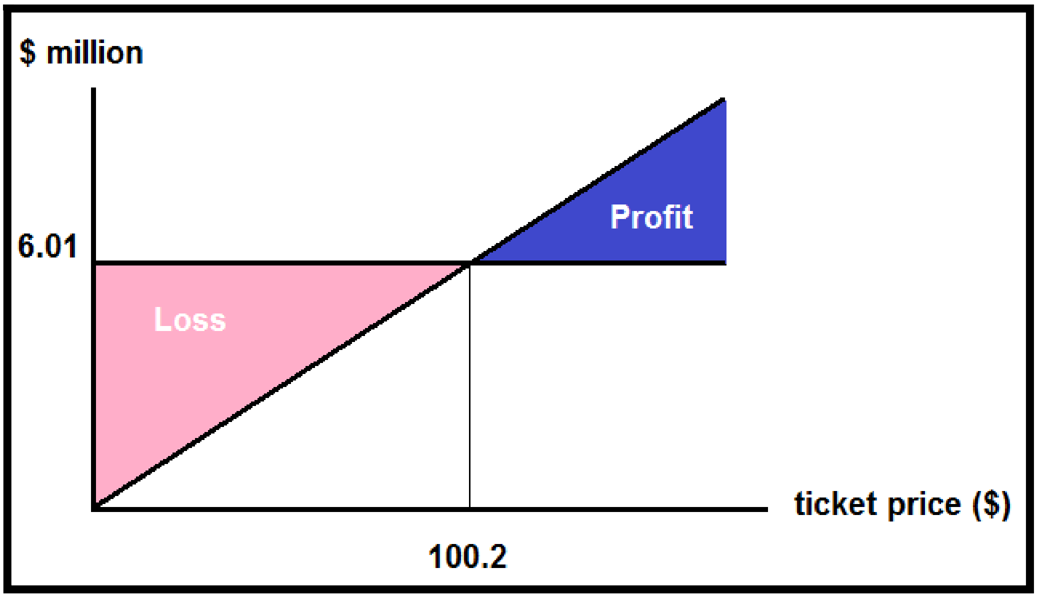


Figure 4.15: 30 years break-even point for Scenario C (11% discount rate)

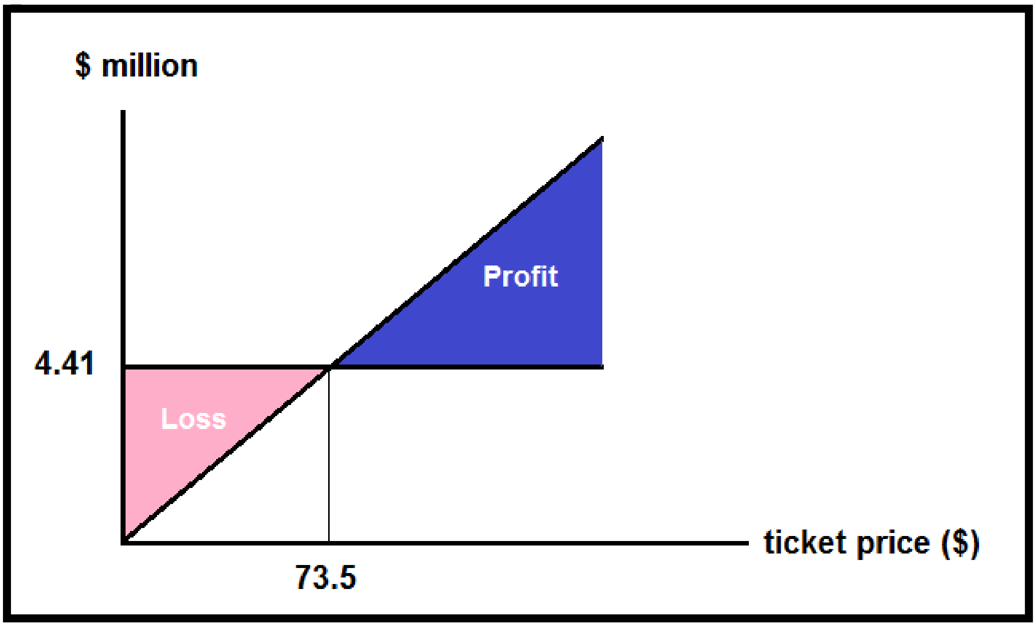


Figure 4.16: 30 years break-even point for Scenario C (7% discount rate)

By adding the, 5% fare profit to break-even price of $100.2, total price will be $110.22 in context of 11% discount rate and for 7% the minimum price including fare profit is $80.85 for annul ridership pass.

It should be mentioned after choosing the appropriate Business Plan, a detailed financial plan including: revenue/expense analysis should be completed by the project partners to determine if revenues generated by the facility through transit pass sales and/or other possible choices would be sufficient to sustain the long-term operating and maintenance costs associated with the monorail system over the next 30 years.

4.7 Project Schedule

A “best guess” schedule for the project would be included as part of this feasibility study. To accomplish the Monorail project in a two-year period, it’s been outlined the following milestones.

The initiation phase will consist of several steps that require about 4 months including: development and cost allocation plan and several steps of design professional/ construction manager selection. In this schedule by the end of Sep 2011, the selected company will start the system engineering and design process. Performing the necessary bureaucracy processes the physical phase of construction will begin in May 2012 and lasts for the next 18 months starts with guide-way infrastructure construction and electrification and mechanical switch montage and ends with station and equipment procurement and development stages.

Moreover, vehicles will be ordered simultaneously to the manufacturer company where the estimated lead time for delivery is 15 months. By starting the year 2014 everything will be ready to do final testing on the guide lines using the actual trains and if everything goes well the METU monorail will be opened for public services by the end of Apr 2014. For a detail project scheduling please refer to the attached Gantt chart (Figure 4.17).

