EVALUATING PUBLIC TRANSPORTATION ALTERNATIVES IN THE METU CAMPUS WITH THE AID OF GIS

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

EVALUATING PUBLIC TRANSPORTATION ALTERNATIVES
IN THE METU CAMPUS WITH THE AID OF GIS

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Geographical Information Systems (GIS) have been rapidly developed in the fields that need spatial data and transportation planning is one of these fields. Since transportation data is spatially distributed and need spatial, statistical and network based analysis; GIS applications have contributions to transportation planning. In this study, it is aimed to determine a new public transportation mode and route in the METU campus with the aid of GIS by considering the stations of Çayyolu metro route. Besides, it is also aimed to show that GIS can be a useful tool for constructing transport planning database and exploring, analyzing planning data. Gross settlement area of the campus, covering about 220 hectare land on the southern side of the Ankara – Eskişehir highway, is the study area of this thesis. First, campus land-use, topography, population characteristics and transportation structure are explored. Then, campus trip demand and pedestrian traffic are estimated. Afterwards, eight public transport route alternatives are proposed with their stops or stations for three different modes as; guided light transit, modern trolleybus and monorail. Proposed routes and stops or stations are evaluated with their physical characteristics and in terms of service areas shaped relative to pedestrian accessibility for determining the suitable public transport service in the METU campus. Consequently, “Trolleybus B” alternative is selected as the first degree suitable public transport service in campus. Besides, “Monorail B” and “Trolleybus A” services are determined as the second degree suitable services in campus.

Keywords: Public Transport, Route Planning, Accessibility, METU, GIS

ÖZ

ODTÜ KAMPÜSÜNDE TOPLU TAŞIM ALTERNATİFLERİNİN
CBS YARDIMIYLA DEĞERLENDİRİLMESİ

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Coğrafi Bilgi Sistemleri (CBS) mekansal veriye ihtiyaç duyan alanlarda hızla gelişmiştir ve ulaşım planlaması da bu alanlardan biridir. Ulaşım verilerinin mekanda dağılmış olması ve mekansal, istatistiksel ve ağ tabanlı analizler gerektirmesi nedeniyle; CBS uygulamaları ulaşım planlamasına katkıda bulunmaktadır. Bu çalışmada, ODTÜ kampusunda yeni bir toplu taşım türü ve hattının, Çayyolu metro hattının istasyonları da dikkate alınarak, CBS yardımıyla belirlenmesi amaçlanmaktadır. Ayrıca, CBS'in ulaşım planlaması veritabanı oluşturulmasında ve planlama verilerinin incelenmesi, analizinde yararlı bir araç olabileceğinin gösterilmesi de amaçlanmaktadır. Ankara – Eskişehir karayolunun güneyinde yaklaşık 220 hektar arazi kaplayan kampus brüt yerleşim alanı bu tezin çalışma alanıdır. Öncelikle, kampus arazi kullanımı, topografyası, nüfus özellikleri ve ulaşım yapısı incelenmiştir. Ardından, kampus yolculuk talebi ve arzu hatları tahmin edilmiştir. Daha sonra, sekiz toplu taşım hattı alternatifi, durakları veya istasyonları ile üç farklı tür; yönlendirmeli hafif taşıma, modern troleybüs ve monoray için önerilmiştir. Önerilen hatlar, duraklar veya istasyonlar fiziksel özellikleriyle ve yaya erişilebilirliğine göreli şekillenen servis alanları açısından değerlendirilmiştir. Sonuç olarak, “Troleybüs A” alternatifi kampusta birinci derecede uygun toplu taşım servisi olarak seçilmiştir. Ayrıca, “Monoray B” ve “Troleybüs A” servisleri kampusta ikinci derecede uygun alternatifler olarak belirlenmiştir.

Anahtar Kelimeler: Toplu Taşım, Güzergah Planlaması, Erişilebilirlik, ODTÜ, CBS

To My Parents

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CHAPTER 1

INTRODUCTION

The movement of people, freight and information, has always been a fundamental component of all human societies. Settlements exhibit increasing mobility during day and night, thus increasing mobility demand must be planned (Gülgeç, 1998). Mobility can be provided by modes of transportation; walking, cycling, public transit, private vehicles or ridesharing and other modes. Increased speed, safety, service quality or affordability of a mode improves access by that mode (VTPI, 2004). Access is the ultimate goal of any transportation mode. The demand for transportation is a derived demand, arising out of travelers' needs for products and services, dispersed over space. Any transportation mode can be evaluated by its effectiveness in delivering travelers to the desired opportunities. Koenig (1980) refers to a definition fundamentally proposed by Dalvi (1978) where, accessibility indicates the ease of reaching any land use activity from a particular location, using a particular transport system. Thus accessibility refers to a given origin–destination, transportation mode and opportunity as land use activity. METU (Middle East Technical University) campus, considered as a smaller version of a city, depends on the same accessibility terms defined.

1.1. Study Area and Problem

Theoretical study area of this thesis is the METU campus; covering about 4.250 hectare land on Ankara. However, practical study area of this thesis is the northern part of the METU campus, which holds most of the facilities and built-up environment of university. In year 2004, gross built-up area of the campus has reached up to 155 hectare which was about 65 hectare in 1970's. This basic measure denotes that METU campus has widened for more than two fold with the new spatial extensions, especially constructed on the western side of campus, like ODTÜKent residential zone, METU Technopolis, METU Foundation Primary and High School.

As Günay (1997) and Gökbulut (2003) stated, in 1961 METU campus schema was designed to serve a maximum population of 15.000 people including students, academics and other staff. But, based on the data obtained from presidency office in the year 2003, the overall campus population is about 30.000, comprising from 20.372 university students, 2.593 academic staff, 2.851 staff, 1.805 primary and high school students, 299 primary and high school staff, 1.660 technopolis staff. In addition to this population, METU residences have about 1.000 inhabitants. Moreover, cultural conventional center, technopolis and sport center produce temporary population on campus.

METU campus was built in the 1960's on a pedestrian alley and a surrounding service ring. Interior alley was designed for unimpeded pedestrian access to academic and administrative facilities; service ring, encircling campus facilities, was proposed for motorized modes of transportation (Gökbulut, 2003). However, this compact structure of the campus has been gradually distorted by the recent spatial extensions that become inevitable with the growth of the university. Especially, the western spread of the campus land use structure decreased pedestrian accessibility between formerly built core campus facilities and the recent extensions like Faculty of Education, METU Technopolis, ODTÜKent residential zone and western dormitories. Decreased pedestrian accessibility between distinct academic facilities also revealed time budget problems for students of inter disciplinal programs. In addition to decreasing pedestrian accessibility, this recent extensions caused additional motorized traffic load in campus. For instance, according to the records obtained from the directorate of domestic works, the approximate number of entrance cards, pertaining to METU Technopolis, has increased twice in two years and reached up to 500 in 2004, which was about 250 in 2002. In addition, the approximate number of guest entrance cards has increased from 1.000 to 1.200 between 2002 and 2004 which denotes recent facilities joined to campus have increased the attraction of METU.

The number of private cars in Ankara was 27.000 and the city population was 1.236.000 in 1970 (ABB – EGO, 1987); over 30 years the number of private cars has increased 22 times and reached 582.000 in 2000 while the city population was 3.278.000 (DIE, 2000). In addition, between 2000 and 2004, the number of private cars has also increased by 20 % and reached 698.000 (DIE, 2004) while the projected city population is 3.578.000 according to the population increase rate of 2,215 % in Ankara determined by the State Institute of Statistics (DIE, 2000). Hence, private car ownership rate in Ankara, which was 22 cars per thousand person in 1970 (ABB – EGO, 1987), has increased 8 times and reached 178 cars in 2000 (DIE, 2000). Private car ownership rate in 2004 is 195 cars per thousand person, calculated with the aid of projected city population (DIE, 2000 and DIE, 2004). Besides, Ankara 2015 Transportation Master Plan (ABB – EGO, 1994) denotes a significant increase in the trip attraction of METU by modes of public transit. For instance, 2015 Transportation Master Plan estimates trip attraction capacity of METU by public transport in morning peak time, between 08:00 and 10:00, as 19.700 passengers in 2015, however it was 9.400 passengers in 1985. Assisting this estimation, the number of motorized vehicles entering campus in morning peak time, between 08:00 and 10:00, has increased from 923 vehicles to 1824 vehicles at gate A1 and from 858 vehicles to 1278 vehicles at gate A4 between 2000 and 2003 (Gökbulut, 2003:93-96).

Daily trip generation coefficient of Ankara is 1,96 trip per person including all modes of transport and 1,32 trip per person for motorized modes of transport (ABB – EGO, 2000). It is clear that METU would attract and/or generate at least 2 daily trips per person. This basic approach demonstrates that METU attracts and/or generates at least 60.000 trips per day with a population about 30.000. Today transportation in campus is supplied by buses, private minibuses, personnel services, private cars and taxis. Campus inner circulation is supplied by campus ring services and private cars. Pedestrian accessibility is not convenient between distinct zones of campus. Besides, service level and capacity of the present bus ring route cannot compete with private cars. According to the transportation data obtained from Gökbulut's study (2003:89), in the year 2003, 41 % of the passengers reached campus by EGO and private buses, 13 % of them preferred minibuses, 7 % of them walked and 39 % reached by private cars. Usage of private cars in campus has increased from 24 % to 39 % between years 1996 and 2003. Insufficient parking spaces appear as another problem caused by the increased usage of private cars. Paid entrance card policy of the campus does not appear to be a complete solution for attracting public transport since 10.791 vehicle entrance cards were sold or registered in the year 2004.

Ankara 2015 aimed Transportation Master Plan proposes 22 kilometers Ankaray light rail system and 45 kilometers Metro heavy rail system before 2015 (ABB – EGO, 1994). Today, 8,6 kilometers Ankaray light rail system has been in operation between Söğütözü and Dikimevi since 1996; 14,2 kilometers Metro heavy rail system has been in operation between Kızılay and Batıkent since 1997. 17,2 kilometers new Metro route between Kizilay and Çayyolu passes through the A1 and A2 gates of METU which is planned to start revenue service in 2006. With its two stations, station ODTÜ at gate A1 and station Bilkent at gate A2, new Metro route will ease campus transportation by connecting campus to the city center and integrating campus to the current and planned heavy and light rail network of Ankara.

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) also stated, sustainable solution for increasing ODTU and Bilkent stations' service area should be a connection to another public transport service operating within the campus.

By this chance, campus inner transportation structure should be revised in the perspective of public transportation and increased accessibility while expanding the service coverage areas of two new Metro stations with the aid of geographic information systems (GIS).

1.2. Objective

The aim of this study is to determine a new public transportation mode and route for the METU campus with the aid of GIS by considering the conditions after the new metro route. In this study, it is also aimed to show that GIS can be a useful tool for constructing transport planning database and exploring, analyzing planning data. Three different public transport modes; guided light transit, trolley and monorail systems are proposed and mutually evaluated with the aid of GIS analysis. This study also aims to develop a methodology for determining the potential service area of a stop or station and then to estimate a route's overall service area with the aid of accessibility analysis on pedestrian road network. Essentially, this study proposes a new public transport mode, route and stops/stations; by considering the new metro route and transportation problems of METU; in order to ease the accessibility within campus and to increase the service areas of two new metro stations by integrating METU to the new metro route.

1.3. Scope and Methodology

Methodology of this study partially refers to the four fundamental steps of analytical transportation planning [(1)]. First, campus physical, population and transportation structures are explored. Then, campus trip demand and desire lines are estimated. Afterwards, alternative routes with stops/stations are proposed in the campus for three different public transport modes. Proposed routes and stops/stations are evaluated via physical and accessibility analysis. Finally, suitable service mode(s) and route(s) are determined by discussing the results of feasibility analyses. Flowchart of the study is given in Appendix A.

This thesis is composed of six chapters. The next chapter, Chapter 2, explains characteristics and applications of GIS-T (GIS for Transportation Applications). A literature review about public transport route planning is also given in Chapter2. Besides, main software packages for GIS-T are explained.

In chapter 3, physical structure and population characteristics of the METU campus are explored in terms of; land use, structural density, topography and slope, spatial distribution of the campus population and its density, campus entrance cards and private car usage in the campus.

Campus transportation structure, existing transport facilities and rail public transportation network of Ankara are explored in Chapter 4. Besides, characteristics and prerequisites of different public transport modes (eg. light rail transport, guided light transport, modern trolleybus, monorail…) are explored in this chapter. Public transport route alternatives, relating to these modes, are proposed in the campus with their stops or stations.

[(1)] "In analytical transportation planning, travel behavior of people and trip demand in an area are tried to be explained with mathematical models. Four fundamental steps of analytical transport planning are; Trip Generation, Trip Distribution, Modal Split and Traffic Assignment (Gülgeç, 1998:5-7, 14-16)."

In Chapter 5, proposed public transport services are evaluated by physical analysis and accessibility, service area analysis. Physical analysis include, route lengths, number of stops – stations and route slopes. Accessibility analysis includes potential ridership and potential service coverage area estimations with a limited time budget. Pedestrian accessibility is calculated with the aid of network analysis. Then, analyses results are summarized according to the service mode and route alternatives taking the first three ranks in each analysis. Finally, by discussing these summarized results of analyses, suitable public transport service(s) are determined in campus.

Final chapter concludes this GIS aided transportation study and contains several recommendations arising from this study.

CHAPTER 2

CHARACTERISTICS OF GIS-T AND PAST STUDIES RELATED TO PUBLIC TRANSPORT ROUTE PLANNING

This chapter includes the previous studies carried on public transport route planning and evaluation with the aid of GIS-T. The special term, GIS-T is used to denote GIS applications dealing with transportation. First, characteristics and applications of GIS-T are explained. Then, the previous studies, related to public transportation, are presented by means of their route planning and evaluation methods. Some of these methods, developed by previous studies and utilized in this thesis, are also explained. Finally, main software packages for GIS-T and these used in this thesis are explained by means of their capabilities.

2.1. Characteristics and Applications of GIS-T

"Geographical Information Systems (GIS) have been rapidly developed in the fields that deal with spatial data analysis and transportation is one of these fields (YU, 2001:12)." GIS applications have contributions to transportation planning since transportation data is spatially distributed and need spatial, statistical and network based analysis. Common necessities for using GIS in transportation studies can be defined as; transportation related land use, population and travel behavior (eg. trip generation coefficient) data storage, query and visualization, thematic mapping, transport network based accessibility analysis and service area estimations. As Sikdar and Gupta (2003) stated, the adoption of newly emerging technologies, such as GIS, can improve planning and decision making process for efficiently using limited funds.

“Geographic Information Systems for Transportation, termed as GIS-T, is a specific field of GIS dealing with transportation issues and dates from the 1960s as a very earliest interest in GIS. Although the roots of GIS-T date from the 1960s, yet there is no book devoted solely to the GIS-T (Goodchild, 1999:2).” A definition of GIS-T was given by Fletcher (2000:1); “GIS-T is interconnected systems of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing and disseminating information about areas that are affected by transportation activity.”

Goodchild (1999) defines the evolution of GIS-T from three perspectives as; map view, navigational view and behavioral view. According to Shaw (1999); the map view implies a static perspective of the transportation system, the navigational view assumes that information of a dynamic nature must be represented on the static geometry of a network and the behavioral view deals with the mobile characteristics of discrete objects on or off a linear network.

GIS has a map view as base function, due to its roots in cartography. GIS-T provides a way of storing, managing, editing and visualizing geographic data in digital environment. Thus, transportation features of real world are abstracted into symbol sets that can be recognized by computer. Points, lines and polygons compose the fundamental symbol set used in GIS-T studies for the representation of transportation elements. In this thesis, while constructing the study database, points are used to represent campus gates; planned metro stations; bus, minibus and campus ring stops on the transport network. Similarly, lines are used to establish the campus road network and public transport routes. Polygons are used to represent traffic analysis zones.

“For the navigational view of GIS-T, links and nodes have remained the prevailing objects of networks, with their advance for topological tasks as shortest path and service area analysis (YU, 2001:16)”. Link – node or arc – node structure of transportation network models lead for the construction of basic node topology for handling the navigational view of GIS-T. With the aid of this structure, route(s) or path(s) through the network can be defined as series of network nodes registered in the topology file. In this thesis, since centerlines of the campus roads are digitized as road segments splitting at junctions or intersections; basic arc – node topology is constructed. Then, pedestrian accessibility analysis and service coverage area estimations are carried for the proposed stop or station points in Chapter 5. The third view of GIS-T, that is the behavioral view, deals with the behavior of discrete objects such as, people or vehicles, either on or off the transportation network, considering both space and time aspects of geographic information (Egenhofer and Golledge, 1998). Hagerstrand (1970) examined the behavior of discrete objects moving in time with identities and introduced the notion of time as a third dimension in navigation. However in this thesis, all navigational analyses are performed two dimensionally, on the x and y axes of planar road network. Temporal navigation is neglected since the aim of performing network analysis is to determine the approximate service area, ridership for the stops or stations and the cumulative service areas, ridership for the routes rather than determining individuals’ temporal navigation.

“The life cycle of a transportation service consists of planning, construction, management and rehabilitation phases, which are all data intensive (Khan, A. M. and Armstrong, J. M., 2001:2).” Today’s GIS packages are capable for many issues as; vector and raster data visualization, editing, basic arithmetic and statistical calculations, buffer and overlay analysis, listing and charting, thematic mapping and surface modeling. However, GIS-T packages offer more specific tools for carrying transportation analysis. GIS-T packages, such as ArcInfo, ArcGIS of ESRI and TransCAD of Caliper Corporation, have special data models for setting up planar and non planar networks, dynamic network segmentation support, trip demand and supply modeling, route planning, accident analysis, environmental assessments and simultaneous multiple database access.

Capabilities of GIS-T can be grouped into seven categories (Caliper Corporation, 1996; Waters, 1999; Sikdar and Gupta, 2003).

- Fundamental GIS Functions,
- Overlay and Buffer Functions,
- Dynamic Segmentation Capability,
- Surface Modeling Functions,
- Raster Display and Analysis,
- Navigation and Routing Analysis,
- Analytical Transportation Planning and Modeling Functions.

Fundamental GIS functions are used for editing, displaying and measuring base maps. Since all transportation studies need transportation network, editing function allows users to construct the network by adding or deleting points, lines or polygons and coding attributes of these objects. Display function generates thematic maps according to the selected attributes by using various symbols and/or colors. Measurement functions are used for calculating the length of lines and the area of polygons. In this thesis, campus road network is constructed via arc – node based editing in ArcEditor, an extension of ArcGIS. Thematic maps, presented in Chapters 3 and 4, displaying campus physical, population and transportation structures are prepared in ArcGIS. Measurement functions are used to calculate the areas of analysis zones, building floor areas, service coverage areas and the route lengths of proposed modes.

Overlay function enables simultaneous display of two or more layers. Buffer function allows proximity analysis over network for detecting service coverage areas of facilities as transit stops, stations and routes. However, in this thesis, network based accessibility analysis are preferred for estimating stops or stations service areas rather than using over estimating buffer analysis.

Dynamic segmentation involves the division or segregation of network links into scalable segments which are homogeneous for the specified attributes. The segmentation is dynamic since it is created with respect to the attributes of network. Changes in the attributes of network objects, like pavement types or number of lanes, dynamically change the structure of network and result a new segmentation via new attributes. ArcGIS and TransCAD allow dynamic segmentation via editing network attributes. Dynamic segmentation support is useful for testing "what if" scenarios on road or utility networks, since network segments can be enabled or disabled just by editing the relevant attributes. Dynamic segmentation support is not utilized in this thesis, since it is not applicable with the basic arc – node topology offered by ArcView Network Analyst.

Surface modeling function creates three dimensional prediction surfaces for land forms, known as Digital Elevation Models (DEM), or other cost surface models. Surface models are essential for road design, route planning and accessibility, service area analysis. In this thesis, campus slope map is derived from campus DEM and accepted as a cost surface while proposing different public transport modes and routes in Chapter 4; besides in Chapter 5, pedestrian walking speeds are calculated with the hiker function according to the road slopes, derived from slope raster.

Raster handling capability permits aerial photographs and satellite images to be incorporated in GIS-T. Overlaying raster with vector base maps can be used for base map updating purposes, such as adding new links or intersections and correcting errors. In this study, campus land use and road network database, originally derived from the Infrastructure Information Structure of Ankara (AYBIS), is updated from the satellite imagery of campus (INTA, 2004).

Topological network structure, supported in GIS-T environment, enabled network analysis and routing capabilities based on a defined cost field like time, distance or fare. In Chapter 5, service area and potential ridership estimations of the proposed public transport modes' stops – stations are carried via pedestrian accessibility analysis (eg. potential ridership of a stop: number of persons accessing from campus buildings to the stop within 3 minutes by walking)

Analytical transportation planning extensions of GIS-T enabled travel demand modeling with the capabilities of digital mapping, spatial database management, graphics presentation and statistical model application. Besides, GIS-T database became capable for storing traffic analysis zones with the relevant attribute information as transit network, population, employment, buildings and boundaries. GIS-T can enhance analytical transportation planning phases by supporting travel demand modeling, illustrating demand – supply interactions and facilitating the evaluation of transportation systems. A flowchart, presenting the steps of a transportation planning study in GIS-T environment which is adapted from Khan and Armstrong (2001), is given in Figure 2.1. Besides, the flowchart of this thesis, given in Appendix A, utilizes from this flowchart given in Figure 2.1. Although the methodology of this thesis refers to the four fundamental steps of analytical transportation planning, some steps are not fully implemented since this study is a short ranged public transport planning study that aims to determine the suitable mode and route in the campus in accordance to Çayyolu metro route. Thus, neither a growth factor nor a calibration is applied in GIS-T to the zonal trip demand, estimated in Chapter 4.

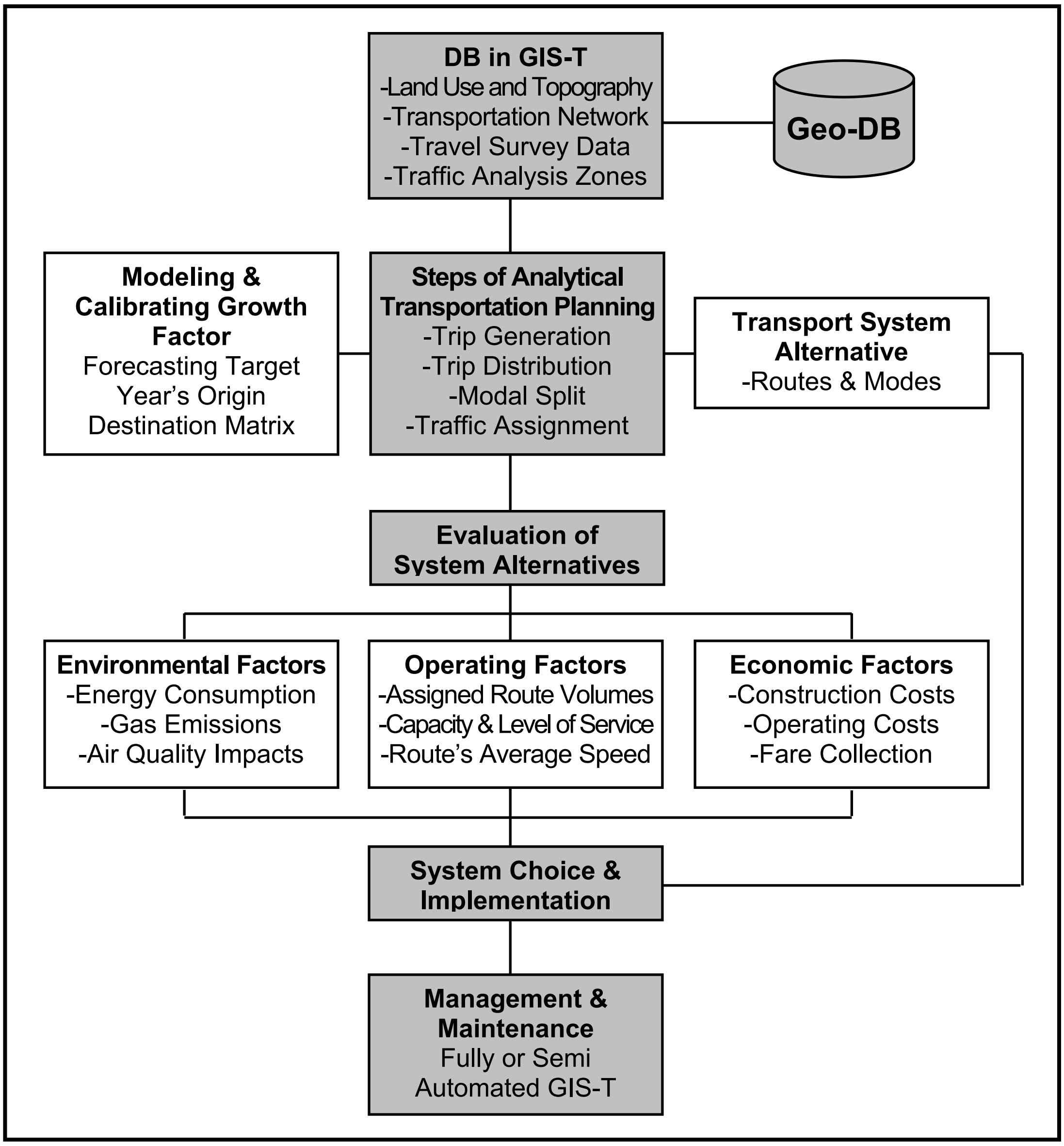


Figure 2.1 Flowchart of a transportation planning study in GIS-T environment adapted from Khan and Armstrong (2001).

2.2. Past Studies Related to Public Transport Route Planning and Methods Utilized in the Thesis

"Route design is one of the most important elements of public transport service planning in urban areas (Spasovic et al, 2001)." In urban public transport service planning, public transport routes (eg. bus, rail or trolley routes) are proposed on the main thoroughfares relative to the spatial travel demand. However, considering the heterogeneous distribution of travel demand in many traffic analysis zones, just demand based route planning may not produce optimal routes from either operator's or user's standpoint.

Public transport operators and passengers both prefer least costing routes where cost can be time, distance, respectively operating costs or fares; or combination of them. Besides, passengers usually prefer the most accessible service routes operating between their origins and destinations by also considering the relevant mode's service quality. Thus, sometimes tortuous service routes are operated for reducing the access impedance and increasing the ridership through the route. On the other side, these tortuous routes arise some problems as; increased operating costs for service operators and time budget problems for passengers or decreased safety with increased traveling speed for keeping passengers' time budget.

In the past thirty years, many studies (eg. Byrne and Vuchic, 1971; Hurdle, 1973; Wirasinghe et al, 1977; Spasovic and Schonfeld, 1993) have been carried for determining the optimal public transport routes, usually with many-to-one dedicated patterns (eg. from residential zones to central business district (CBD)), by using analytical methods. In these studies, homogeneity of the spatial trip demand is assumed for a group of traffic analysis zones or for a specific area, then public transport system elements (eg. modal chooses, stops or stations, headways etc.) are optimized for a set of routes feeding a major transfer point of a main line (eg. commuter rail routes, interurban terminals) or some central points, attraction zones (eg. CBD., recreational areas, public service areas etc.)

In contrast to above studies, which are trying to optimize public transport routes with demand based many-to-one approach, an alternative route planning and optimization method is developed by Welch et al (1993). In the out-of-direction method, spatial trip demand is assumed heterogeneous, which is more realistic, and it varies through the segments of a route. According to this method, public transport routes have potential ridership in their service areas varying relative to the accessibility of potential passengers around the stops or stations. Thus, to improve the feasibility of a public transport route, passenger accessibility should be improved along the route segments relative to the heterogeneous trip demand. This method also allows redirection of spatial trip demand towards the routes which are eased to access.

In this thesis, both methods are utilized. With the perspective of many-to-one approach, trip demand of the campus is assumed homogenous as a traffic analysis zone of Ankara and alternative public transport routes are proposed for connecting campus to the upcoming stations of new metro route which will connect southwestern corridor of Ankara to the CBD (Kızılay). With the perspective of out-of-direction method, trip demand in the campus is assumed spatially heterogeneous relative to the campus structure, explored in Chapters 3 and 4. Then route alternatives and their stops or stations are proposed relative to the trip demand and physical factors in order to widen the service coverage and attract potential passengers around the route segments with increased service accessibility. With this approach, it is also aimed to redirect a portion of the passengers to the A2 gate, which is located by the Bilkent Station, for reducing passenger load at the A1 main gate. Thus, routes proposed in this study are linked to both A1 and A2 gates with their stops or stations.

Some recent studies in the transportation literature; McGinley (2001), Spasovic et al (2001), Dhingra and Verma (2003), also practiced similar methodology with this thesis. They tried to determine optimal public transport routes, stops or stations and fleet sizes with spatially varying ridership demands relative to the passenger accessibility around the route segments.

These studies also used GIS applications and MCDA techniques for constructing mathematical models and mutually evaluating traveling, operating costs from passengers' and operators' standpoints.

McGinley (2001) carried a study for evaluating potential bus routes with a very similar methodology utilized in this thesis. He assumed that the ridership on a typical public transport route depends substantially on the population within a defined walking catchment. The framework of his case study, in Australia – Melbourne, described a series of catchment analysis for the routes to be evaluated. He calculated the population within the walking catchment areas, which are 400 m. route buffers performed in GIS. Then, he estimated the potential ridership of each route by multiplying the trip generation coefficient with the population in the catchment areas. Finally he estimated the potential ridership for each route and analyzed mutually with other physical factors (eg. route lengths) with the aid of GIS for determining the suitable routes. However in this thesis, catchment areas are determined with detailed stop or station centric accessibility analysis with the aid of campus road network rather than overestimating 400 m. route buffers. Besides, more physical constraints (eg. route slope and length, number of stops/stations etc.) are accounted in Chapter 5.

2.3. Main Software Packages for GIS-T

Many software packages and extensions are developed to deal with various transportation problems in GIS environment. However ArcInfo with ArcNetwork extension, ArcView (all 3.x versions) with Network Analyst extension, ArcGIS (only the recent 9.1 version) with Utility Network Analyst extension and TransCAD software of Caliper Corporation provide more comprehensive data models and more powerful analysis toolsets for transportation studies. According to Waters (1999), ArcInfo and TransCAD can be considered as the fully developed GIS-T packages.

Network Analyst extension of ArcView has functions as generating complicated networks, route finding, assigning portions of a network to a facility or supply in order to explore its service area. However, as an extension of generic GIS software, ArcView Network Analyst with its basic arc node topology and static network model is inadequate to compete with dynamic network analysis and analytical transportation planning (Stewart and Wegener 2000). Recent software of ESRI, released in 2005, ArcGIS v.9.1 supports construction of planar and non planar geometric networks, dynamic segmentation and accessibility analysis on these networks with Network Analyst Extension, inherited from ArcView 3.x environment. However, in this thesis, ArcView 3.x Network Analyst is used for network based accessibility and service area analysis since recent release of ArcGIS v.9.1 is not available. Else, dynamic segmentation support, offered in ArcGIS v.9.1, is not necessary for the accessibility analysis performed in this thesis. In addition to ArcView, ArcGIS Desktop v.9.0 with ArcInfo geo-processing server support is used for constructing the study database and exploring, analyzing planning and transportation related data (eg. land-use, topography, population and transportation infrastructure etc.)

TransCAD, comprehensive GIS-T software of Caliper Corporation, is a special package for analytical transportation planning. TransCAD, by means of its extended data model, supporting higher level of spatial objects, is capable for handling more sophisticated transportation issues as, directed roads, underpass and overpass, route systems over transportation infrastructures and connectivity of links at nodes (Caliper Corporation, 1996). Dedicated analytical transportation planning modules of TransCAD, fully support the four fundamental steps of analytical transport planning; trip generation, trip distribution, traffic assignment and modal split. However, TransCAD software is not used in this thesis since the aim of this study is not to implement a complete analytical transportation study for the METU campus. Moreover, specific capabilities of TransCAD, neither an origin – destination matrix that needs growth factor, nor a model that needs calibration, are needed in this study.

CHAPTER 3

PHYSICAL STRUCTURE AND POPULATION CHARACTERISTICS OF METU CAMPUS

In this chapter, physical structure and population characteristics of the METU campus is explored with the aid of Geographic Information Systems (GIS) in order to present current situation and upcoming trends about the campus structure before proposing new public transport modes and routes for the campus. This chapter also aims to demonstrate how GIS can be a valuable tool for analyzing base planning data (e.g. land-use, topography…) and to construct a reference data and analysis set for the further transport studies relating to METU campus.

First, brief history on the foundation and development of METU campus is given. Then, the location of the study area is described. Campus physical structure is examined in terms of land-use and topography. Legal structure and development strategies of the campus are examined through the master development plans of METU. Besides, campus population characteristics as, spatial distribution of the campus population, population densities and campus entrance card ownership, are also explored.

Thesis database, storing information about the campus structure, is constructed in GIS. Sources of datasets, used in this chapter, are given in Table 3.1.

Table 3.1 Sources of land-use, topography and population datasets

Dataset	Data	Source	Year
Land-use	IKONOS Satellite imagery of the study area, pan-sharpened multispectral (RGB) imagery with 1meter/pixel resolution.	INTA Space Imaging Cop. Ankara / Turkey (INTA, 2004)	06.08.2004
	Aerial photo of Ankara	General Command of Mapping, Ankara / Turkey (GCM, 2002)	2002
	(*) Buildings and roads layers from the infrastructure information system of Ankara (AYBIS)	Water and Sewerage Administration (ASKI) of Ankara Metropolitan Municipality (ABB) (ABB – ASKI, 1998)	1998
	1/1.000 scaled plans of the buildings under construction	Directorate of Construction and Technical Works of METU	2004
	1/5.000 scaled master development plan of METU	Metropolitan Municipality of Ankara (ABB, 1994)	07.02.1994
	METU Campus and Technopolis Urban Design Project	Urban Design Studio (UDS) of City and Regional Planning Department of METU	1997
Topography	1/5.000 scaled CAD based maps covering the study area, sheet codes: I9B06D, I9B06C, I9B11A and I9B11B	Water and Sewerage Administration (ASKI) of ABB	1998
Population	Students' population data	Registrar's office of METU	2003 - 2004 acad. Year
	METU staff's population data	Personnel affairs of METU	
	METU Technopolis staff's population data	Public relations office of Teknopark Inc.	2004
	METU Foundation Primary and High School's population data	Headship of the school	2003 - 2004 educ. Year
	Metu residences and guesthouse capacity data	General secretariat of METU	2004
	METU dormitories and student guest houses capacity data	Directorate of Dormitories, METU	2004
	Campus entrance cards' data	Directorate of Domestic Works of METU	2004
(*) Data is processed and updated to 2004 by site study.			

3.1. History of Middle East Technical University

METU was established in 1956 under the name of Middle East High Technology Institute to train Turkish and foreign students in scientific and technical fields. The foundation act was enacted in 1959.

According to the original plan, designed in 1961, university structures, covering about 65 hectare land, were sited on the northern part of the campus land, which totally covers about 4.250 hectare land. Other bare land, covering about 4.150 hectare, was afforested or preserved as natural areas. According to the original plan, university campus was proposed to combine applied and social sciences; within this perspective METU grew parallel to the original campus plan between the years 1963 – 1980. However, initially designed campus area came to its limits in the 1980's. As Günay (1997) also denoted, new departments and facilities like ODTUKent residences, METU Technopolis and METU Foundation High School; started to disperse over the northwestern parts of campus. Spatial extensions have widen the built up area of the campus about one kilometer to the west while decreasing the pedestrian accessibility and increasing the motorized traffic on METU campus; which was originally planned on a pedestrian alley for unimpeded pedestrian access and a surrounding service ring for the motorized modes of transport.

Following instances also prove that METU campus has grown more than its spatial and demographic limits proposed in the original plan. In the year 2004, gross built-up area of the campus has reached 155 hectare (Figure 3.1-a) which was about 65 hectare in the 1970's (Figure 3.1-b). Moreover, gross settlement area of the campus has reached 220 hectare in 2004. This basic measure denotes that METU campus has grown more than two fold within the last 25 year. Besides, according to the transportation data obtained from Gökbulut's study (2003), between the years 2000 and 2003, rate of the passengers arriving to METU by private cars between 08:00 and 17:00 in workdays, had increased from 24 % to 39 %. Moreover, based on the registries of 2003 – 2004 academic year, METU was offering 37 undergraduate programs in five faculties and 67 graduate programs in five graduate schools, constituting a student population of 20.372. Besides, the overall campus population was about 30.000 based on the same data.

However, as Gökbulut (2003) also stated in her study, in 1961 METU campus schema was designed to serve a maximum population of 15.000 inhabitants including students, academics and other staff.

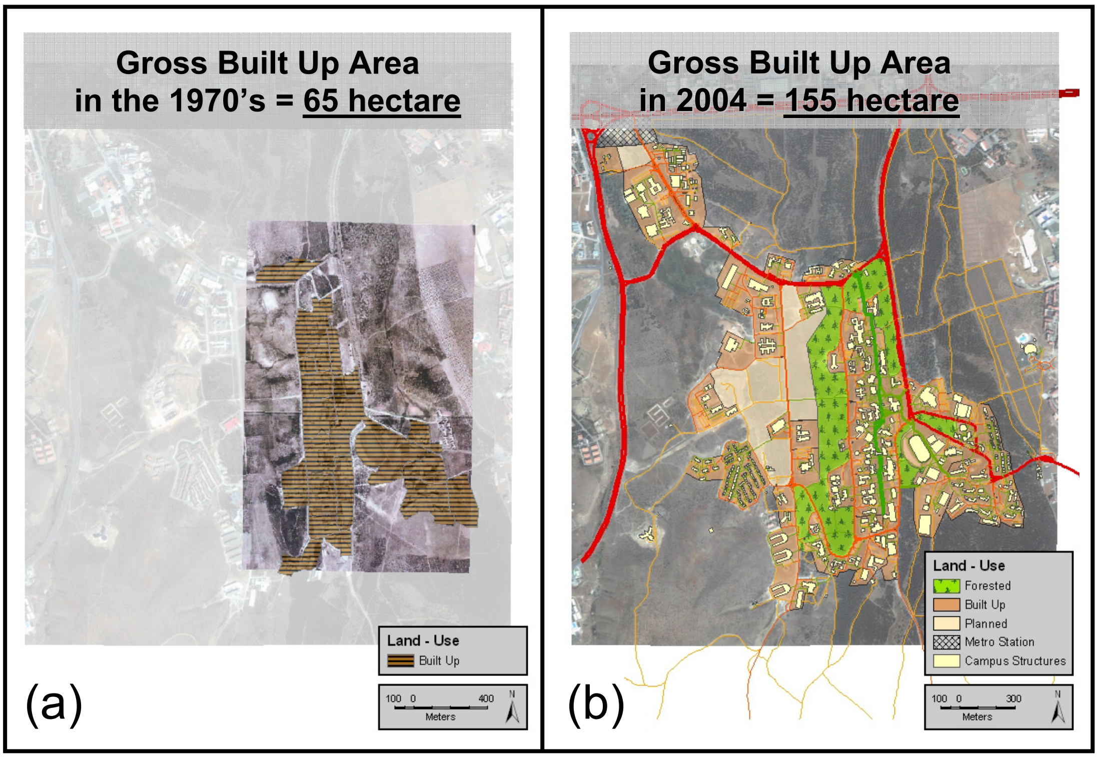


Figure 3.1 Built up area of the METU Campus (a) in 1970's and (b) in 2004

3.2. Location of the Study Area

METU campus is located on the southwestern part of Ankara (Figure 3.2-a). All faculties and departments are located in the same campus which is covering about 4.250 hectare land on the southern side of the İnönü Boulevard also known as Ankara – Eskişehir highway. Geographical extents of the METU campus is between 39 Degree, 54 Minute, 34 Second, North by 39 Degree, 48 Minute, 40 Second North and 32 Degree, 45 Minute, 50 Second, East by 32 Degree, 51 Minute, 15 Second, East on earth (Figure 3.2-b). Most of the campus structures and all of the faculties and departments are located at the northern part of the campus area which is practically perceived as “METU Campus” in daily life (Figure 3.2-c). Gross settlement area of the campus, covering about 220 hectare on the southern side of the Ankara – Eskişehir highway, is accepted as the study area of the thesis. Hence in this chapter; land-use, topography and population analysis are performed for the northern part of the METU campus, which is laying between Ankara – Eskişehir highway and METU student dormitories.