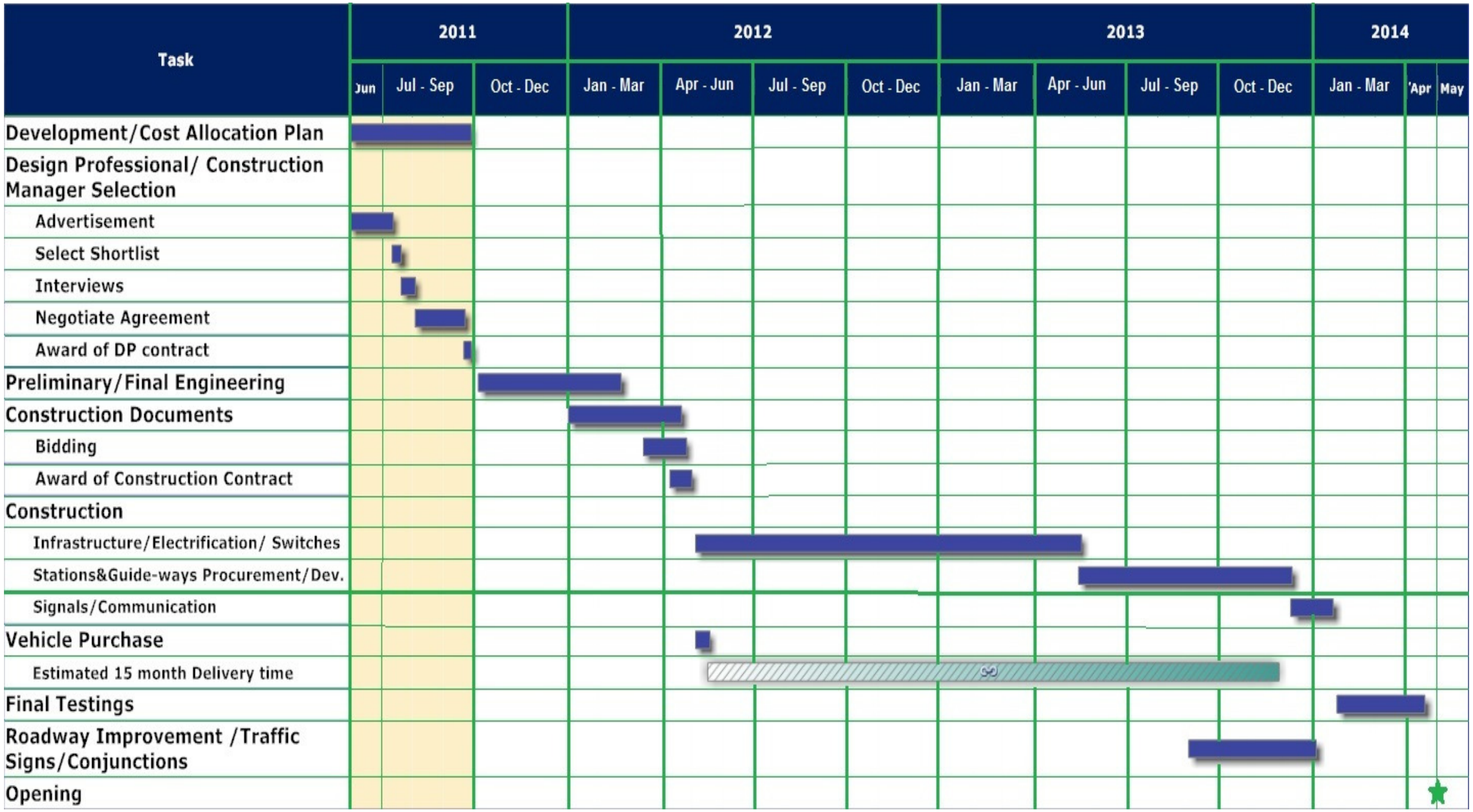


Figure 4.17: The Best Guess Schedule for Proposed Monorail Project

CHAPTER 5

CONCLUSION

The swift evolutional technical advancements are inseparable part of our contemporary urban societies. These ongoing evolutional modifications, which will continue to reconstruct future cities, are inevitably leading us to dissect the consequent influences on our lives. Within the context of transportation, modern cities and dense compilations, such as campuses or research institutions, require environmentally friendly, fast and convenient commuting systems in order to function successfully. While, the conventional public transportation does not yet provide the comfort level of a private vehicle, probably the most sensible way to deal with the negative effects of such transformations is to employ recent technical enhancements in our everyday transit systems.

This research aimed at bringing together the two conflicting sides of technological developments by planning for sustainable urban transit using the smart transportation technologies. For this purpose a comprehensive review of the literature was made in chapter two of this study, in order to analyze the methods used by some pioneer institutional campuses in North America to handle the increasing transportation demand using hi-tech approaches. Some brief explanations including advantages and disadvantages of each popular private and public transportation modes on university campuses; automobiles, walking and bicycling, buses, minibuses, trolleybuses, light rails and monorails – were reviewed and case studies of successful applications of each mode on campus communities were given in brief. It was discussed in detail that, the car-based transportation has many hidden costs and it is expensive and inefficient over short distances and is a major contributor to global warming. Moreover, the environmental, financial, and social pressures exerted by current levels of automobile dependence include greenhouse gas emissions, rapid land consumption, air quality and public health degradation, and deteriorating overall welfare and quality of life of urban populations. As indicated by many scholarly articles, the most widely implemented solutions are categorized as:

- ✓ Improving infrastructure and programs to encourage walking and biking;
- ✓ Implementing parking management techniques, raising parking rates to reduce demand, using so-called “parking cash out” to pay employees not to drive school, and banning first- or second-year students from bringing cars to campus;
- ✓ Apply demand management methods in educational institutions including: providing access to shared vehicles for some trips through nonprofit or commercial “cars hare” programs or on-campus car rentals and park and ride schemes;
- ✓ Use of the telecommuting technologies such as internet and video to provide online classes and transportation information and allowing compressed work weeks;
- ✓ Shift to alternative Biofuels like Bioethanol and Biodiesel;
- ✓ Encouraging the usage of environmental friendly vehicle technologies like Hybrid or Electric cars in campus vehicles by economic incentives;

- ✓ Developing high-frequency, reliable, and smart public transit services including APM technologies and provision of transit passes to students and employees allowing access rights to transit services;

While various strategies are available to manage the congestion and traffic problems in university campuses, this study specially proposes the smart APM transit service as the best applicable solution for METU campus. APMs are used and applied extensively to campuses and downtowns, as an integral part of expanding communities. While providing efficient, cost-effective circulation, building links and parking control, APMs are safe automated transit systems that are able to serve more attractive, high frequency, and efficient rides and air-conditioned comfort for faculty, students, alumni, and visitors of METU campus.

As it was stated in chapter three of this article, among the various types of APM systems, Monorail are one the most efficient and applicable systems on university campuses, public and private leisure and institutional settings. Monorails can carry from 2,000 to 25,000 passengers per hour per direction with headways as short as or even shorter than 60 seconds for small systems. They vehicles travel at speeds up to 80 km/h. The vehicles, which are typically, comprised cars of urban transit bus size, typically in the range of 6–12 m in length. They can be divided into straddle type, in which the vehicle sits astride the rail, and the suspended type, in which the vehicle is suspended from the rail and both types use rubber tires and air springs for their bogie suspension to reduce vibration and noise. Most modern urban monorails are equipped with VVVF (Variable Voltage, Variable Frequency) drives, composite or aluminum body shell and ATO (Automatic Train Operation) system. In addition, because of the special structure of the monorail system, there is no danger of derailment. The monorail can withstand severe weather conditions, such as strong winds, ice and snow.