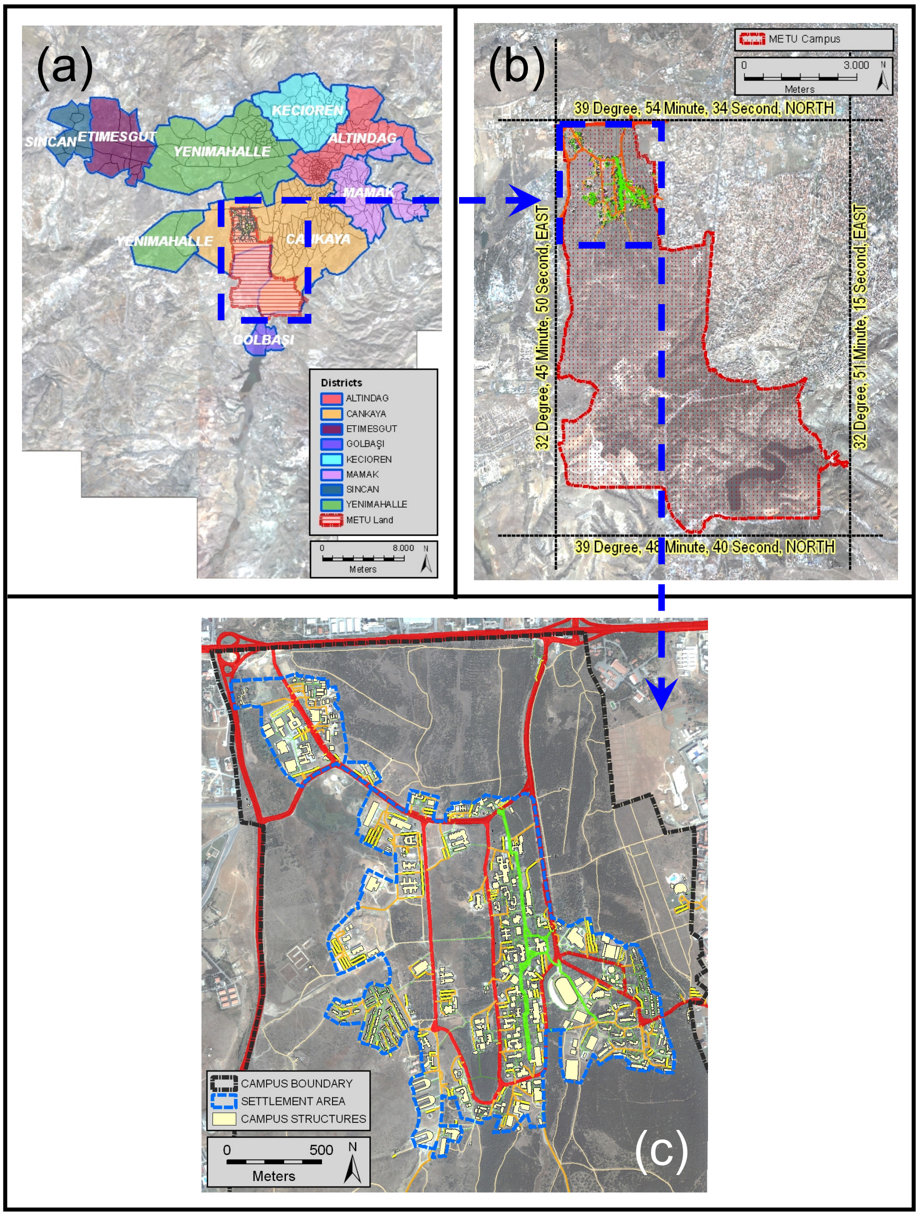


Figure 3.2 Location of the (a) METU Campus in Ankara (b) METU Campus Land and (c) study area

3.3. Physical Structure of the METU Campus

Physical structure of the campus is analyzed in terms of land use and topographic domains. Land use categories, campus structures, gates and boundaries are examined through the spatial database constructed in GIS environment. In addition; land use categories and floor space indices [(2)] are examined through the 67 determined analysis zones, comprising the settlement area of the campus. Besides, land use and construction permits in campus are presented according to the current 1/5.000 scaled METU Master Development Plan, approved by the Metropolitan Municipality of Ankara (ABB) (ABB, 1994). Digital elevation model (DEM) and slope map of the study area are produced for examining topographic domains, directly affecting to the design and evaluation process of the public transportation modes and routes. Finally, for a better visual perception, 3D scene of the study area is produced for land use and topographic features.

3.3.1. Land Use of the Campus

Land use of the campus is produced by constructing a spatial database in GIS via updating the structural changes that were not available in the Infrastructure Information System of Ankara (AYBIS, 1998). Land use information of the study area is updated from the IKONOS satellite imagery of the campus (INTA, 2004) and from the photographs of the campus acquired between May 2004 and November 2004. Besides, 1/1.000 scaled plans are used for digitizing the new buildings under construction.

[(2)] Floor Space Index: "Ratio of the gross floor area of a building or structures to the gross area of the lot on which the building or structures are located. The term floor area ratio has also the same meaning. For example, a floor space index of 2 would indicate that the total floor area of a building could be up to 2 times the gross area of the lot on which it is located. (PWGSC, 1983)" Thus, floor space index can be accepted as an indicator of structural density in a lot or zone.

IKONOS satellite imagery is pre-processed for radiometric corrections and enhancements. Adaptive majority filtering with a 3x3 pixel kernel is applied for the removal of individual salt & pepper noise. Also, min – max histogram stretch is applied on each band for visual enhancement. Lastly, image is registered with the 40 selected ground control points (GCP) and geometrically rectified with a third order polynomial function resulting a root mean square (RMS) error of 3,4 meter. Since an RMS error of 3,4 meter is a reasonable result for updating the land use database, satellite imagery was not orthometrically rectified. The satellite imagery and all datasets of the thesis have the same projection system of Gauss Kruger (Transverse Mercator) Projection, Central Meridian : 33, based on the European Datum 1950, using International Spheroid 1924, which are also common for the AYBIS database.

All the buildings and/or segments of the buildings and other structures in the study area are digitized from the geo-rectified satellite imagery. Besides, SATGEB and MILSOFT buildings located in the Technopolis and the Institute of Informatics building, under construction, are digitized from the 1/1000 scaled plans. Totally 1008 campus structures and/or building segments are registered into the spatial database with the attributes of; number of floors, base area, floor area, land use category and land use annotations. Adjacent segments of the composite campus structures are merged and dissolved into integrated buildings as faculties and departments; also functional differentiations between the segments of the same buildings are generalized into a dominant land use category which is determined from the category having the most floor area in the building (Figure 3.3 and Table 3.2). Building segment based digitization, merging and dissolving procedure for achieving a generalized land use map enabled detailed calculation of the buildings' floor area which can be assumed as an indicator of usage in the buildings. For the population analysis in this chapter and for the population based transport coverage analysis in Chapter 5, floor areas of the buildings, calculated from the land use database, are used as an independent variable for proportionally distributing the campus population to the buildings when spatial distribution of the population is indefinite and/or multiple buildings occur for a department, faculty, unit or any campus facility since the attribute, floor area is assumed as an indicator for spatial usage and activity.

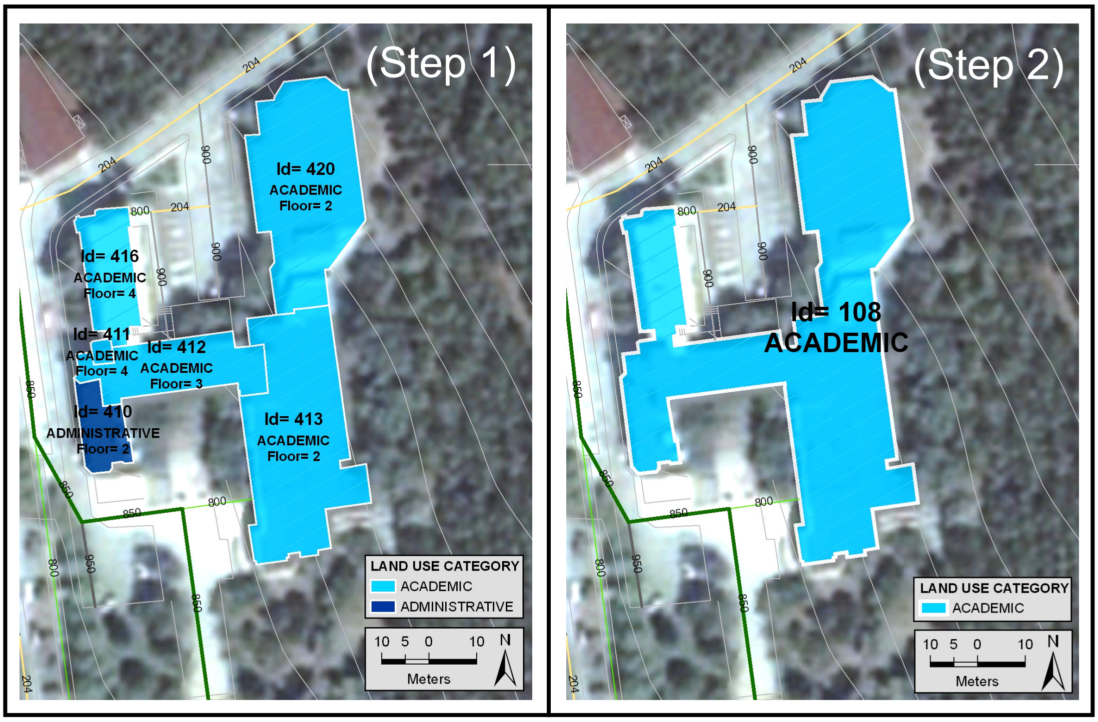


Figure 3.3 Constructing land use map; Step1: digitizing building segments, Step2: merging segments and generalizing land use category

Table 3.2 Constructing land use database; Step1: registering digitized building segments, Step 2: reregistering merged building with generalized land use category

<table>
<tr><th>Id</th><th>Base Area (m²)</th><th>Floor Area (m²)</th><th># of Floor</th><th>Land Use Category</th><th colspan="2">Land Use Annotation</th></tr>
<tr><td colspan="7">Step 1: Digitized Building Segments and Database Attributes</td></tr>
<tr><td>410</td><td>158</td><td>317</td><td>2</td><td>Administrative</td><td rowspan="6">Faculty of Economic and Administrative Sciences</td><td rowspan="3">Dean’s Office</td></tr>
<tr><td>411</td><td>22</td><td>89</td><td>4</td><td>Academic</td></tr>
<tr><td>412</td><td>403</td><td>1.209</td><td>3</td><td>Academic</td></tr>
<tr><td>413</td><td>991</td><td>1.983</td><td>2</td><td>Academic</td><td rowspan="3">Department of Economics - Department of Political Science and Public Administration</td></tr>
<tr><td>416</td><td>280</td><td>1.120</td><td>4</td><td>Academic</td></tr>
<tr><td>420</td><td>888</td><td>1.775</td><td>2</td><td>Academic</td></tr>
<tr><td colspan="7">Step 2: Merged Building Segments and Generalized Database Attributes</td></tr>
<tr><td>108</td><td>2.743</td><td>6.492</td><td>~2,4</td><td>Academic (including 5 academic, 1 administrative segments)</td><td colspan="2">Faculty of Economic and Administrative Sciences: Dean’s Office - Department of Economics - Department of Political Science and Public Administration</td></tr>
</table>

As a complementary part of the study database, transportation structure elements as; vehicle roads, pedestrian paths, parking lots, public transportation routes, stops and ODTÜ, Bilkent Stations of the upcoming metro route (Metro of Çayyolu, planned to start service in 2006) are digitized and registered into the database. By means of this database, transportation structure of the campus is analyzed in Chapter 4. Totally, 1291 pedestrian paths, 1013 vehicle roads and 318 parking lot segments are digitized from the campus satellite imagery (INTA, 2004) and stored as path or road segments centerline database. Although road centerlines have a linked segment structure built via arc node topology; all the road or lane segments longer than 15 meter are divided into equal segments varying about 10 meter of each, totally constituting; 3026 pedestrian paths, 7702 vehicle roads, 991 parking lot segments in the campus. New spatial segmentation enabled accurate calculation of the roads’ or paths’ slopes which affect transportation analysis like; pedestrian walking speed, travel time estimation or transport mode and route evaluations, performed in Chapter 5. Parking lots are digitized as path centerlines and centerlines are registered either one sided parking lot or double sided parking lot. Routes, stops and timetables of available public transportation modes; Metro of Çayyolu (construction started in 2002; planned to start service in 2006), bus, minibus, campus ring and staff services were registered into the study database. However, these domains are explored in the transportation structure part within Chapter 4.

Land use map of the METU campus is presented in Figure 3.4. Land use functions of the campus structures are grouped into 12 categories (Table 3.2). Similarly, vehicle roads, pedestrian paths and parking lots in the campus are graded into 11 categories (Appendix B). Campus gates are also presented in the land use map (Figure 3.4) as; A1 main gate, located on the northern part of campus on the Ankara – Eskişehir highway (İnönü Boulevard); A2 service gate located on the northern part of the campus by the Bilkent bridge on the İnönü Boulevard; A4 gate, called as 100. Yıl gate, located on the eastern part of the campus by the gendarme station and A7 gate, called as Bilkent gate, located on the western part of the campus on the Bilkent Boulevard.

Table 3.3 Land use categories of the campus structures

Land Use Category		
ID	**Name**	**Scope**
1 – 01	Academic	- Faculties, departments and institutes - Preparatory school - Undergraduate programs - Graduate programs - Continuing education center
2 – 02	Administrative	- Presidency office - General secretariat - Personnel affairs - Students affairs - Computer center - Directorate of administrative and financial affairs

Table 3.3 (continued)

<table>
<tr><th colspan="4">Land Use Category</th></tr>
<tr><th>ID</th><th colspan="2">Name</th><th>Scope</th></tr>
<tr><td>3 – 03</td><td rowspan="2">Socio – Cultural</td><td>Social</td><td>- Student clubs
- Directorate of social services
- Cafeterias
- Post office
- Foundations and relevant associations
(METU Dev. Found., M. Parlar Found. etc.)</td></tr>
<tr><td>3 – 04</td><td>Cultural</td><td>- Library
- Museum
- Cultural and convention center</td></tr>
<tr><td>4 – 05</td><td colspan="2">Sports</td><td>- Sports fields
- Sports centers
- Tennis courts
- Swimming pool</td></tr>
<tr><td>5 – 06</td><td colspan="2">Health</td><td>- Health and physiological center</td></tr>
<tr><td>6 – 07</td><td colspan="2">Education</td><td>- METU Foundation Primary and High School
- Day nursery</td></tr>
<tr><td>7 – 08</td><td rowspan="2">Accommodation</td><td>Residential</td><td>- METU residences
- ODTÜKent</td></tr>
<tr><td>7 – 09</td><td>Dormitory</td><td>- Students' dormitories
- Guesthouses</td></tr>
<tr><td>8 – 10</td><td colspan="2">Commercial</td><td>- METU Technopolis
- Shopping centers
- Food and drink services
- Banks</td></tr>
<tr><td>9 – 11</td><td colspan="2">Technical</td><td>- Directorate of construction and technical works
- Transportation affairs
- Electrical affairs, transformer stations
- Water and heat affairs
- Mechanical workshops
- Depots</td></tr>
<tr><td>0 – 12</td><td colspan="2">Other</td><td>- Gendarme station
- Greenhouses
- Other undefined structures</td></tr>
</table>

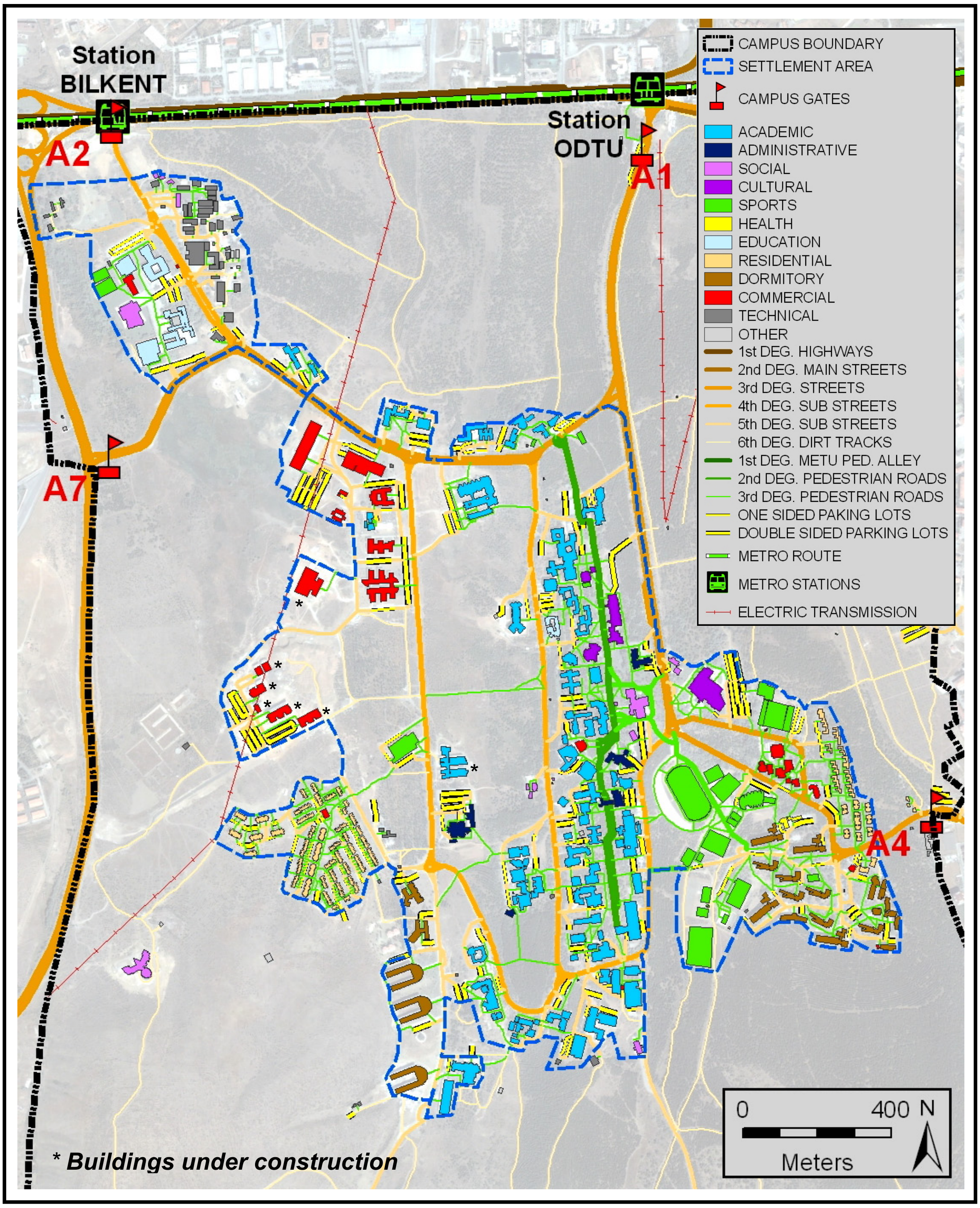


Figure 3.4 Land use of the METU Campus according to the categories of campus structures

Figure 3.4 contains 338 structures and/or building blocks in 12 land use categories, constituting a total base area of 316.000 m^2 and a total floor area of 680.000 m^2. According these indicators, average number of floors in the campus is detected as 2,15 floors which denotes a horizontal settlement with respect to human scale.