However, the relatively high cost of monorail construction has undoubtedly been a factor in limiting the size of these operating systems. Advocates are strong to defend the monorail system, including statistics noting that no passenger accidents have ever occurred, as opposed to other transit modes. Although, soaring costs, long construction timeframe, and immense complexity of required design elements prevent this type of transportation mode to be looked at seriously within the metropolitan areas, the overall benefits make monorail as one the best solutions for institutional usages. At present, two third of about 130 APM installations in operation around the world are within and around airports, shopping and entertainment centers and university campuses.

This thesis has aimed to investigate the financial feasibility of monorail transportation services in METU and its consequent economic and institutional impacts on campus society. For this purpose a detailed Cost Benefit Analysis (CBA) was completed in chapter four trying to quantify the construction and maintenance costs of the system and resultant financial and social benefits. The predicted benefits of METU monorail system include faster, more frequent, and more reliable transit service; savings in automobile operating and parking costs for drivers who switch to the monorail; and reduction in accidents. Three groups stand to benefit from the monorail project: transit riders, former drivers who switch to the monorail, and continuing auto users who may experience a slight decrease in traffic delays because bus and car trips have moved off the road.

***Geographic Scope*:** The monorail project affects the whole METU campus area. The regions most immediately affected by the project will be western part of the campus including dormitories and residential units and Teknokent business district.

Time Period for Analysis: The time period for the analysis is from 2012 to 2042, which covers two years of construction and 28 years of operation. A base year of 2010 is used for cost and benefit comparison, with the average rate of lira to dollar exchange rate of 2010 and values discounted to 2010 dollars with two 11% and 7%.

Benefits, Magnitude, and Value: Travel time savings were valued at $5 per hour. Those who switch travel modes from automobile to the monorail benefited from auto maintenance and fuel cost savings. There is a huge savings in university expenses and greenhouse gases emissions from ceasing the current costly and old bus ring services in campus.

Based on 11% discount rate and the assumptions mentioned above, the resulted Benefit to Cost Ratio is 1.42, with the present value over 30 years $22.37 million. And for 7% discount rate with the same assumptions Benefit to Cost Ratio is 1.60, and the net present value of the project is $37.41 million. Furthermore as it is usual in public projects feasibility studies, the following minimum criteria are defined within the framework of cost effectiveness assessment for METU campus public transit system:

- ✓ To be accessible to the wider range of students, staff and faculties: current bus and minibus services are not acceptable because, they pose a barrier to use because of limited space and amenity on board;
- ✓ Conveniently scheduled: the service is needed at a reasonable hour and the lack of departure options during the day,

particularly from the western part of the campus, makes the existing services unfavorable;

- ✓ Have adequate luggage and bicycle space, conveniently available: people want to bring a reasonable amount of day-to-day luggage and other reasonable items like bicycles, without needing to make special arrangements.”
- ✓ Comfort and Environmental issues: the service must provide a high standard of on board comfort befitting the journey time, along with compromising the international environmental friendly standard qualification;

Based on the purposely conservative and progressive analysis, I am pleased to report that it is advisable to expend the monies for the monorail. I believe that this project will significantly improve the quality of transportation at the university and landscape and environmental issues, while at the same time, accelerates regional business growth and attract tourists and other scholars to Middle East Technical University. The monorail project is definitely worth further immediate consideration. The monorail transit solution appears very promising in both solving passenger transportation needs along the congestion problems and generating measurable profits for METU presidency office and the campus area in general. It will enhance university’s destination resort image, provide unparalleled visitor convenience, and eventually improve the transportation linkage with the rest of Ankara city.

This study provides a thorough and straightforward benefit-cost analysis for a proposed transit investment. However, there is no one correct answer, nor a “one size fits all” technology solution. There is no simple answer to the “right” APM. Each project has its own set of requirements and solutions in the iterative, often non-linear process of obtaining an APM. Also, different manufacturers have their own range of technologies with different capabilities, performance, and costs. Unfortunately, the market is relatively small, and the number of manufactures is limited. This makes supporting many suppliers and technologies difficult. On the other hand, a drawback to the analysis is the lack of other transit alternatives considered. It would have been useful to compare the benefits and costs of a monorail system with that of a light rail system, a Trolleybus transit system, and an increase in roadway and parking capacity.

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APPENDIX A

APM & PRT: Differences and Rationale

There are differences between Automated People Movers (APM) and Personal Rapid Transit (PRT). The similarities are numerous, which may cause some planners to blur the distinction. The technologies are quite similar, in terms of the guideway, vehicles, and control system. In fact, the exact same system could conceivably be used as PRT or APM with only software changes. The true distinction between the two is the service offered.

- PRT service is offered to an individual or group wishing to travel together and therefore the vehicle goes non-stop to their destination. The existing technology that compares with this service mode is the taxi. While people sometimes share taxi rides that occurs only by their choice, and the same is true with PRT service.
- APM service, on the other hand, is not private. Many people may board together, and the vehicle stops at each passenger's destination. It skips stops if no one needs to get off or on. An APM service in a widespread area probably needs to use regional boundaries and hub stations or other methods to group people together who are going to similar destinations. The existing technologies that compares with this service mode are the elevator and the airport shuttle van.

Because of the basic service distinction, several other technology and planning-related differences between PRT and APM arise:

- APM vehicles are generally envisioned as larger than PRT vehicles. But, there is no exact line between the number of seats that constitutes a PRT vehicle and one that is APM. An intermediate size vehicle of 4-8 seats could conceivably offer either type of service.
- A guideway strong enough to carry groups (APM) is usually larger than a PRT guideway. It may also require smaller spans between supports. Therefore it may be more expensive to build and more intrusive in an urban setting.
- The control software obviously has to behave differently with respect to routing and empty vehicle management.
- Planning of the network layout would be different. A plan for APM service would more likely follow major corridors only, while PRT service could become a linked network with overall greater coverage.
- Stations may be different. PRT stations need as little as one berth regardless of the overall network size. Typically developers suggest about three berths. APM stations in predominantly corridor-oriented networks could also have as few as one berth, but stations in widespread networks (particularly hub stations) would need many berths in order to group people together by their destination region.