The first step in any analytical transportation study is the determination of the analysis zones (Lane et al (1971 in Gülgeç, 1998)). Campus study area is segregated into adjacent zones by grouping campus buildings. Analysis zones are allocated according to the spatial and functional distribution of the campus structures and buildings. Totally, 67 adjacent analysis zones are determined. Campus land use structure is reevaluated by means of these 67 analysis zones which enabled zonal explorations as calculation of the structural density, represented by zone's floor space index. In addition to the land use analysis, spatial distribution of the campus population and its density is calculated for the same analysis zones. Moreover, based on these zones, transportation analysis as; trip generation – attraction and travel desire lines estimations, are performed in Chapter 4.

Land use of the campus, presented in Figure 3.4, based on the land use categories of campus structures, is reevaluated according to the analysis zones. Zone based land use map of the campus, presenting dominant land use category in each zone, is given in Appendix C. Dominant land use category of each zone is determined according to the usage category, having the largest floor area in the relevant zone. Zone based explorations as; total floor area of the structures within each zone and floor space indices of the analysis zones are presented in Appendix D. Finally, spatial attributes and indicators of the study zones are summarized with a list, given in Appendix E, covering all analysis zones.

Total floor areas in the zones and floor space indices of the zones are overlaid in Figure 3.5, in order to explore built up distribution and structural density together.

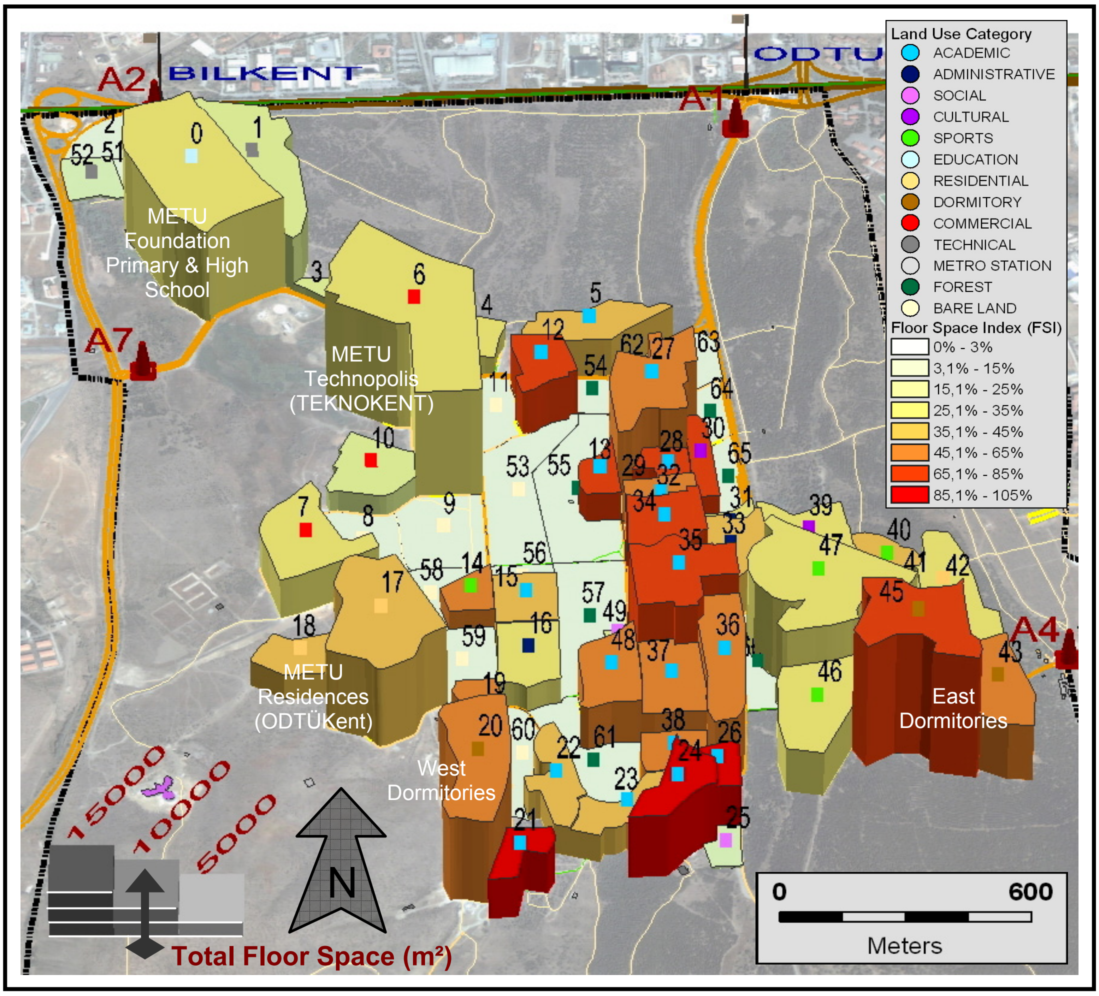


Figure 3.5 Total floor areas in the analysis zones overlaid with the floor space indices of the analysis zones

In Figure 3.5, total floor area in each analysis zones is visualized by proportionally extruding the zone in Z axis according to the cumulative floor area in that zone. Floor space indices are given via graduated color symbology. Besides, land use categories of the zones are symbolized with colored dots.

Floor space index (FSI) values vary between 31 % and 74 % within the core campus ring which comprises presidency office, library, cafeteria and most of the departments. Besides, FSI values of the academic zones within the core campus ring vary between 48 % and % 74. However, when the whole built up area of the campus is considered, FSI values vary between 4 % and 105 %. Since FSI is an indicator of structural density for a zone, this exploration denotes that structural density variations increase and built up homogeneity decreases towards the western and eastern zones of the campus.

3.3.2. Development Strategies and Master Plan of the Campus

Current 1/5.000 scaled Master Development Plan of the METU campus was approved by the Metropolitan Municipality of Ankara (ABB) on 07.02.1994 (ABB, 1994) as a part of the Ankara 2025 aimed Metropolitan Development Plan. According to this plan, 418 hectare land was allocated as the gross settlement and development area of the campus. 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 Technopolis on the west and METU Residences (ODTÜKent) on the southwest. Thus, main development direction of the campus is determined westwards according to the plan.

According to the development strategies of master plan, within the western road ring, adjacent to the core campus road ring, 43 hectare land is allocated for academic, cultural and administrative usages. In this zone 12 hectare land is used for academic and administrative domains and 20 hectare land is afforested because of the hard topography. However, 11 hectare bare land is still available for the expansion within this zone. In addition, a subsidiary administrative unit is proposed on the south junction of Technopolis, crosswise the gymnasium. According to the same plan, 16 hectare land is allocated for the METU Foundation Primary & High School and 6 hectare land is still available on the northwestern segment of the campus for new educational structures.

Presidency of METU offers housing opportunities within the campus for its academic and administrative staff. In the year 2004, METU was offering totally 454 housing units and a guest house. 120 residences and a guest house are located on the eastern part of the campus. Besides, 334 houses are available in the ODTÜKent residential zone, covering 9 hectare on the western side of the campus. According to the plan, 75 hectare bare land is allocated for the expansion of ODTÜKent towards southwest of the campus.

“In the year 1996, 3,5 hectare campus land was allocated on the western side of the campus for the establishment of METU Technopolis (MetuTech, 2005).” In 2000, buildings of İkizler and Halici Software Companies are established in this zone. According to the METU Campus and Technopolis Urban Design Project (UDS, 1997), Technopolis comprises from 6 segments totally covering 73 hectare land on the western and southwestern segment of the campus (Figure 3.7). However, this project has not been legally approved yet by the Metropolitan Municipality of Ankara. According to the legally approved plan, the only campus land allocated to the Technopolis is located on the western part of the campus and covers 24 hectare.

In the year 2005, METU Technopolis covers 19,6 hectare land and almost settled within the development area proposed by the legally approved plan. METU Technopolis has been the most rapidly growing part of the campus for the last five years with the buildings of; Silver Blocks finished in 2002, MODSİM finished in 2002, Silicon Blocks finished in 2005; moreover SATGEB and MilSoft buildings under construction.

Master plan of the campus also proposes changes in the transportation structure of the campus. In addition to the existing gates, a new gate is proposed on the Bilkent Boulevard, for redirecting ODTÜKent traffic from gate A1 to the new gate. According to the Ankara 2025 aimed Metropolitan Development Plan, two new metro stations are proposed on the northern boundary of the campus. In this study, ODTÜ and Bilkent Metro Stations are two dominant transportation elements for the evaluation of the public transportation structure of the campus since they supply direct or indirect connection possibility for the campus to the rail network of Ankara. In addition to the rail transportation facilities, Anadolu Boulevard is proposed to connect the ring road of Ankara in the north to south direction according to the Ankara 2025 aimed Metropolitan Plan. Hence, Anadolu Boulevard is proposed to be extended southwards by the eastern boundary of the campus. Also, a new junction is proposed on the Anadolu Boulevard, by the eastern side of the campus, corresponding to the Faculty of Economic and Administrative Sciences in the horizontal direction. Besides, a new connection road is proposed between the junction on the Anadolu Boulevard and the junction by the Department of Basic English as an alternative entrance to the gate A4 according to the Ankara 2025 aimed Metropolitan Development Plan.

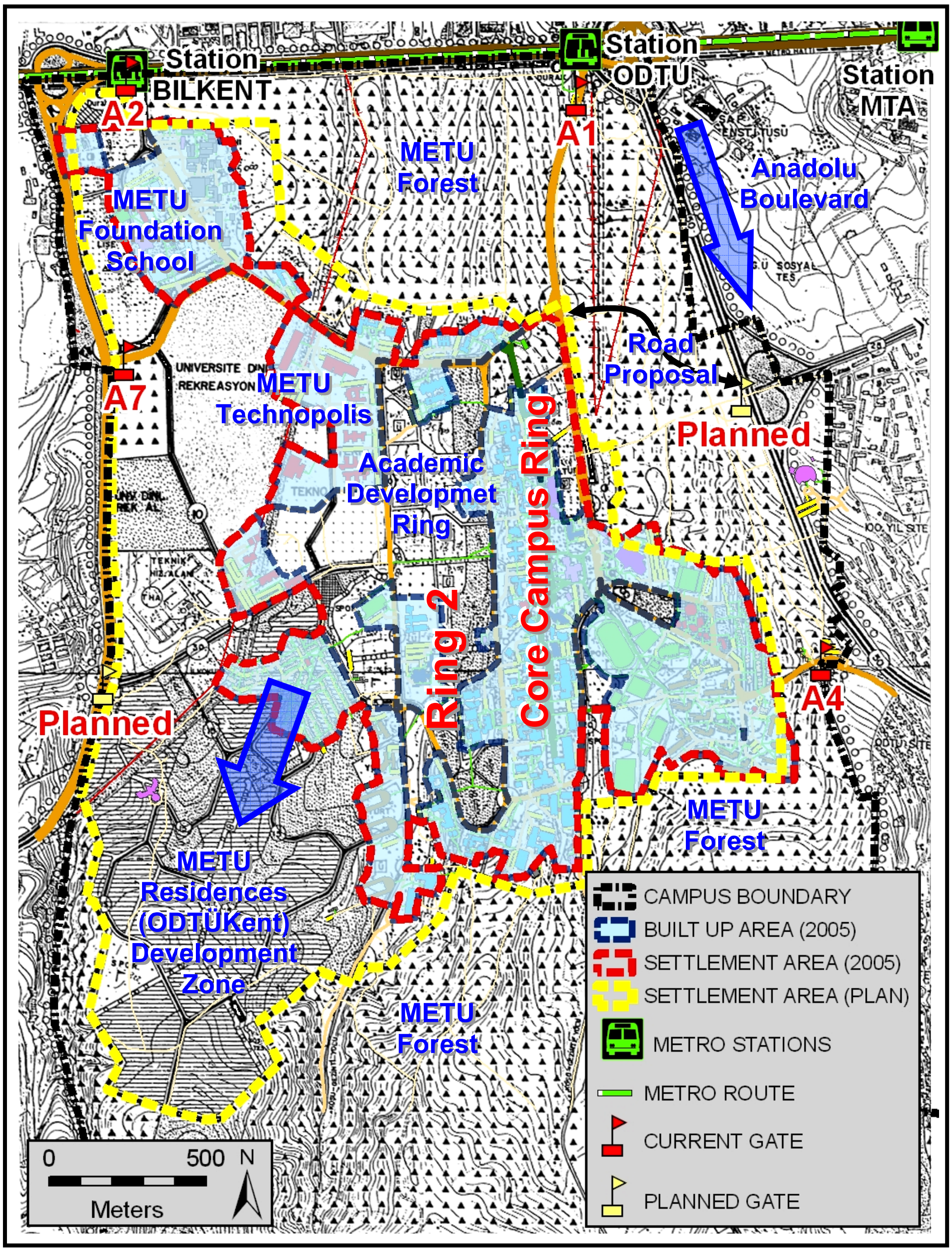


Figure 3.6 Master Development Plan of the METU Campus (ABB, 1994)

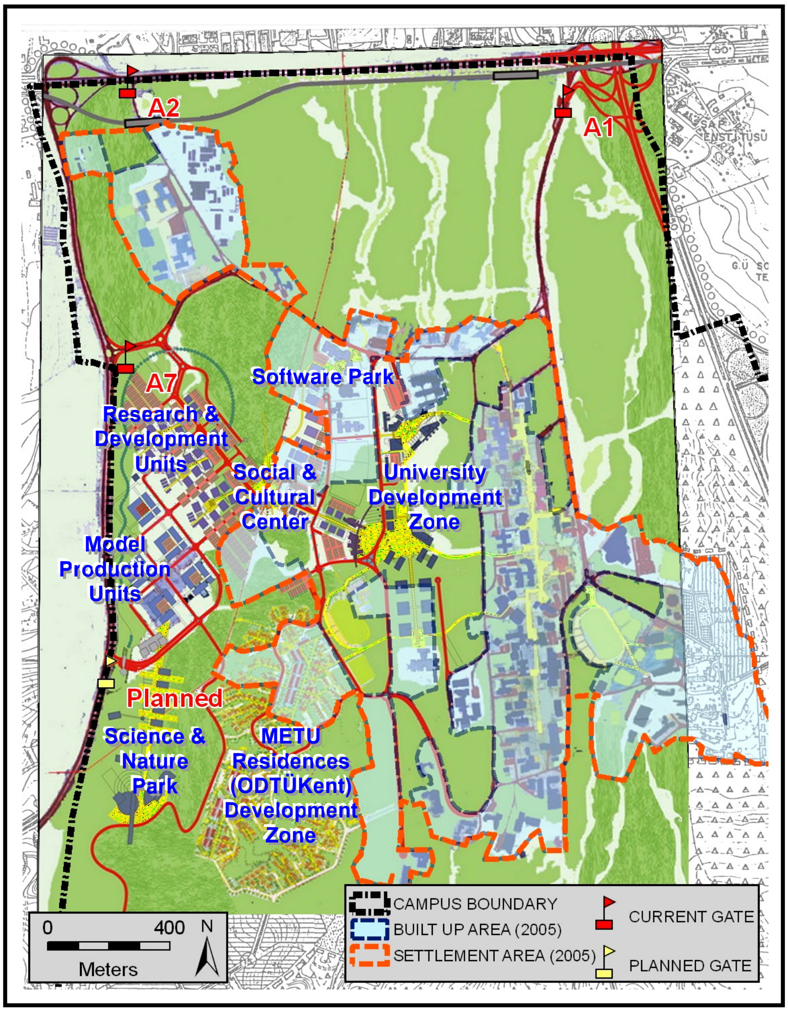


Figure 3.7 METU Campus and Technopolis Urban Design Project (UDS, 1994)

3.3.3. Topographic Characteristics of the Campus

Digital elevation model (DEM) of the study area is generated via ESRI ArcGIS v.9.0 Geostatistical Analyst Extension in order to explore the topographic characteristics of the study area. Four sheets of 1/5.000 scaled CAD maps, covering northern part of the METU campus, are used to generate the DEM. Topography layers of these maps, having 1 meter contour intervals, are imported into GIS database and the contours are merged into one integrated polyline shapefile. The shapefile, storing contour data, is cropped relative to the study area in order to exclude the excess amount of data from the interpolation process. Since, geostatistical analyst extension of the ArcGIS v.9.0 can only generate prediction surfaces by interpolating values from the point datasets, cropped polyline contour dataset is converted into points from the nodes and vertices of the contours. Preparation stages of the point based elevation dataset are presented in Figure 3.8.

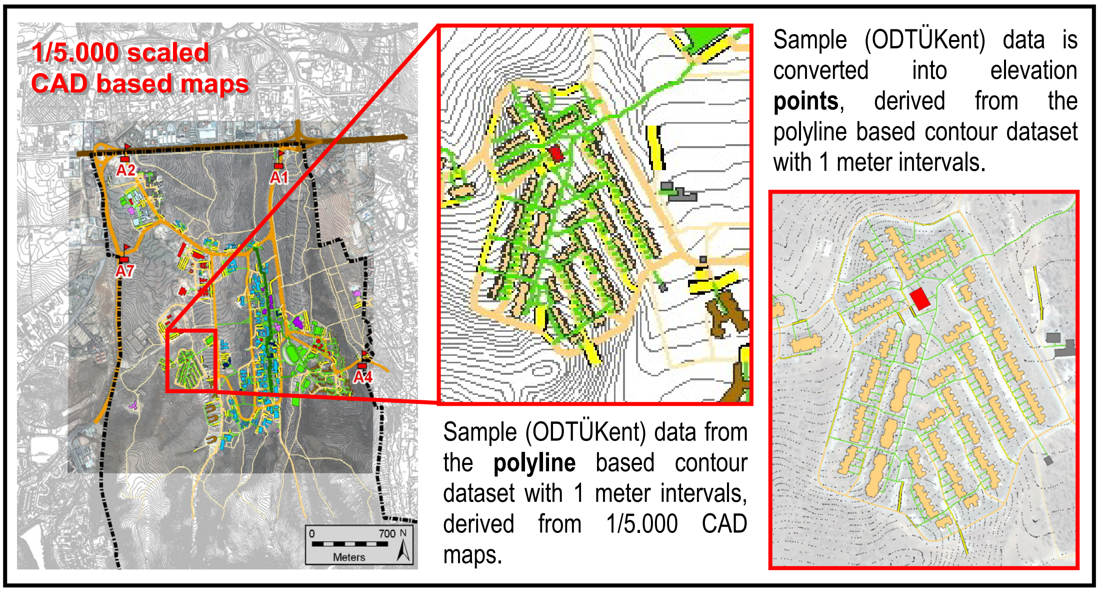


Figure 3.8 Preparation of the point based elevation dataset of the campus

DEM of the study area is generated via Kriging Interpolator [(3)] with the aid of the geostatistical analyst. Totally, 218.033 points with the elevation values varying between 845 and 1024 meters are included in the interpolation process. According to the prediction error statistics for the Universal Kriging

[(3)] Kriging Interpolator: "An interpolation method in which the surrounding measured values are weighted to derive a prediction for an unmeasured location. Weights are based on the distance between the measured points, the prediction locations, and the overall spatial arrangement among the measured points. (ESRI, 2004)" interpolation [4], root mean square (RMS) error of the DEM was calculated as 0,357 meter. Predicted geostatistical layer is exported into ESRI grid format with 1x1 meter/pixel resolution (Figure 3.9). Then, hill shade layer is derived from the DEM via spatial analyst for visualizing the terrain relief on campus.