APPENDIX B

TYPICAL COST BREAKDOWN OF SHUTTLE-TYPE APM SYSTEMS

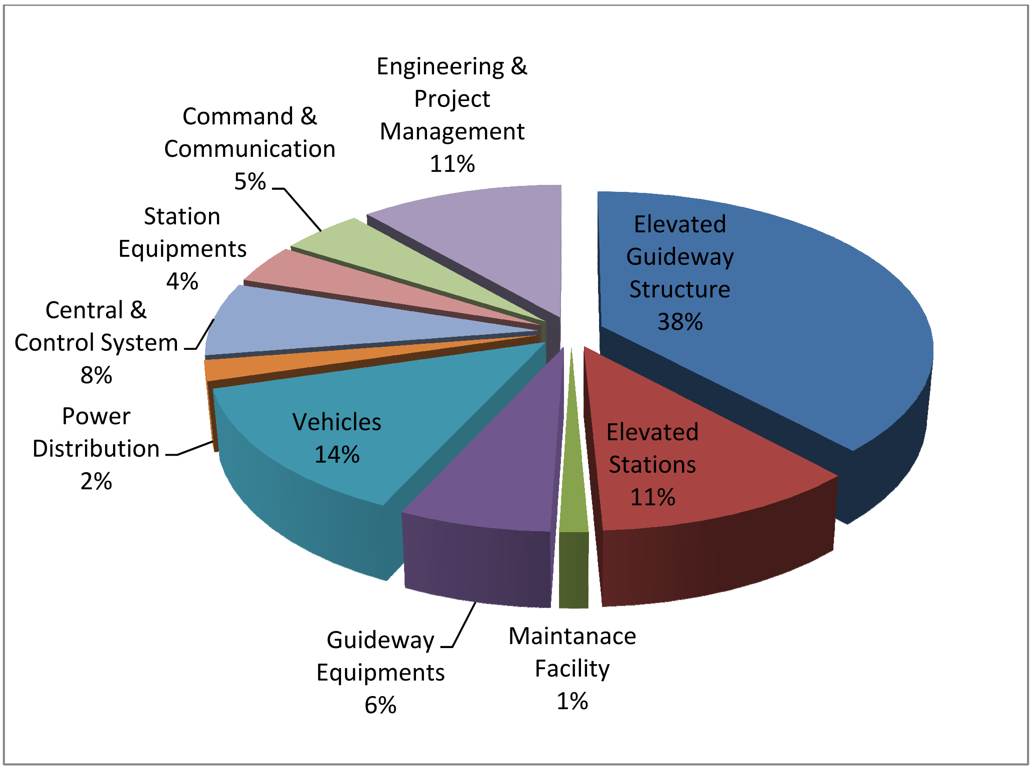

Figure B.1: Pie diagram of total cost breakdown of shuttle-type APM system

APPENDIX C

TYPICAL COST BREAKDOWN OF LOOP-TYPE APM SYSTEMS

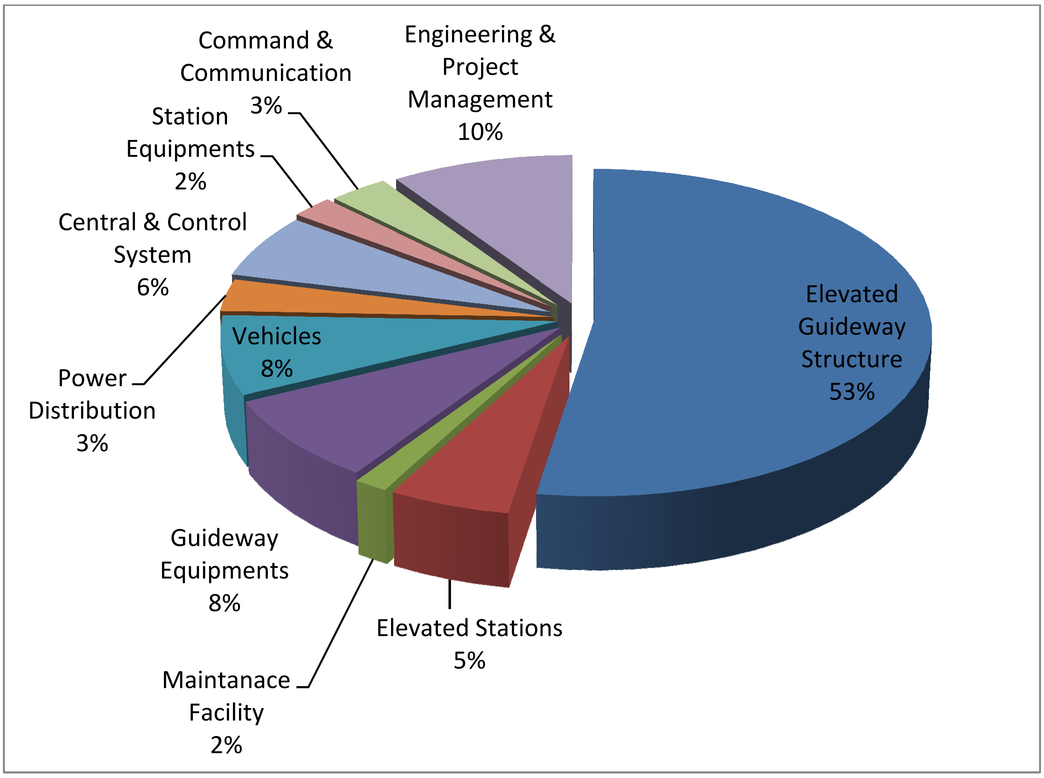

Figure C.1: Pie diagram of total cost breakdown of loop-type APM system

APPENDIX D

LIST OF ORGANIZATIONS AND INDIVIDUALS HAVE BEEN ACCESSED DURING THIS REASEARCH

Table D.1: Individuals and Org. Name List

First and Last Name	Organization	Contact Info.	Provided Information
Mr. Cemal YAVUZ	METU Directorate of Vehicle Management (Head of Dept.)	Tel: 0312 210 2909 Fax: 0312 210 2910	METU bus services annual costs
Mr. Mustafa AKMAZ	Hazine Müsteşarlığı Strategic Planning (Head of Dept.)	Tel: 0312 477 4868 Fax: 0312 477 4832	Cost benefit values justifications
Mr. Ayhan ÖZDEMİR	Özdemir Co., Grp Pipe Investment Consulting	Email: ayhanozdemir @ayhanozdemir.net	Cost values justifications
Mr. Sabahattin ÇELİK	Türkarge Co. , Teknokent, METU	Email: sab@turkarge.gen.tr	Capital Costs justification
Mr. Göksal CÜLCÜLOĞLU	METU, Campus Planning Manager	Tel: 0312 210 6109 Email: goksal@metu.edu.tr	Route alignment, Technical details
Mr. Fehmi TOPTAŞ	Ankaray LRT, Ankara	Tel: 0312 287 0425	Recurrent Costs
----	TCMB Araştırma ve Para Politikası Genel Müdürlüğünde	Tel: 0312 507 5474	Annual discount rates

APPENDIX E

APM SUPPORTED SYSTEMS: AUSTRANS

Table E.1: Contact info of Bishop Austrans Pty Ltd.

Bishop Austrans Pty Ltd.	
Tel	+61 (0) 417 752 535
Fax	+61 (2) 9427 8787
Email	Laurie.Bishop@austrans.com
Web	www.autrans.com
Postal address	PO Box 361 North Ryde, NSW 1670 Australia

The Austrans system is clever but not technically complicated. Slightly larger than a car people mover, Austrans provides high frequencies that make timetables and long waiting periods a thing of the past. This is a system that provides a level of service that, for the first time, allows public transport to compete with the car in many situations. The patented bogie (wheel set) and rail design allows vehicles to climb steep grades and turn sharp corners so that the system is easy to construct in an existing urban environment or in difficult terrain. It carries 8-16 passengers per vehicle. There is no local air pollution and with an automated system existing public transport fare levels would, in many cases, be enough to cover the operating costs. Austrans can be used to build an entire public transport network for a small or medium sized city or, as is more probable, it can be integrated into existing heavy rail, light rail and bus systems. Austrans has markets for immediate commercial systems in the following areas:

- A medium flow, short haul, low speed shuttle (e.g. airport people mover)
- A feeder and distributor for a line haul system
- The principal internal transport mode in a contained area such as a university campus, hospital precinct, business park or shopping centre
- An alternative to light or heavy rail for upgrading a service in an existing developed urban area from bus
- A moderate capacity line haul system (e.g. extension of an existing line haul service to a newly developed satellite new town)
- Such systems have the potential to be upgraded, expanded and integrated into a citywide network.

Some design specifications are as follow:

Table E.2: Design specification of Austrans

Dimensions (m)	**Height**	**Width**	**Length**
Vehicle	2.25	1.9	5.45
Guideway	1.05	1.1	
Min. Curve Radius		8	

AE Bishop, the parent company, is an established Australian engineering firm with other products. Au$10 million has been invested in Austrans R&D over an 11 year period. The state of development is:

- First test track at Chullora, Sydney built and operational

- First prototype vehicle produced and currently undergoing development trials
- Vehicle negotiates 8 meter radius curve as designed, brakes and accelerates as expected - about to proceed with testing ride characteristics when negotiating chicanes
- Prototype switch constructed and undergoing development - operates in less than one second. Notable for lack of noise.
- Station concept and specification completed and proprietary simulation software developed

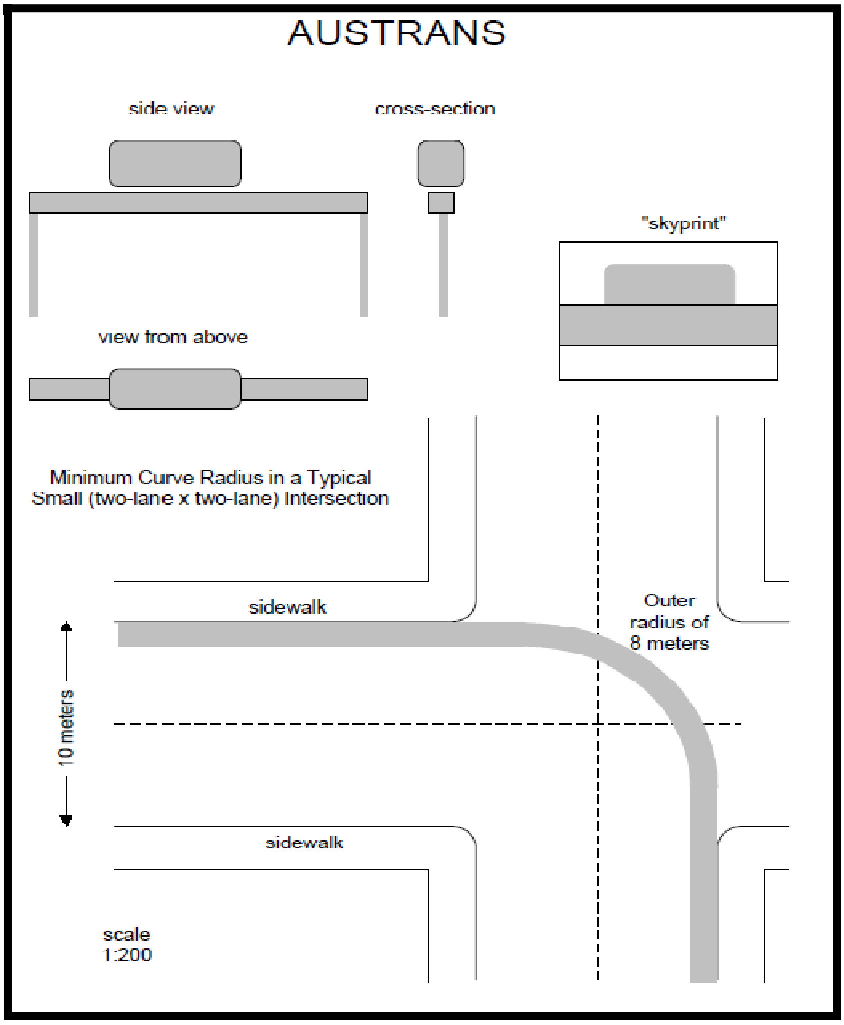

Figure E.1: Austrans Guideway Specifications

APPENDIX F

APM SUPPORTED SYSTEMS: AUTRAN

Table F.1: Contact info of Autran Corp.

Autran Corp.	
Tel	+1 (0) 847 674 4947
Fax	+1 (0) 847 674 4947
Email	vanlund@comcast.net
Web	www.autrancorp.com
Postal address	9220 E Prairie RD #410 Evanston, IL 60203, USA

Autran is a supported technology that resembles the simple supported systems, but also has pallet carriers for cars. The company envisions wide scale networks carrying freight containers, pallets and dual-mode cars as well as PRT/APM cabins. They assert that PRT advocates and dual-mode advocates can help each other by using a system designed flexibly from the start for both purposes. Each vehicle seated 8-10 passengers. The guideway is a single box beam with a slot at the top. The wheel set is entirely inside the box beam. Two sizes are planned: a lightweight size for PRT and light freight, and a heavier size for auto carrying pallets. The guideway is constructed in spans of 20 m using two prestressed concrete side beams that support steel frame members for support of tracks. Adjustments of the positions of frame members relative to the beams can be made to obtain very smooth travel. Steel wheels on steerable front and rear bogies are driven by an induction motor through an electronically controlled transmission and two differentials. Steering, switching and increased traction when necessary are all obtained through control wheels engaged with separate tracks. The vehicle can negotiate tight radius curves because the front and rear axles swivel on a vertical axis.

Some design specifications are as following table. The current design is for supported vehicles/carriers, but features of the design could allow for suspending vehicles in the future. The system includes a tilting mechanism which improves comfort in curves. Loads are automatically tilted as a function of speed and the radius of a curve.