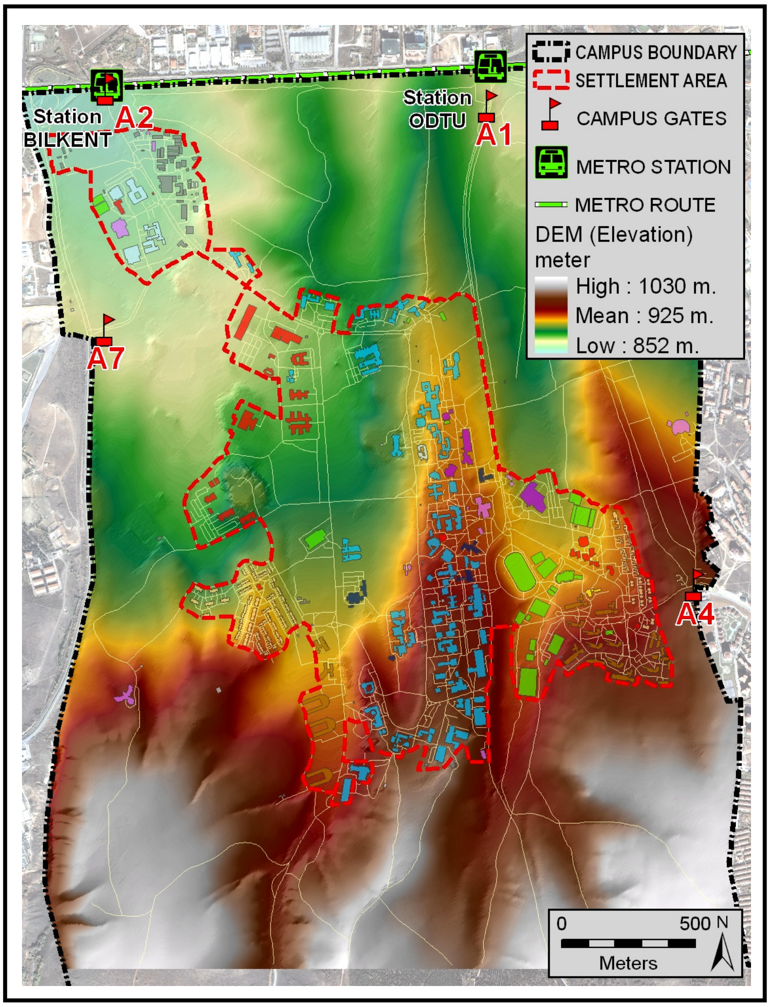


Figure 3.9 Digital elevation model (DEM) of the campus

[4] Universal Kriging Algorithm: "Produces interpolation values by assuming a trend surface with unknown coefficients, but allowing local influences due to nearby neighboring values. It is possible to over fit the trend surface, which does not leave enough variation in the random errors to properly reflect uncertainty in the model. When used properly, universal kriging is more powerful than ordinary kriging because it explains much of the variation in the data through the nonrandom trend surface. (ESRI, 2004)"

Slope map of the study area is derived from the DEM of the campus (Figure 3.10).

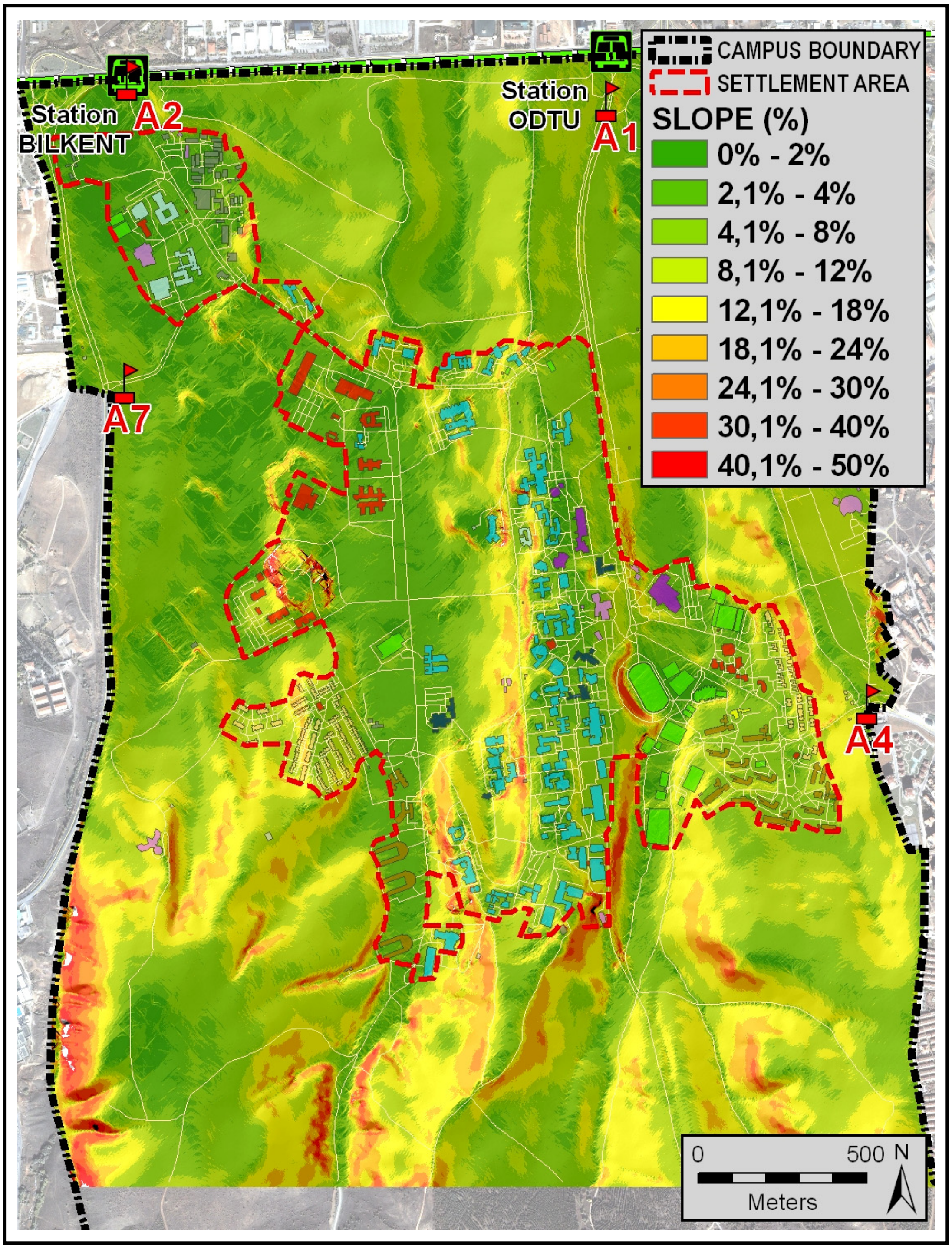


Figure 3.10 Slope map of the campus

In Figure 3.10, it is possible to track some paths and alleys through the vertical axis on campus however it is not possible to track any apparent path from west to east and east to west because of the bevels in the horizontal axis.

Slope characteristic of the campus can be a restrictive factor for choosing the suitable public transport mode; moreover slope and topographic characteristics can be guiding factors for designing transport modes' routes. Within this context, slope tolerances limits for several public transportation modes are given in Chapter 4 and slope values on the campus are spatially queried according to these limits.

3.3.3.1. Exploring slope characteristics of campus roads

In public transportation route planning, existing roads can constitute suitable service paths since they are usually interconnected with the land use. Thus most of the public transportation service routes are planned with the guidance of road schemas. Similarly, existing campus roads can guide while proposing service routes for the probable public transport modes in the campus. Within this scope, routes of the probable public transport modes can be proposed parallel to the existing campus roads; until they cover the trip demand in the campus.

In order to explore slope characteristics of the campus roads, previously digitized road segments are divided into equal sub segments with track lengths varying between 10 and 15 meter for increasing the calculation accuracy. Each segment's average slope is calculated with the aid of the ArcView extension; "surface tools for points, lines and polygons (Jenness, 2005)" and slope map of the campus roads is given in Figure 3.11.

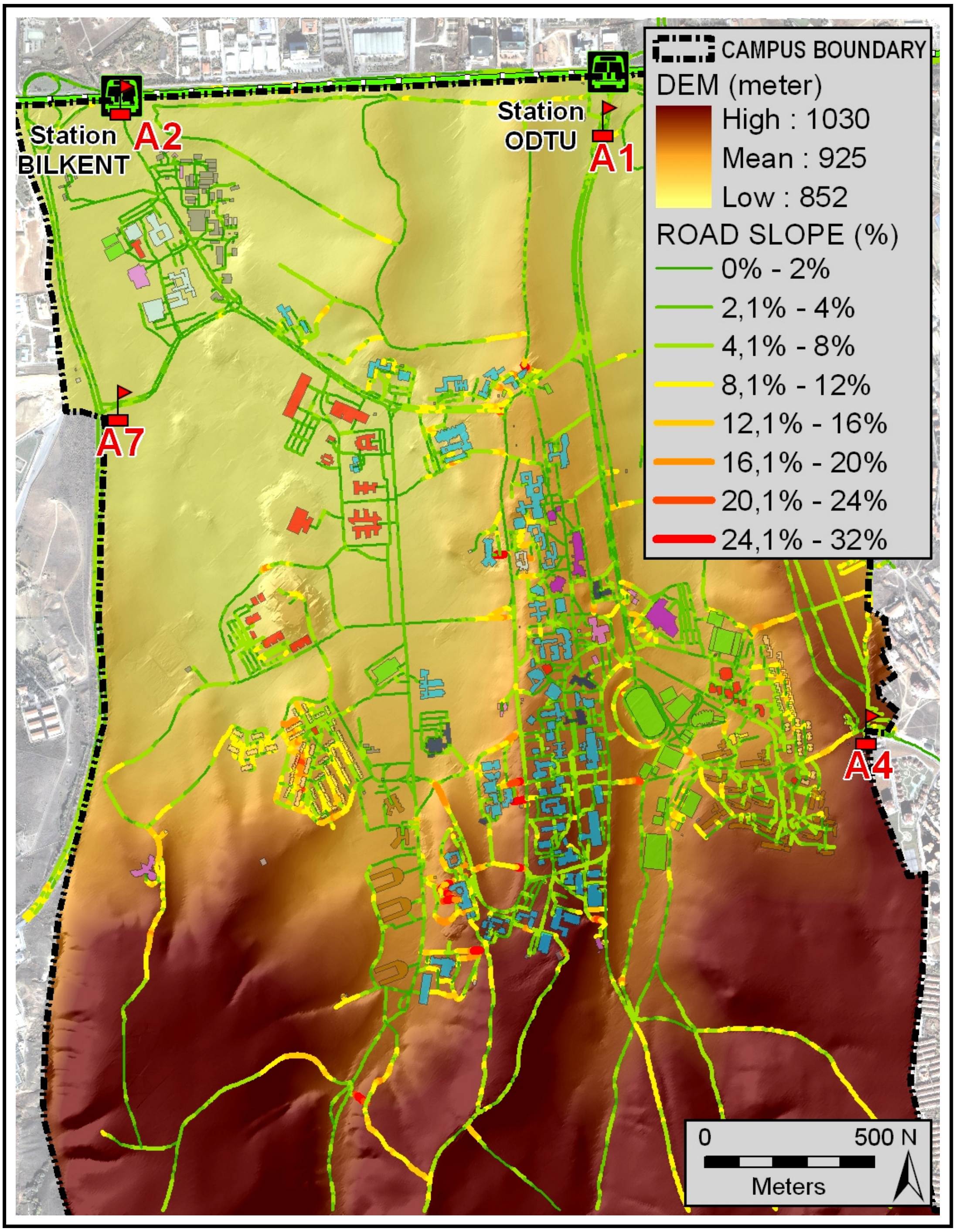


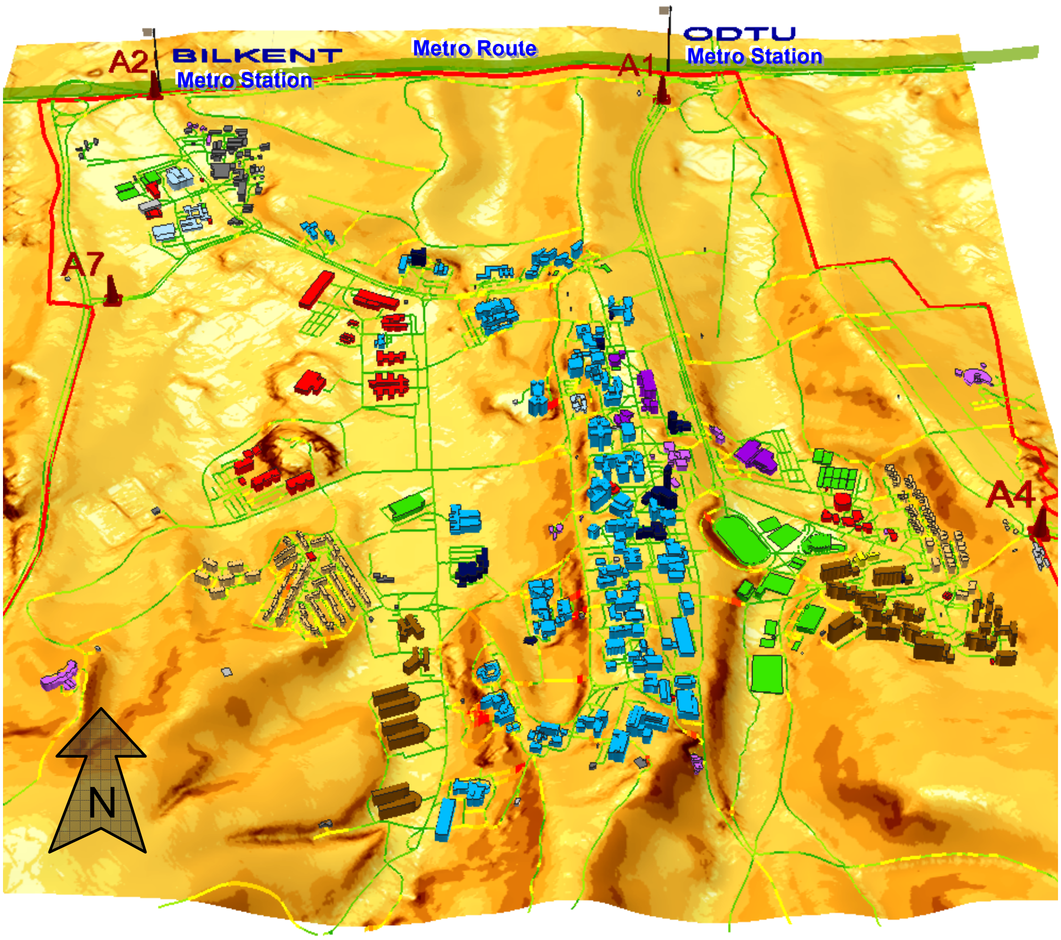
Figure 3.11 Slope map of the campus roads

According to Figure 3.11, some main roads having steeper slope more than 12% (slope upper limit for guided light transit) are: the road connecting Technopolis junction to the junction by the Department of Basic English, the road segment connecting ODTÜKent junction to the Department of Food Engineering and the road connecting the junction in the east dormitories zone to the A4 gate.

By calculating the average slope for each road segment, in Chapter 4, campus roads are spatially queried for the determining the suitable service route of each public transport mode according to mode's slope tolerance limits. Besides, average slope values of the campus roads are also used in Chapter 5 for assessing the proposed station's or stop's accessibility and service coverage area which depends on the pedestrian travel speed on the distributive and collector road segments.

3.3.3.2. Visualizing of the Campus in 3D

For a better visual perception, study area is modeled in 3D space with its land use and topography. Land use includes campus buildings and roads; topography includes DEM and the slope map. 3D visualization is performed via ArcScene which is a supplementary application in the 3D analyst extension of ArcGIS for 3D visualization. In Figure 3.12, slope map of the study area is extruded with the elevation values derived from DEM. In order to ease the perception in the vertical axis, elevation values of DEM are exaggerated two times. Then campus buildings and roads are overlaid on the slope map. Buildings are extruded according to their floor heights. Finally, campus roads are overlaid on the extruded slope map and visualized with proportional widths and colors according to their slopes given in Figure 3.11.



* 3D visualization of the campus is schematic; it does not have any constant scale.
** Campus topography is exaggerated by 2 times the original DEM.
*** Metro of Çayyolu is under construction and planned to start service in 2006.

LAND USE CATEGORY
ACADEMIC
ADMINISTRATIVE
SOCIAL
CULTURAL
SPORTS
EDUCATION
RESIDENTIAL
DORMITORY
COMMERCIAL
HEALTH
TECHNICAL
OTHER

CAMPUS BOUNDARY
SETTLEMENT AREA
ROAD SLOPE (%)
0% - 2%
2,1% - 4%
4,1% - 8%
8,1% - 12%
12,1% - 16%
16,1% - 20%
20,1% - 24%
24,1% - 32%

SURFACE SLOPE (%)
0% - 2%
2,1% - 4%
4,1% - 8%
8,1% - 12%
12,1% - 18%
18,1% - 24%
24,1% - 30%
30,1% - 40%
40,1% - 50%

Figure 3.12 3D visualization of the campus with slope map

3.4. Population Characteristics of the Campus

In this part, two main topics; campus population and campus entrance card ownership, are analyzed in order to explore the population characteristics of METU campus. First, campus population and different population groups composed of different campus users or inhabitants (e.g. students, academic staff, technopolis staff…) are explained. Then, the spatial distribution of the overall campus population and population density is explored according to the previously determined 67 analyses zones. Afterwards, different types of campus entrance cards, offered for different groups of campus users, are explored for estimating the level of private car usage in the campus. Finally, spatial distribution of the campus entrance cards and card ownership is queried according to the same analyses zones.

3.4.1. Population Structure of the Campus

Campus population structure can be categorized in to the following groups: students; academics, administrative and other staff; METU Technopolis staff; METU Foundation School's staff and students. In addition, there are two other population groups formed relative to the capacity of the METU residences and student guesthouses, dormitories. Population of the students living in the student guesthouses and dormitories is a sub-population group under the population of all students. Similarly, academic and administrative staff inhabiting in the METU residences is a sub category of all staff. However, family members of the staff, inhabiting in the METU residences, constitute an additional population on the campus. Hence, overall population of the METU campus could be estimated by summing the following population groups: all students, all staff, METU Technopolis staff, METU Foundation School's staff, students and staff's family members living in the METU residences. However, temporarily existing population on the campus, attracted by the campus facilities, is ignored within this calculation since no data is available. Data for the population groups and sub groups are presented in Table 3.4.