Table F.2: Design specification of Autran

Dimensions (m)	**Height**	**Width**	**Length**
Vehicle	1.6	1.1	4.75
Guideway	1.4	1.8	15m Sections
Min. Curve Radius		5.2	

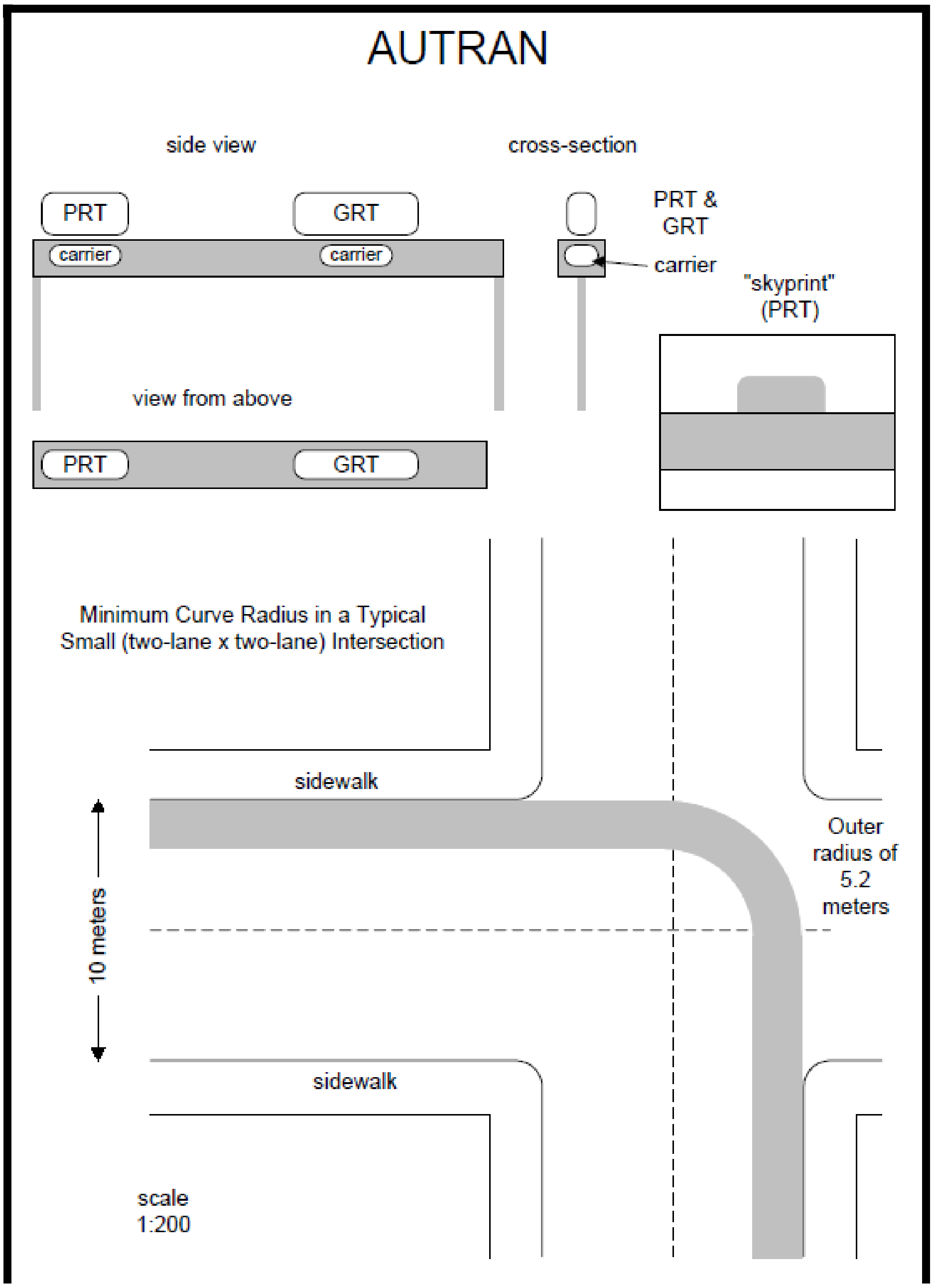

Figure F.1: Autran Guideway Specifications

APPENDIX G

APM SUPPORTED SYSTEMS: CYBERTRAN

Table G.1: Contact info of Cybertran Int'l Inc.

Cybertran Int'l Inc.	
Tel	+1 (0) 510 215 5221
Fax	+1 (0) 510 215 5225
Email	www.cybertran.com
Web	www.cybertran.com
Postal address	1301 South 46th St. Building 300b Richmond, CA 94804

The CyberTran team is led by the developer of the system, Dr. John A. Dearien. Dr. Dearien is a Professional Engineer with degrees in Civil and Structural Engineering and 30 years experience with the Idaho National Engineering and Environmental Laboratory. The Cybertran guideway is a double steel rail, like conventional rail, with the standard gauge of 1.43 m. Single axle propulsion bogies allow for tight turns with low wheel/rail wear and low noise. Six of the standard steel guideway sections are field welded together to provide an operational unit 97 m long, at the end of which temperature expansions are handled, emergency egress to the ground is provided, and sensor packages of system control are located. A second type of guideway section is a pre-stressed concrete section with the

same dimensions as the steel section, but not rigidly connected in the field. This guideway type is approximately 10 times heavier than the steel version and is used where aesthetics rule out simple steel sections. The vehicle types have different seating arrangements, but only one body size is proposed. Seating ranges from 6 to 20. Multiple doors
provide direct access to each seat or row of seats, with easy accessibility. Propulsion units are designed to utilize a variety of motors and power transmission units, depending on speed range and power requirements of application. The long 11+ m length is partly due to aerodynamic cones on both ends.

Table G.2: Design specification of Cybertran

Dimensions (m)	**Height**	**Width**	**Length**
Vehicle	1.9	1.9	11.6
Guideway	1.6	2.6	16m
Min. Curve Radius		16	