Table 3.4 Population groups in the campus

Population Groups			**Population or Capacity**
University	Students (*)	Undergraduate Preparatory School (Prep.)	2.341
		Undergraduate	12.171
		Graduate Prep.	62
		Graduate	3.491
		Postgraduate Prep.	13
		Postgraduate	1.500
		Master and Doctorate Integrated Program Prep.	60
		Master and Doctorate Integrated Program	214
		Private Students	240
		Secondary Education	280
	Staff (**)	Academic Staff	2.593
		Administrative and Other Staff	2.851
		Sub Total :	**25.816**
METU Technopolis	Staff		1.660
		Sub Total :	**1.660**
METU Foundation Primary and High School	Students	Primary School	1.411
		High School	394
	Staff	Instructors	197
		Administrative and other staff	102
		Sub Total :	**2.104**
METU Residences and Guesthouse (***)	East Residential Zone	Residences and Guest House	121 Residences ~ 363
	West Residential Zone	ODTÜKent Residences	334 Residences ~ 1.002
		Sub Total :	**1.365**

Table 3.4 (continued)

Population Groups			Population or Capacity
METU Dormitories and Student Guesthouses (****)	East Dormitories Zone	Dormitories	9 Dormitories: 4.160
		Student Guesthouses	5 Guesthouses: 1.280
	West Dormitories Zone	Dormitories	3 Dormitories: 1.872
		Research Assistant's Guesthouses	2 Guesthouses: 72
		Sub Total :	**7.384**
Grand Total : (University Students and Staff + METU Technopolis Staff + METU Foundation School Students and Staff + 2/3 of the METU Residences Population)			**30.490**

(*) 14 students registered to the Institute of Marine Sciences were excluded since its campus is located in İçel – Erdemli. In addition, 76 Students registered to the informatics online program, were excluded.

(**) 22 academic and 54 administrative and other staff working for the Institute of Marine Sciences in the İçel – Erdemli campus were excluded. In addition, 26 staff working for the ODTÜ – MET were excluded since the organization is located outside the campus by the Ankara – Eskişehir Highway.

(***) Population was estimated by assuming an average family size of 3 persons in one METU residence; one METU staff and two family members. In addition, estimation was carried by assuming 100% of the residences were occupied. One third of the estimated population was also counted within the population of university staff.

(****) Population was estimated by assuming 100% occupancy for the capacity of dormitories and guesthouses. Estimated population of 7.384 students was also counted within the student's population.

Overall campus population is estimated to be 30.490 according to Table 3.6. Campus population groups, defined in Table 3.4, are distributed to relevant campus buildings such as; faculties, departments, social, cultural and technical buildings, dormitories etc. However, some faculties or departments do have more than one building. For instance, Faculty of Architecture and Faculty of Economic and Administrative Sciences do operate in two buildings. Population of these faculties or departments is directly distributed to the relevant buildings if the distribution is known. However, if the exact distribution is not known, population of the relevant faculty or department is distributed proportionally to the floor area of the buildings used by that faculty or department. Floor areas of these buildings were previously calculated and registered into the study database while exploring the campus land use. Furthermore, working locations of 842 workers, employed by METU, is indefinite. Hence, these workers are also distributed proportional to the floor areas of the campus buildings that can possibly contain university staff. Distribution of the campus population according to the campus buildings is given in Appendix F.

Registering the population of each campus building into the study database enables calculation of the clients' population within the service area of any proposed stop or station which is drawn with the aid of the time based accessibility analysis carried in Chapter 5 via network analyst. Client's population using the relevant stop or station within the service area is used as a performance indicator in Chapter 5 for estimating the route efficiency of the proposed public transport mode together with the indicator; cumulative accessible floor area within the same service area.

Building based distribution of the campus population is generalized for the 67 analysis zones by summing the populations of the buildings within these zones. Spatial distribution of the campus population, comprising from all students and staff, is presented in Figure 3.13. Population living in dormitories, guesthouses and residential zones are also given in this figure together with the students and staff population. Thus, Figure 3.26 presents the zonal population distribution for 38.322 persons based on the "Total" column in Table 3.4. Spatial distributions of the other population groups are given in Appendix G. Besides a detailed list, presenting the population characteristics of the analysis zones is given in Appendix I.

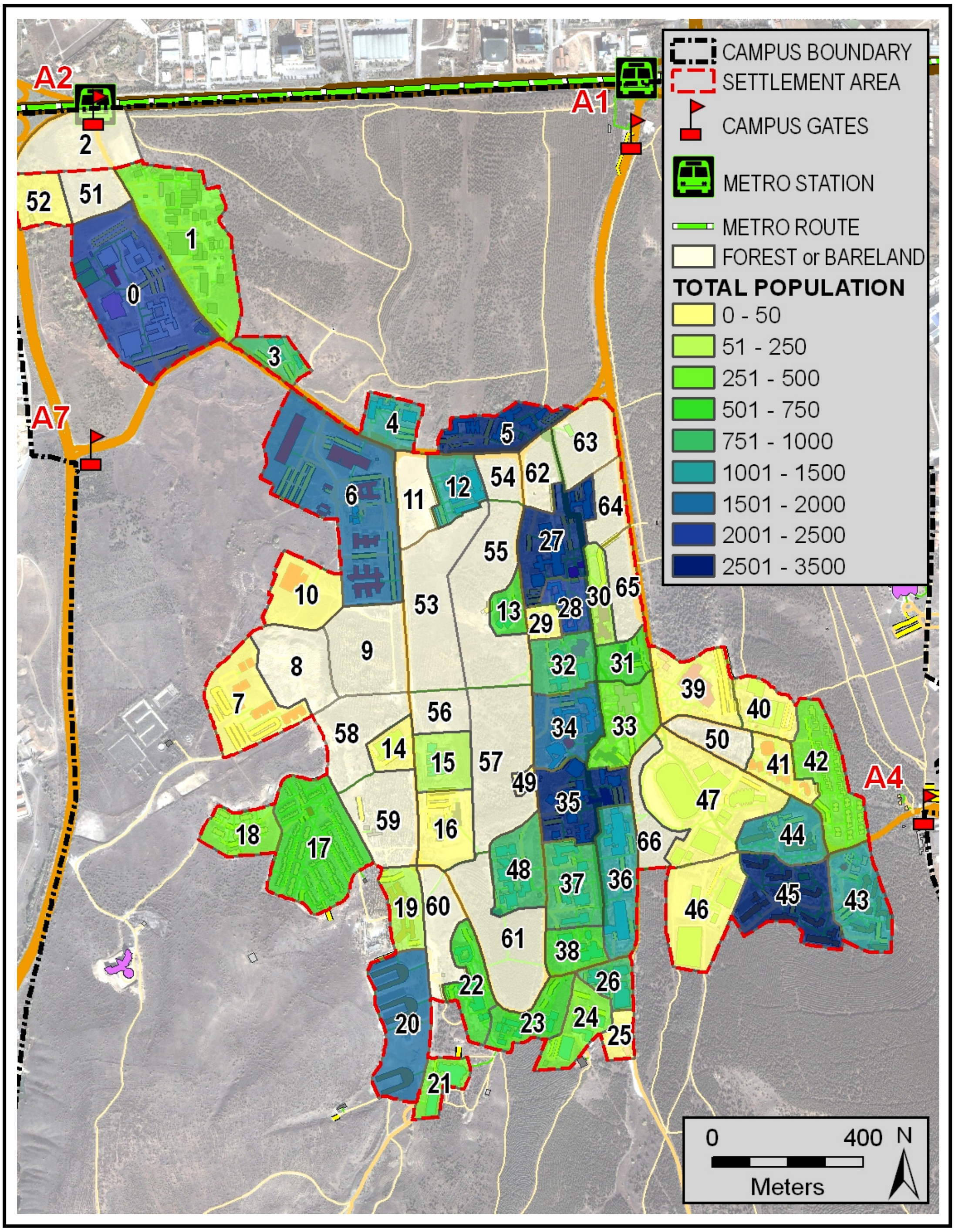
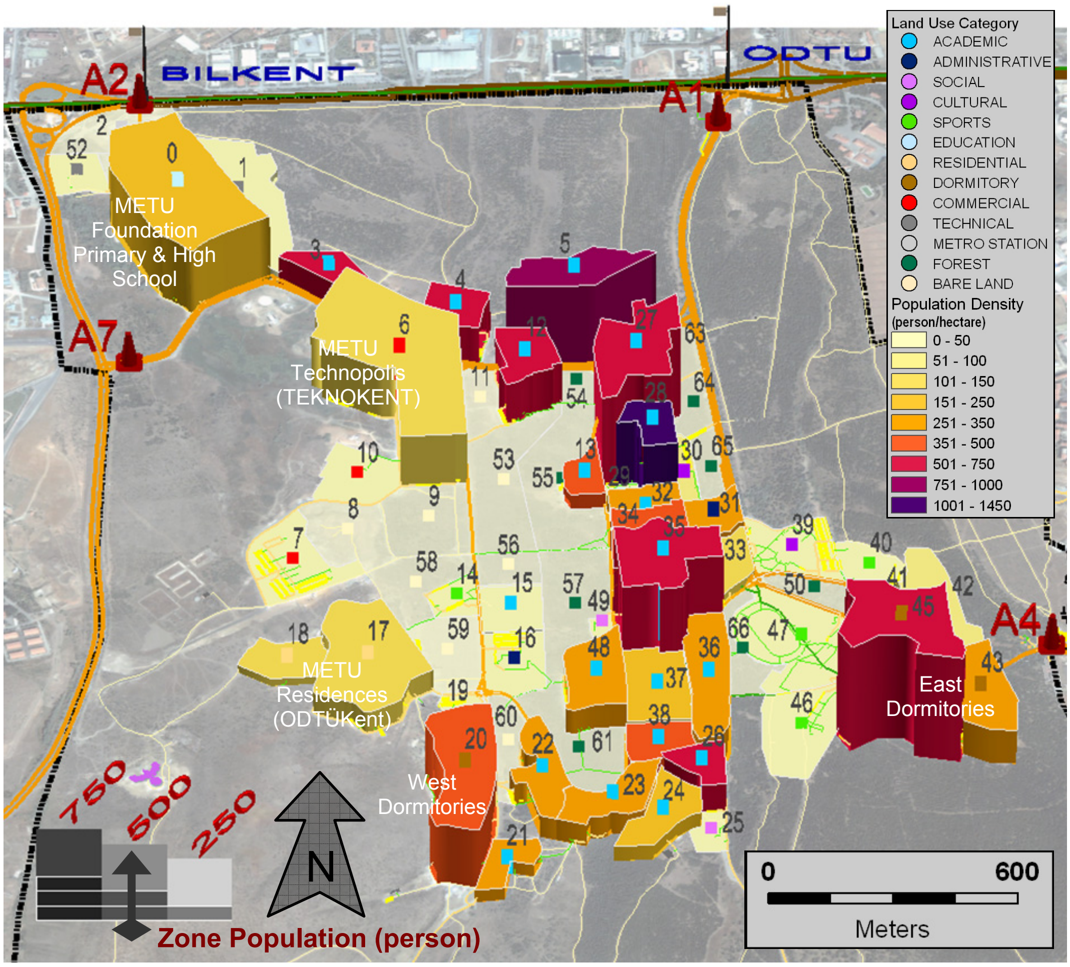


Figure 3.13 Distribution of the overall campus population according to the analysis zones

Population density of the zones can be used as a supplementary indicator together with the zones' population in order to determine the zones with higher priority in public transport service planning. Especially, zones having populations and population density values higher than the average, are considered as transport zones generating higher trip demands. Spatial distribution of these zones affects to the locations of the public transit stops relative to the routes of different modes, proposed in Chapter 4. These zones are listed in Figure 3.14.

Zonal distribution of the overall campus population and population densities in the zones are overlaid for enabling mutual exploration between these indicators (Figure 3.14). In Figure 3.14, zone's base area is extruded in Z axis, proportional to the overall population in the zone. Zone's population density was visualized by graduated colors.



Zones with Population>650 persons (~avg.) & Pop. Density>200 per./hect. (~avg.)			
ID	**Annotation**	**ID**	**Annotation**
0	METU Foundation Primary&High Sch.	32	Dept. of Physics and Dept. of Biology
3	Faculty of Education (Build. 2)	34	Dept. of Chem. & Stats. and Ind. Eng.
4	Faculty of Education (Build. 1)	35	Dept. of Elec.&Elect. and Comp. Eng.
5	Department of Basic English	36	Dept. of Civil Eng.
12	Faculty of Econ.&Admin. Sci. (New)	37	Dept. of Mech. Eng. and Metal. Eng.
20	West Dormitories Zone	38	Dept. of Chemistry Eng.
22	Department of Food Enginnering	43	East Dorm. Zone Std. Guesthouses
23	Dept. of Mining Eng. and Geo. Eng.	44	East Dorm. Zone and Medical Serv.
26	Dept. of Envi. Eng & Civil Eng. (K4-K5)	45	East Dormitories Zone
27	Faculty of Arch. and Econ.&Adm.Sci.	48	Dept. of Mechanical Engineering
28	Social Sci. Building & Dept of Math.		Totally 21 analysis zones.

Figure 3.14 Zonal distribution of the overall campus population overlaid with the zones' population densities

3.4.2. Campus Entrance Cards and Private Car Usage in the Campus

In Ankara, number of the private cars and private car ownership rate (the number of cars per 1.000 persons) are increasing rapidly when compared to the developments in the public transportation services. The number of private cars in Ankara was about 27.000 in 1970 while the city population was 1.236.000 (ABB – EGO, 1987); over 30 years the number of private cars has increased 22 times and reached up to 582.000 cars in 2000 while the city population was 3.278.000 (DIE, 2000). Between 2000 and 2004, the number of private cars has also increased by 20% and it reached up to 698.000 cars (DIE, 2004) while the projected city population was 3.578.000 (DIE, 2000). Private car ownership rate in Ankara, which was 22 in 1970 (ABB – EGO, 1987), has increased 8 times and reached up to 178 in 2000 (DIE, 2000). Moreover, private car ownership rate in 2004 could be estimated as 195, with the aid of projected city population (DIE, 2000 and DIE, 2004).

As a part of the city, METU is also not an exception and private car usage rate has increased rapidly in the recent years. According to the transportation data obtained from Gökbulut's study (2003:89), in the year 2003, 41% of the passengers reached campus by EGO and private buses, 13% of them preferred minibuses, 7% of them walked and 39% reached by private cars. However, the ratio of the passengers reaching campus by private cars was about 24% and 56% of the passengers were traveling with either bus or minibus in 1996. Within seven years, between 1996 and 2003, the ratio of the passengers reaching campus by private cars has increased 15% and denoted a modal shift towards private cars rather than public transport. Moreover, as Gökbulut stated in her study that; "private car usage rate of the passengers was about 7% in 1985 (Gökbulut, 2003:89)."

The main aim of this study is to propose modern and safe public transportation modes on suitable routes with accessible stops or stations, having wider service areas. Campus entrance card ownership, an indicator for the rate of campus users preferring private cars, is explored because a public transit mode, having higher service quality and a public transit route, linked to the metro stations (planned to start service in 2006), would attract some of the private car users in time and decrease the motorized vehicle traffic in campus. In this part of the study, spatial distribution of the campus entrance cards is analyzed since it is a direct indicator for estimating the rate of the trips to or from that zone by private cars.

In the year 2004, 10.790 entrance cards were sold and the overall campus population was 30.490 in the same year. Distribution of the campus entrance cards are given in the following table for the years 2002 and 2004 according to their types.

Table 3.5 Distribution of the campus entrance cards

Entrance Card Types		2002	2004
Academic	Permanent(*)	2.000	3.000
	Temporary(**)	1.000	1.000
Administrative	Permanent	1.350	1.700
	Temporary	60	60
Student	Local(***)	2.250	1.450
	General(****)		650
Graduated Students(**)		500	400
Guest(**)		1.000	1.200
METU Technopolis(**)		250	500
METU Development Foundation(**)		500	500
METU Dev. Foundation School(**)		-	330
Total			**10.790**

Approximate number of entrance cards presents the distributions in 2002 and 2004.
Data was derived from the Presidency Office, Directorate of Domestics Works in 2004.

(*) Permanent entrance cards are valid for 3 years.
(**) Temporary entrance cards are valid for 1 year.
(***) With a local entrance card, it is allowed to use both local and general parking lots.
(****) With a general entrance card, it is only allowed to use general satellite parking lots.

Permanent academic entrance cards are supplied for the academic staff as; professors, assistant professors, instructors and those who were retired from these services. Temporary academic entrance cards are supplied for the academics as; research assistants and part time academic staff. Since derived data, for the number of the academic entrance cards, includes both working and retired staff and the population of the retired academic staff is not known; academic staff's car usage rate is not calculated. But it is clear that; academic staff's car usage rate in the campus is relatively higher since there were about 4.000 academic entrance cards (supplied for working and retired staff) and 2.593 working academics in 2004. Similarly, since the entrance card distribution for the working and retired administrative staff is not known, administrative staff's car usage rate is not also calculated.

Paid entrance card policy is carried for two types of students' entrance cards. With, brown entrance cards, only general satellite parking lots can be used. However with the yellow cards, both satellite parking lots and faculties', departments' local parking lots can be used. Students' entrance cards are available for all METU students and private students in the campus. Based on year 2004 data, there were 20.372 university students and 2.100 entrance cards, denoting an average car usage rate of 10% (103 entrance cards per 1.000 students) in the campus. Moreover, approximately 500 cards in 2002 and 400 cards in 2004 were sold to the graduated students.

Guest entrance cards are offered for the users or guests who exhibit temporary relations with the campus. Number of guest cards has increased 20%, from 1.000 to 1.200 cards, between 2002 and 2004. This is another supporting fact that trip attraction amount of METU is increasing because of the campus' inner facilities as; cultural convention center, sports facilities, and new commercial buildings etc.

The most rapidly growing zone in the campus is the METU Technopolis. In 2000, there were only three buildings in this zone; however in 2005, 11 buildings exist in this zone including the buildings under constructions. Parallel to this rapid development, number of entrance cards given to Technopolis staff has increased from 250 to 500 cards within two years, from 2002 to 2004. According to the population data in 2004, 1660 personnel was working in the campus, while 500 entrance cards were sold. It can be estimated that, 30% (301 entrance cards per 1.000 personnel) of the staff prefer private cars. Besides, this rate is more than 30% because staff is allowed to enter the campus with their identity cards from A7 gate, without needing an entrance card. In working hours, until 18:00, there is not a public transportation service enabling direct access to the Technopolis zone from the city. Thus, a modern public transport mode interconnected with the new Metro route could attract the staff and the visitors with its stops/stations allocated to the Technopolis zone and also could decrease the staff's car usage especially in the peak hours.

According to the gate counts data, obtained from Gökbulut's study (2003:93,95), in 2003 between hours 08:00 and 17:00 and 87% of the vehicles, entered to the campus from A1 and A4 gates, were private cars. Within these cars, 73% of them had entrance cards and 27% of them had no entrance cards. This denotes, number of the private cars being used in the campus could be estimated approximately 25% more than the existing entrance cards.