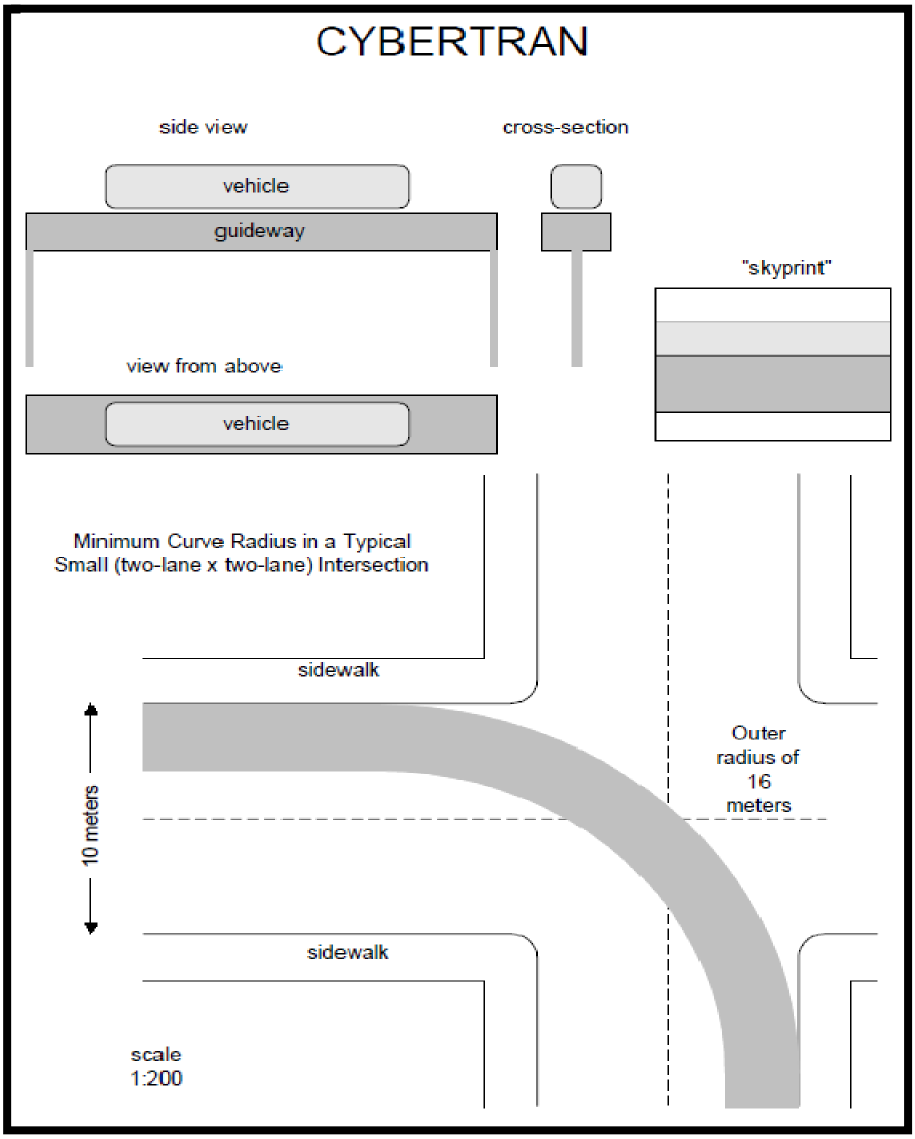

Figure G.1: Cybertran Guideway Specifications

APPENDIX H

APM SUPPORTED SYSTEMS: MEGARAIL

Table H.1: Contact info of Megarail Transportation Systems Inc.

Megarail Transportation Systems Inc.	
Tel	+1 (0) 817-367-2373
Fax	+1 (0) 817-367-2373
Email	contact@megarail.com
Web	www.megarail.com
Postal address	P.O. Box 121728 Fort Worth, TX 76121, USA

The MegaRail guideway consists of two steel box beams side by side. Wheels are inside the boxes, and the axle passes through slots on the sides of the beams. This configuration provides weather protection for the traction surface, communications, and power pick-up, and it prevents derailment. It also allows for a very small skyprint. The rail beams are self supporting with no superstructure. Wire mesh spans the space between the rails for use as an emergency walkway, but this is designed to block very little light passage. MegaRail is a multifunction concept, offering pallet transport for cars, plus APM and PRT service. Non-stop 65-mph urban, and 85-mph commuter rail passenger services with small (max 16 passenger), automated cars operate on a 24-hour, seven-day, on frequent schedule basis for no-wait travel. The smaller individual personal transport cars travel on a non-stop basis from local station to destination station without time-wasting and trip-time extending intermediate station stops typical of conventional city buses and light rail or monorail trains. Passengers are accommodated in spacious seats in quiet, smooth-ride cars. The larger 16-passenger cars offer frequently scheduled, 24-hour, seven-day service with stops only where passengers are waiting to be picked up or let off. Some design specifications are as follow:

Table H.2: Design specification of Megarail

Dimensions (m)	**Height**	**Width**	**Length**
Vehicle	2.2	2.7	6.1
Guideway	0.9	2.9	
Min. Curve Radius		14.7	

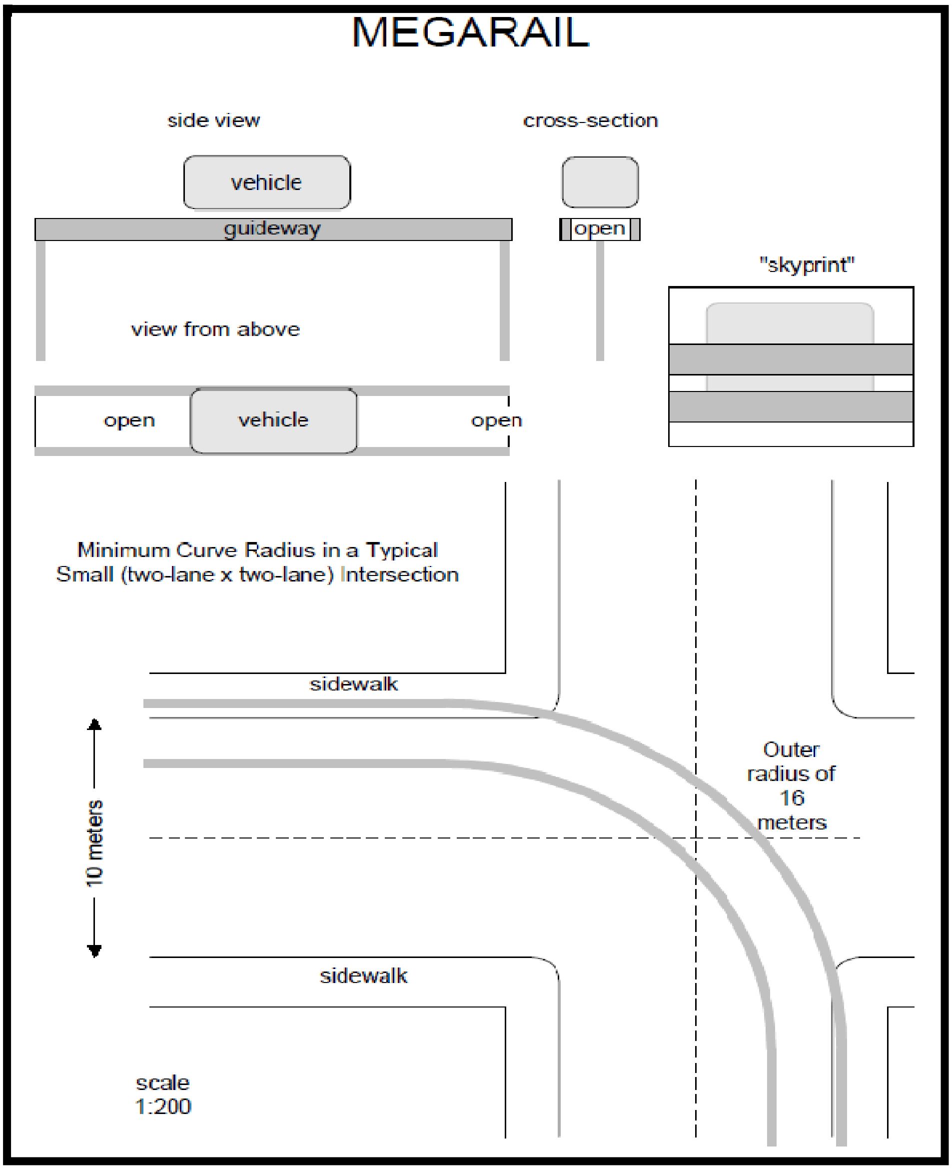

Figure H.1: Megarail Guideway Specifications

APPENDIX I

APM SUPPORTED SYSTEMS: T2

Table I.1: Contact info of T2 Corp.