Based on the data about campus entrance cards, spatial distribution information is only available for the local (yellow) entrance cards offered to the students. Thus, 650 general (brown) student entrance cards are distributed to the analysis zones, proportional to the local (yellow) card distribution. Then for each zone, car usage rate is estimated by dividing the number of the student entrance cards to the students' populations in that zone. Additionally, Technopolis and METU Foundation School entrance cards are also accounted in the following figure. Figure 3.15 displays the number of the entrance cards in the zones and the same zones' probable car usage rates, calculated by rationing the number of entrance cards to the population.

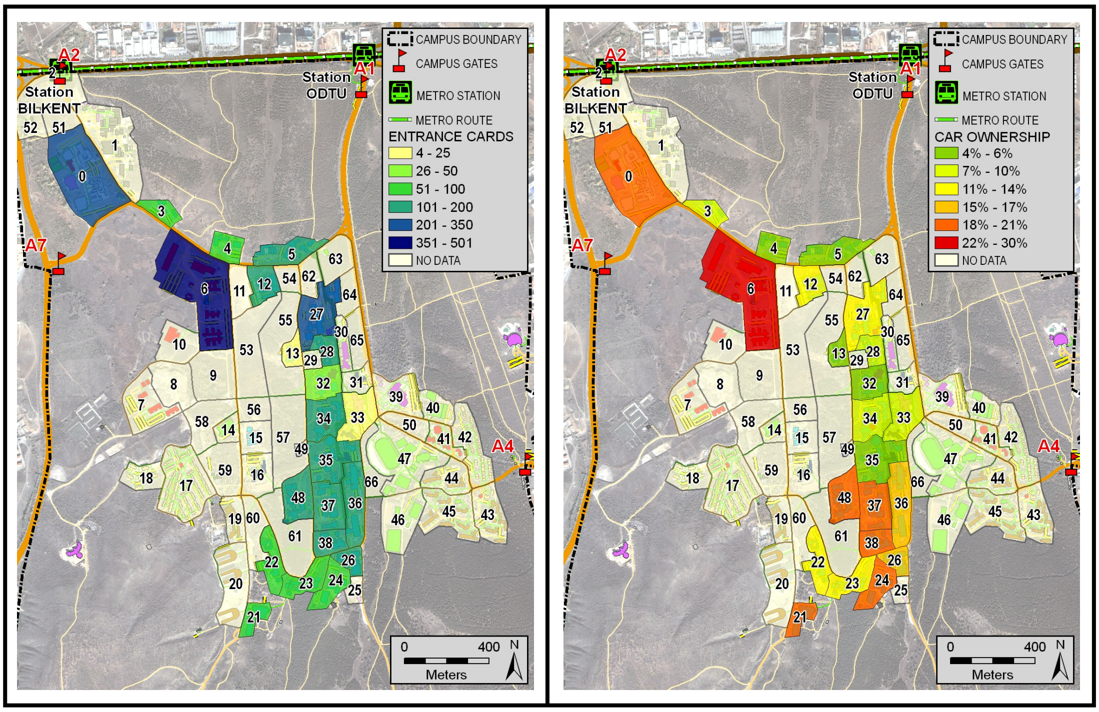


Figure 3.15 Distribution of the (a) student, Technopolis and METU Foundation School entrance cards and (b) car ownership rates in the zones

CHAPTER 4

EXPLORING TRANSPORTATION STRUCTURE AND PUBLIC TRANSPORT ALTERNATIVES IN METU CAMPUS

The flowchart of this study is organized parallel to the general methodology of transportation planning, defined by Lane et al (1971). This methodology includes following steps: research & exploration, analysis & modeling, and system evaluation. Research and exploration step includes study area zoning and domains as exploration of transportation and city planning variables, exploration of present transportation structure, transport modes and facilities. In Chapter 3, study area zones are determined and land use, topography, population related planning variables are explored. In this chapter, transportation structure of the campus is studied. As a part of analysis and modeling, the second step in transportation planning, campus trip demand surface, possible traffic flows on campus and significant zones are estimated with the aid of MCDA. Lastly in this chapter, characteristics, prerequisites and slope tolerance limits for different transportation modes are explored; then alternative service modes (eg. guided light transit, trolleybus and monorail) are proposed together with their routes and stops/stations in campus.

4.1. Transportation Structure of the Campus

Campus transportation network elements, including campus entrances, vehicle roads, pedestrian paths and vehicle parking lots, are explored in this part. Existing public transport services are also explored with their timetables, routes and stops in campus. Besides, campus trip demand is estimated by calculating zonal trip generations and attractions. Furthermore, by means of

MCDA, zonal distribution of the trip demand is evaluated together with structural distribution and density to determine the significant zones that are prioritized for public transport services.

4.1.1. Components of the Campus Transportation Network

Original transportation network of METU campus was designed with the principle of unimpeded pedestrian access. According to this design; faculties and other educational structures were located along the main pedestrian alley that defines an educational core, encircled by a vehicular road ring that is connected to main entrance (A-1). METU grew parallel to this plan between the years 1963 – 1980. However, initially designed campus area came to its limits in the 1980’s and started to disperse over the northwestern parts of METU Land (Günay, 1997). Because of this spatial dispersion, a secondary vehicular road ring is established on the west.

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. Second loop is adjacent to the first loop 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. According to Gökbulut’s study (Gökbulut, 2003) carried in 2003, totally 3.849 vehicles (308 bus/minibus and 3.541 private car/taxi) entered to the campus from A1 gate between hours 08:00 and 17:00. According to the same study, from A4 gate, totally 2.642 vehicles (148 bus/minibus and 2.494 car/taxi) entered to the campus between 08:00 and 17:00. Although there is not any data available about the traffic density on A7 gate; this gate could be assumed as having less priority than A1 and A4 gates, since there is not any public transport service available from A7 gate. However, METU Technopolis staff uses A7 gate more than other campus users since they are allowed to enter the campus from A7 gate by their private cars without needing a paid entrance card.

As an upcoming rail public transport facility for the campus, Çayyolu – Kızılay metro route is planned to start service in 2006. Two stations of this route are under construction on the northern boundary of campus. Metro Station ODTÜ is located by the A1 gate and Bilkent Station is located by the A2 gate. Thus, when the new route starts service, A1 gate will gain more importance and A2 gate will be probably opened for daily usage in order to enable access from Bilkent Station.

The backbone of pedestrian circulation in campus is the main pedestrian alley. Length of this main alley is about 1,9 kilometers. In addition, there is a secondary pedestrian path about 600 meters which connects east dormitories zone to the core campus. However, neither a main pedestrian path, nor a hierarchic pedestrian network is available in the western segment of campus.

Private car usage rate in the campus has increased rapidly; in 1996 the rate of passengers arriving campus by private cars was 24%. However in 2003, this ratio reached 39%. Moreover, paid entrance card policy was also insufficient to reduce the rate of private car usage; in 2004 the number of registered entrance cards reached 10.790 while the overall campus population was about 30.000. However in 2005, according to the study database, estimated capacity of the parking lots is about 5.000 cars within the campus settlement area and about 20 cars in the A1 entrance, 40 cars in the A4 entrance. So, the number of vehicles registered with campus entrance cards is twice the capacity of parking lots available in campus.

In Figure 4.1, components of the campus transportation network are shown.

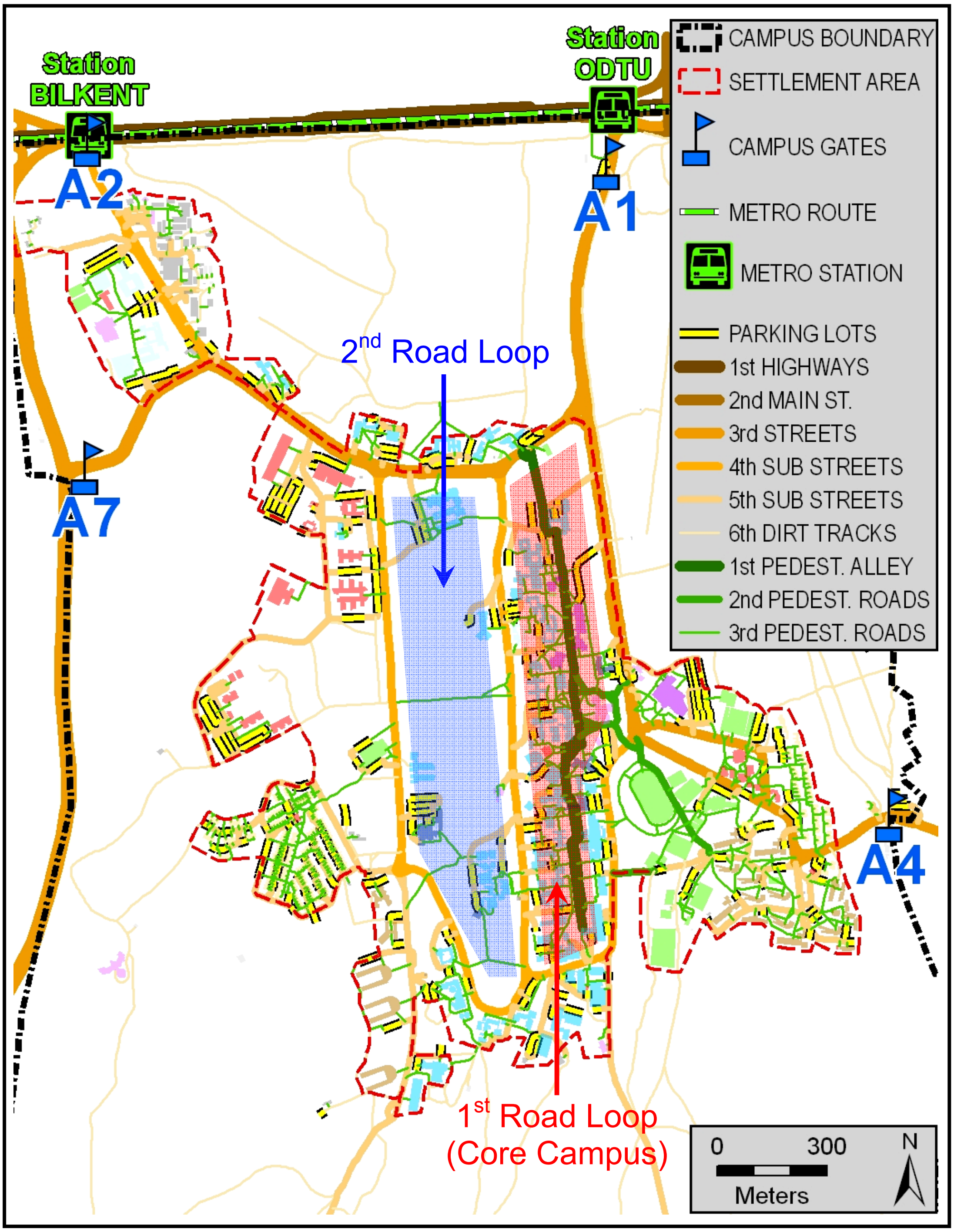


Figure 4.1 Campus transportation network

4.1.2. Existing Transport Facilities in the Campus

Public transportation between city and campus is provided by EGO buses, privately operated buses/minibuses and METU service buses for university staff. Besides, taxis and private cars are used for personal needs. Campus inner circulation is provided by the ring services that are operated with the buses of METU on two main and two supplementary routes. Modes, routes and timetables of public transport services in campus are given in Table J.1 (Appendix J). On the other side, for personal transportation needs, approximately 8.500 campus entrance cards (nearly 80% of the total entrance cards) were registered for private cars in 2005. This indicates that private cars compose a widespread transportation mode within the campus.

4.1.2.1. EGO and Privately Operated Bus Services

EGO buses are operated by the Metropolitan Municipality of Ankara and services are available for different districts of city. The bus service, from Kızılay to campus, is available between 08:30 and 23:00 in every 30 minutes. Another bus service, from Ulus and Kızılay to campus, is available in every 15 minutes between 06:30 and 23:00. Besides for working days, between 07:30 and 17:45, there are two bus services from campus to Tunus St. and Sıhhıye district (and vice versa). In addition to these primary services, there are 10 different EGO district services; operating between city and campus in morning rush hours (07:00 – 09:00) and in the evening peak (17:45). Apart from EGO services, privately operated buses are available from Keçiören – Aktepe district to campus, between 06:30 and 22:30 in every 15 minutes. However, after the new metro route becomes operational, these bus services will be canceled or service frequencies will be decreased by the local government since two metro stations are under construction by A-1 and A-2 gates to enable rail transport service for METU. Routes and stops of bus services are given in Table J.2 (Appendix J) relative to the periods of day.

4.1.2.2. Privately Operated Minibus Services

Privately operated minibuses are available on three different routes, from Kızılay, Ulus and Ayrancı districts to campus (and vice versa). All services start at 07:00 and continue throughout the day until 24:00 with service periods proportional to the trip demand on the routes. Kızılay and Ulus minibuses depart/arrive campus through A-1 main gate. Therefore, these services also meet the additional demand that is arising from the trips between campus settlement area and Inönü Boulevard. However, it is clear that neither of these minibus services will be sufficient for meeting the arising demand after ODTÜ Metro Station becomes operational. Routes and stops of minibus services are given in Table J.3 (Appendix J) relative to the periods of day.

4.1.2.3. Bus and Campus Ring Services Operated by METU

Campus ring services are operated for providing the circulation in campus through working hours (from 08:25 to 16:45). 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 2005, 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. Besides METU – AŞTİ (Ankara intercity bus terminal) ring buses operate between campus and AŞTİ four times in a day. Routes and stops of campus ring services are given in Table J.4 (Appendix J) relative to the periods of day.

According to the data obtained in 2005 from the directorate of construction and technical works – transportation management department, METU 47 buses, operated for public transport services. However these service buses have already completed their economic lifetimes (the oldest one 1977 & the newest one 1985 model) and should be renewed. Moreover, with their diesel engines, neither of them can meet the Euro emission norms, announced in 2000 and onwards for decreasing air pollution. On the other hand, neither of these ring routes connects campus settlement area to the upcoming metro stations. Even if ring routes are extended to cover the metro stations; existing fleet capacity must still be increased after these stations become operational due to the arising trip demand. So, a modern service fleet, that allows flexible capacity management and operates with low or no emission engines, should be considered in METU for easing inner circulation and connecting campus to the upcoming metro stations.

4.1.3. Estimating Trip Demand and Traffic in the Campus

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. In the city scale, these trips can be named as “inter zonal trips” and the demand arising from them can be named as “inter zonal trip demand” (Kaplan, 1991). Besides, there is also a trip demand within the campus, arising from the trips attracted/generated between different zones of campus. These inner trips can be named “in(side) zone trips” and the arising demand is “in-zone trip demand” (Kaplan, 1991). At present, inter zonal trip demand is served by EGO (via buses) and private sector (via bus and minibus). Besides, in-zone trip demand is served by the campus ring services.

In a public transport planning study, trip demand of the study area must be surveyed and/or modeled; and if necessary should be projected for future. Public transport routes and so the locations of stops/stations are proposed relative to the spatial distribution of trip demand. Besides, amount of zonal trip demand determines the frequency and capacity of proposed transport services for that zone. Therefore in this thesis, as a small scaled public transport planning study in METU, campus transport demand and its spatial distribution must be determined in order to propose service routes for alternative modes of public transport and their stop/station locations in campus.

In this study, it is not possible to conduct a survey in METU Campus to determine the trip generation coefficients exactly for each population group in campus. Since METU Campus is a traffic analysis zone (TAZ) of Ankara, it can be assumed as a compact educational zone at the city scale. Thus, it is not reasonable to produce an inner origin – destination (O/D) matrix for campus by sub-zoning the campus area and surveying to exhibit the traffic between different zones of campus. However, campus daily traffic can be explored in order to estimate the trip generation coefficients for different population groups in campus (eg. students, students living in dormitories, METU staff, METU Technopolis staff etc.)

Campus daily traffic and zonal interactions in different periods of working days are explored relative to the probable movements of different population groups (Appendix K). Based on the scenario schemed in Table K.1, each group's trip generation coefficient is estimated and trips generated by these groups are given in Table 4.1 by multiplying relevant group's population with its coefficient.

Table 4.1 Trip generation coefficient estimations for different population groups in campus

Population Groups or Relevant Zones		Population	Trip(s) in Periods of (Working) Days				Estim. Trip Generation Coefficient (Trips/Day) *Estimated Trips*
			Morning Peak (08:00 – 10:00)	**During Day (10:00 – 16:00)**	**Evening Peak (16:00 – 18:00)**	**Evening & Night (18:00 – 24:00)**	
University	All Preparatory School & Under Graduate Students (*)	14.647	1 to campus, regular home or dorm based trip (100% of Pop.)	1 + 1 from/to lunch (50% of Pop.) & 1 + 1 for misc. purposes (25% of Pop.)	1 from campus, regular home or dorm based trip (100% of Pop.)	N/A	**3,5** *~ 51.500*
	All Graduate & Postgraduate & Integrated Prog. & Private Stds. (**)	5.725					**3,5** (0,6 factor***) *~ 12.000*
	Staff (*) All Academic & Administrative & Other Personnel	5.444	1 to work, regular home based trip (100% of Pop.)	1+ 1 from/to lunch (100% of Pop.)	1 from work, regular home based trip (100% of Pop.)	N/A	**4,0** *~ 25.000*
METU Technopolis	Staff (*)	1.660	1 from city to work, regular home based trip (100% of Pop.)	N/A	1 from work to city, regular home based trip (100% of Pop.)	N/A	**2,0** *~ 3.500*
METU Found. Prm & High Sch.	Students & Staff (*) All Primary – High School Students & Instructors & Administrative – Other Staff	2.104	1 to school, regular home based trip (100% of Pop.)	N/A	1 from school, regular home based trip (100% of Pop.)	N/A	**2,0** *~ 4.000*

Table 4.1 (continued)

Population Groups or Relevant Zones		Population	Trip(s) in Periods of (Working) Days: Morning Peak (08:00 – 10:00)	During Day (10:00 – 16:00)	Evening Peak (16:00 – 18:00)	Evening & Night (18:00 – 24:00)	Estim. Trip Generation Coefficient (Trips/Day) / *Estimated Trips*
METU Residences	METU Staff & their families (*)	1.365	1 to campus or to city from residences, regular home based trip (100% of Pop.)	1 + 1 for misc. purposes, shopping, leisure etc. (Either during day, 33% of Pop.)	1 from campus or from city to residences, regular home based trip (100% of Pop.)	1 + 1 for misc. purposes, shopping, leisure etc. (Or in the evening – night, 33% of Pop.)	**2,66** *~ 3.500*
METU Dormitories & Student Guesthouses	Students living in East Dormitories (*)	5.440	1 to campus from east or from west dorms, regular dorm based trip (100% of Pop.)	1 + 1 for misc. purposes, shopping, leisure etc. (25% of Pop.)	1 from campus to east or to west dorms, regular dorm based trip (100% of Pop.)	1 + 1 for misc. purposes, shopping, leisure etc. (25% of Pop.)	**3,0** *~ 16.500*
	Students living in West Dormitories (*)	1.944					**3,0** *~ 6.000*

(*) People in this group exhibit first order, intensive relations with campus (eg. full attendance in campus for working days). Their trips are assumed as continuous & regular for working days.

(**) People in this group exhibit second order, less intensive relations with campus (eg. partial attendance in campus for working days). Their trips are also assumed as regular but not continuous for all working days.

(***) Attendance calibration factor of 0,6 denotes a level of 3 days attendance in 5 working days (eg. unlike a fully attending undergraduate student, a graduate student may not exhibit full attendance and generate trips to campus only for three days in a week.). Thus trips of people in this group are decreased by multiplying with 0,6 to reflect the partial attendance.