T2 (Taxi 2000) Corporation	
Tel	+1 (0) 763.717.4310
Fax	+1 (0) 763.717.4310
Email	info@taxi2000.com
Web	www.taxi2000.com
Postal address	8050 University Avenue N. Fridley, MN 55432 USA

Taxi 2000 (T2) designs point-to-point (P2P) personal rapid transit systems. Our independently verified control system is the "brain" that makes the P2P, non-stop transportation system available now. No other personal rapid transit company has a functioning control system. Using the specific professional services, T2 develops P2P transportation solutions. These solutions are based on ridership studies, route analysis, station requirements, and the transportation system needs of the client/community.

The asynchronous echo™ control system allows Skyweb Express to outperform any other PRT system. echo communicates with each individual vehicle more than ten times per second, continuously updating vehicle data. echo gives Skyweb Express;

Complex network capability - Less congestion , faster trips, shorter wait times, networks too difficult for other control systems are easy for echo

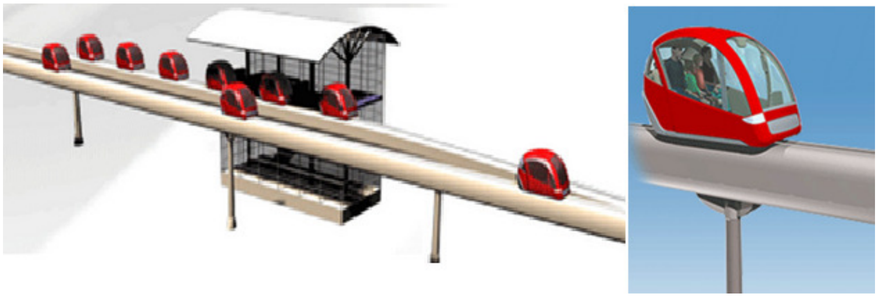

Figure I.1: Schematic view of Taxi 2000 vehicles and guideway

Enhanced safety - Vehicles/echo adjusts to traffic conditions in only 1/10 second, meets current APM standards with a 1.1 second headway

Greater capacity - echo provides up to three times the service compared to other control systems on the same size network

Ridership – The Skyweb Express system incorporates local ridership data into the simulation process. The iterative simulation services provide our clients with multiple route or system layouts.

Routes – TrakEdit, T2's proprietary software, simulates many possible routes to optimize the system layout. The layout is dependent upon ridership data and client goals to achieve an optimal transportation system. T2 has simulated routes as large as 300 km and 15,000 vehicles.

Fleet Size – The number of vehicles in the fleet is optimized to handle variable volumes of traffic according to ridership demand. The size and number of vehicles are optimized in the feasibility program. The variables affecting fleet size are the route, ridership, and service goals. These inter-connected variables become optimized using T2's proprietary TrakEdit simulation software.

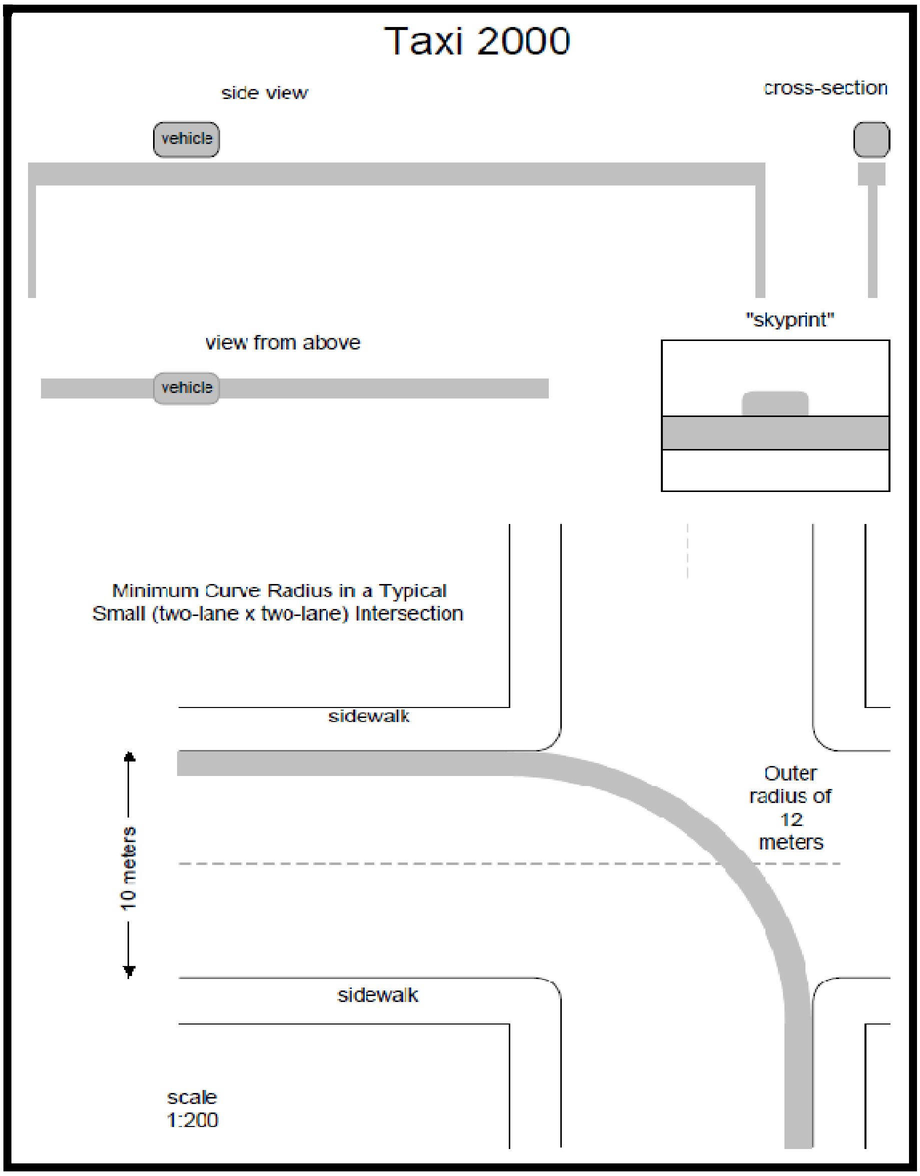

Figure I.2: T2 Guideway Specifications of Taxi2000