(****) Sign "~" denotes for approximation and "." is thousand separator. Estimated trips are calculated for working days by multiplying group's population with its trip generation coefficient. In daily life, estimations may be less or more.

After estimating trip generation coefficients and overall trip demand for different population groups (Table 4.1); each zone's trip demand is calculated by multiplying trip generation coefficients with relevant groups' populations, registered in that zone. A detailed trip demand table, listing each group's and total trip demand according to the analysis zones, is given in Appendix L. Based on this table (Table L.1), spatial distribution of the overall trip demand in campus is given in Figure 4.2. Besides, spatial distribution of the trip demand, arising from different population groups (eg. arising from students', staff's trips) or from the zones they live (eg. generated from dormitories, guesthouses and METU Residences), is given in Appendix M.

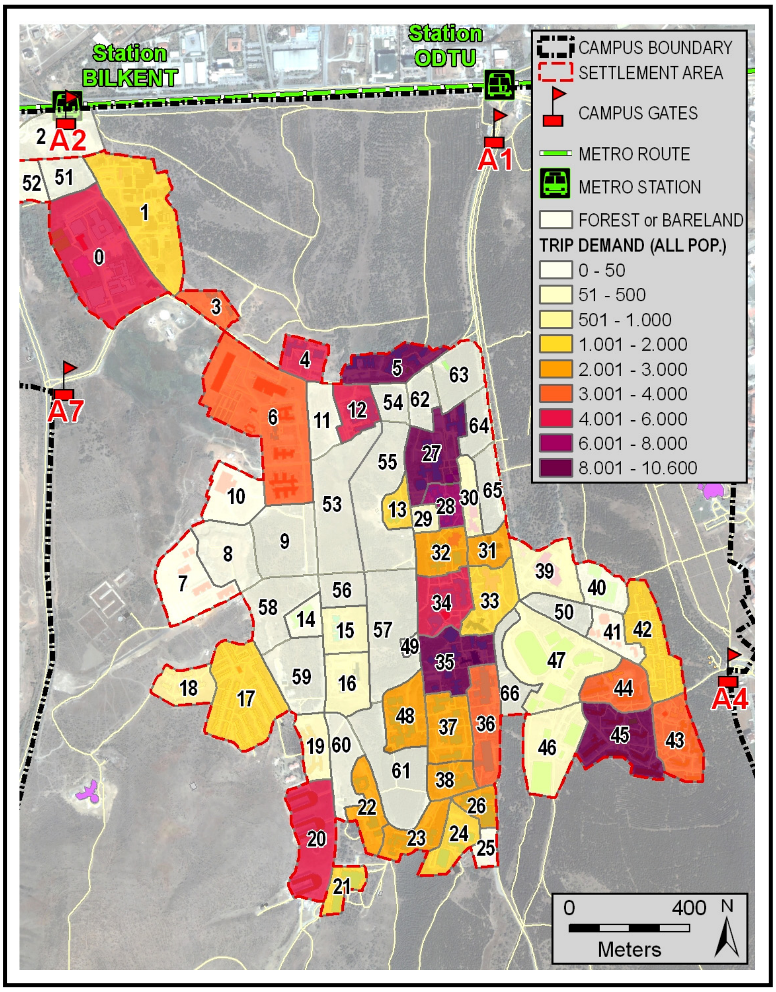
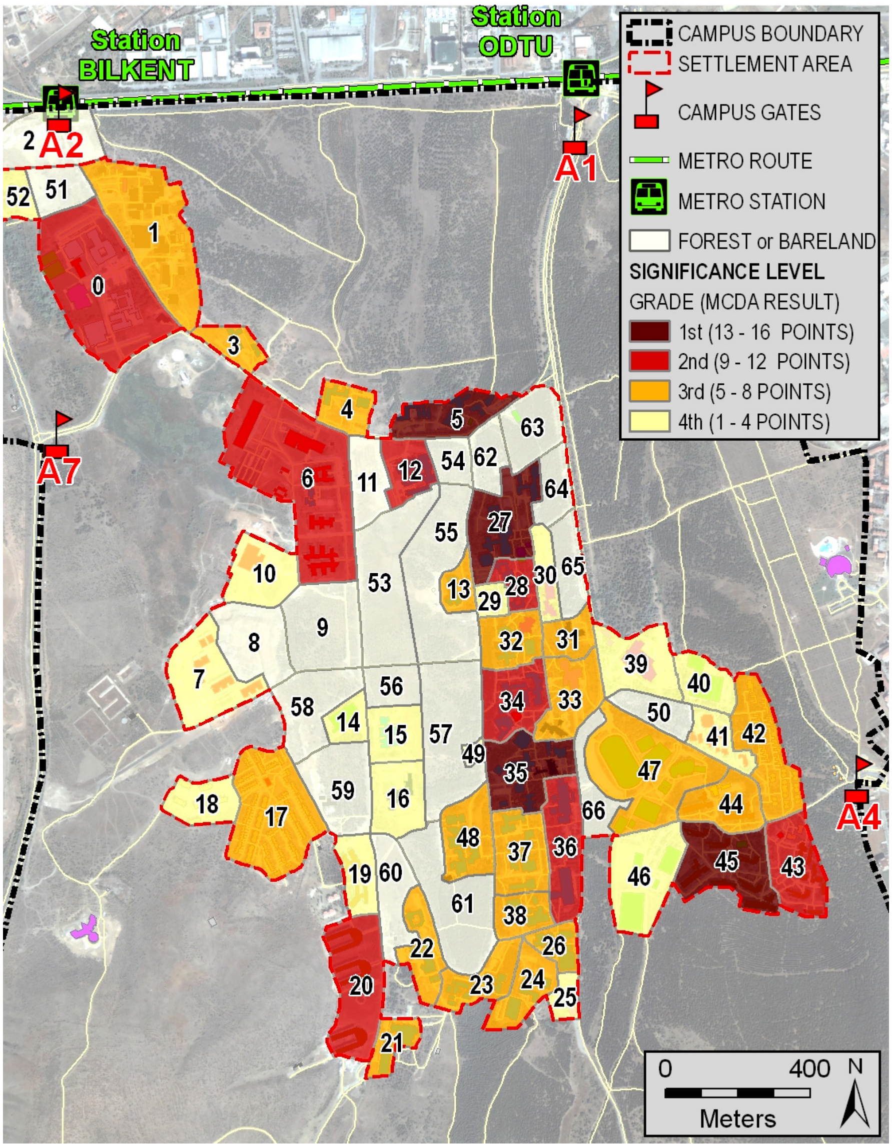


Figure 4.2 Distribution of the overall trip demand according to the analysis zones

According to Figure 4.2, some significant zones presenting higher trip demands than others; so that to be considered while designing service routes and proposing stop/station locations, can be listed as: METU Foundation School (zone 0) on the northwest; Faculty of Education on the north-northwest (zones 4 and 3); Department of Basic English on the north (zone 5); METU Technopolis on the west-northwest (zone 6); Faculties of Economic & Administrative Sciences and Architecture (zones 12 and 27); central zones 28, 34 and 35, respectively identical with Faculty of Social Sciences, Departments of Chemistry and Electric & Electronic Engineering; Department of Civil Engineering on the south (zone 36) and southwestern (new) and southeastern (old) dormitories (respectively zones 20 and 43, 44, 45).

Although spatial distribution of the trip demand and the zones exhibiting higher demands are important guiding factors for service routing and stop/station location selection; this approach accounts only two variables, population and trip generation. Therefore, structural distribution and density in the campus, explored in Chapter 3, are ignored. However, these variables should also be accounted for considering the zones having small or temporary population but important structures and/or higher densities (eg. library – zone 30, cultural & convention center – zone 39, shopping center – zone 41 etc.). Besides, total floor space in a zone is assumed as an indicator of activity in this study. Based on this approach, multi criteria decision analysis (MCDA) is carried for producing a final reference map, denoting significant zones that will guide and be considered before designing routes and selecting stop/station locations for proposed service modes. Ranges, presenting zonal values, in each map are reclassified between 0 (zero) and 16 with multi linear normalization (eg. “0, 1” – “3, 5, 7” – “10, 13, 16”). After reclassifying zonal values into a common range, three maps are evaluated by the following formula:

Index Value (Zone Significance Level) = [(0,6 x Zone's Total Trip Demand) + (0,4 x ((0,7 x Total Floor Area of the Structures in Zone) + (0,3 x Zone's Floor Space Index)))]. Finally, four significance levels are determined and each zone is categorized into a significance level that corresponds to its index value, between "0" (zero) and 16 (Figure 4.3).



* ***Index Value (Zone Significance Level)*** = *[(0,6 x Zone's Total Trip Demand) + (0,4 x ((0,7 x Total Floor Area of the Structures in Zone) + (0,3 x Zone's Floor Space Index)))]*

Figure 4.3 Significance levels of analysis zones for public transport service routing and selection of stop/station locations

According to Figure 4.3, zones to be considered with first and second degree significance for public transport service routing can be listed as; METU Foundation School (zone 0); Department of Basic English (prep. school zone 5); METU Technopolis (zone 6); Faculties of Economic & Administrative Sciences, Architecture and Social Sciences (respectively zones 12, 27 and 28); Departments of Chemistry, Electric & Electronic Engineering and Civil Engineering (respectively zones 34, 35 and 36); finally dormitories and student guesthouses, zone 20 on the southwest and zones 43, 45 on the southeast.

In this study, multi linear normalization is carried for reclassifying the zone values in the relevant maps and simple criteria weighting [(5)] (rating) is applied in the zone significance level formula in order to evaluate the normalized values mutually via MCDA for achieving the zonal significance map (Figure 4.3). In this formula, zonal trip demand is assumed to have greater importance than structural distribution and density; therefore a higher weight factor of "0,6" is given for trip demand while "0,4" is given for structural indicators. Structural indicators are taken as following; total floor area (TFA) of the buildings/facilities in the zones in order to consider structural distribution and floor space indices (FSI) of the zones in order to emphasis structural density. TFA is assumed to have greater importance than FSI; therefore a weight factor of "0,7" is given for TFA while FSI "0,3" is given for FSI in order to emphasis the zones having smaller TFA's but higher FSI's. Zone significance map, given in Figure 4.3, is calculated with these assumptions. However, in different studies, it is possible to assign different weight factors to these zonal indicators, according to the relative importance of each indicator, depending on the aim and methodology of that study. It is

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[(5)] Multi criteria decision analysis requires criteria weighting in order to define the importance of each criterion relative to other criteria. There are different criteria weighting procedures in the multi criteria decision making literature. Some fundamental methods are; ranking, rating, pairwise comparison and trade-off analysis. The publication of Malczewski (1999), regarding to GIS and MCDA, can be referenced in order to explore the accuracy, reliability, easiness to use, easiness to understand and the theoretical backgrounds of each methods.

clear that different weight factors will change the final zonal significance map that will be considered in that study. Therefore, simple weight factors which are assigned to the zonal indicators in this study are not constant values and they cannot be used commonly in other studies. On the other hand, in a comprehensive transportation study, structural indicators (TFA and FSI) of the analyses zones will not be necessary to be evaluated via MCDA, if the origin destination (O/D) matrix is known and the spatial trip demand can be “accurately” estimated with the aid of following variables derived from transport surveys: distribution of population groups in all analyses zones and trip generation coefficients of different population groups.

4.2. Proposing Public Transportation Alternatives in the Campus

In this part of the study, characteristics and prerequisites of several public transport modes are defined. Besides campus topography is evaluated with respect to the slope tolerance limits of several transport modes for topographically – harmonious routing and decreasing construction costs. At the end of this chapter, alternative routes and their stops/stations are proposed for three chosen public transport modes. Proposed alternatives for each of these service modes are evaluated in Chapter 5.

4.2.1. Characteristics and Prerequisites of Different Public Transportation Modes

It is clear that sustainable public transportation services should be considered for METU Campus. Two main objectives must be achieved; designed routes’ stops/stations should be accessible for meeting the trip demand between different zones of campus and proposed service routes should connect campus to the upcoming metro stations. Definitions, characteristics, advantages and disadvantages of some public transport services that can be considered in campus are given below.

- **Bus:**

  Conventional buses, running with diesel engines, have the advantages of low construction and technical maintenance costs. Besides, bus services do not require exclusive right-of-way managements. Therefore, it is perhaps the most common and easy applicable public transport mode all over the world. Moreover, since service (re)routing is just a planning or management issue, it is the most flexible mode operating on streets with rubber tires. However, conventional buses work with fossil fuel (mostly diesel) powered internal combustion engines; thus they have the highest level of per passenger exhaust emission when compared with other modern public transport modes. Moreover, capacities of all buses are generally fixed up to 80 passengers for 12 meters solo and up to 120 passengers for 18 meters high capacity articulated buses. In addition, some very high capacity double articulated buses have capacities up to 180 passengers (Van Hool Corp., 2005). However, a modern tramway has a capacity about 300 passengers and one tramway operator can still drive the same number of passengers that is carried by three or four solo buses. Due to this capacity constraint, the amount of per passenger operational costs increases for the bus service suppliers.

- **Trolleybus:**

  Trolleybus is sensed as a combination of an electric tramway and a diesel powered conventional bus (Wikipedia, 2005-e). Trolleybuses can avoid from the obstacles, which a tramway cannot, and service does not require as much capital investment as a tramway or light rail system. Unlike diesel powered buses, trolleybuses are powered by zero emission electric motors that derive power from overhead wires, via two trolley antennas. Moreover, some modern trolleybuses (eg. trolleybuses

Civis and Cristalis, produced by Iris Bus Corp.) offer similar levels of service quality and safety as light rail vehicles. These vehicles are capable of tolerating gradient slope up to 18% and they can be equipped with optical steering (automated guidance) and traction systems. Example of a modern trolleybus (Iris Bus – Cristalis) is given in Figure 4.4. Advantages and disadvantages of trolleybus services are given in Table 4.2.

Table 4.2 Advantages and disadvantages of trolleybus services

Advantages	Disadvantages
Trolleybus system does not require as much capital investment as a tramway or light rail system.	Trolleybuses have higher start up costs than diesel powered buses.
Trolleybus vehicles are more flexible and can avoid from the obstacles, which a tramway or light rail vehicle cannot.	Trolleybuses have difficulties to compete with the efficiency and capacity of light rail vehicles.
Hybrid trolleybuses, having small diesel engines or rechargeable cells, can run for a while without needing overhead wires in order to bypass some problematic road segments or junctions.	Because trolleybuses do not follow fixed tracks, there is a risk of coming off the route, loosing electric power and getting stuck unless they are dual powered.
Due to their efficient electric engines and traction via rubber tires; trolleybuses are particularly important in areas having steep slopes that a light rail vehicle cannot tolerate.	Trolleybuses suffer from being sensed as "neither a bus, nor a tramway" unless they have inevitable advantages for that area.
Trolleybuses are powered by zero emission electric motors, fed from overhead wires. Therefore in street level, they are cleaner than other vehicles working with fossil fuels.	Double wired overhead networks that feed trolleybuses are twice longer than the single wired networks used by steel wheeled vehicles. Therefore, trolleybus overhead networks have more negative visual impacts on urban space.
Modern trolleybuses can reduce electric consumption by regenerative braking or while going downhill.	
Trolleybus vehicles usually have longer operational lifetimes than diesel powered buses.	
Modern trolleybuses can be equipped with optical steering and automatic traction systems.	

Figure 4.4 Example of a modern trolleybus from Iris Bus Corp. operated in Lyon – France (Adapted from Iris Bus Corp., 2005)

- **Guided light transit (GLT):**

  Guided light transit (GLT) is a public transport system that was introduced in 1998 by Bombardier Transportation Corp. as a successor mode to guided bus transit (Wikipedia, 2005-a). GLT was developed to fill the gap between buses and light rail vehicles; so that it takes the advantages of both modes. GLT vehicles run on rubber tires like a conventional bus; but also they follow a single (central) rail for guidance and work with electric engines like light rail vehicles. Therefore they are called as “tramways on tires”. For the present, GLT vehicles are only being produced by two manufacturers (Bombardier Corp., 2005-b and LOHR Corp., 2005). Bombardier GLT vehicles (Figure 4.5-a) are unidirectional, double articulated and carry up to 150 passengers. The other alternative, LOHR Translohr vehicles (Figure 4.5-b) are bidirectional and allow flexible capacity management by allowing attachable/detachable vehicle series for increasing/decreasing passenger capacity. In addition, both vehicles have low or ultra low floor door designs and they do not need special station platforms since they are designed to operate on streets. Advantages and disadvantages of guided light transit are listed in Table 4.3.

Table 4.3 Advantages and disadvantages of guided light transit

Advantages	Disadvantages
GLT systems are cheaper and more flexible than light rail systems. Besides, they offer higher capacity than solo or articulated buses.	Capacity of a GLT vehicle is still limited when compared with a conventional tramway or light rail vehicle.
Due to their electric powered efficient engines, rubber tires and articulated bodyworks; they can operate on street gradients up to 13% and negotiate complete turns with ~12 meters radii.	GLT system has not been “fully” proven yet. (In 2001, GLT vehicles operating in Nancy – France have experienced some mechanical problems and service paused for one year until vehicles were upgraded.)
GLT vehicles can be fed from single live wire or can be adapted to share any existing double wired trolleybus overhead network.	Unlike light rail systems, GLT is a proprietary system. That means, once having installed, problems might be faced when purchasing new vehicles from different manufacturers.
GLT vehicles work with “clean” zero emission electric engines and run on rubber tires. Therefore, GLT vehicles make less noise and vibration.	
Due to their low floor designs, GLT vehicles can dock without needing station platforms.	
Guidance rail allows GLT vehicles to run in parallel lanes narrower than buses could safely be driven. So, required lane width for a GLT vehicle is narrower than a bus lane.	
Single central rail guidance system is relatively cheaper than the conventional (double) rail system.	

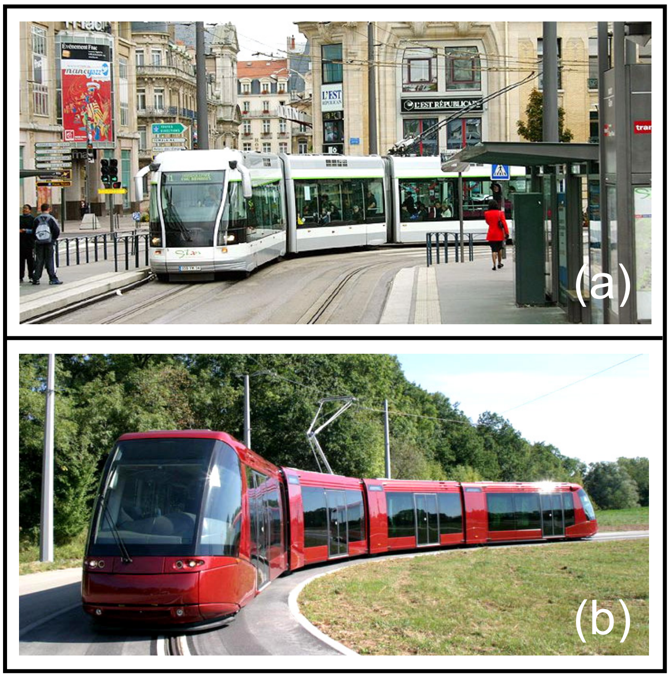

Figure 4.5 Examples of GLT vehicles: (a) Bombardier GLT operated in Nancy – France and (b) LOHR Translohr on test track Clermont – France (Adapted from Bombardier Corp., 2005-b and LOHR Corp., 2005)

- **Tramway and light rail transit systems (LRS):**

  Light rail transit is usually sensed as a successor mode to tramway since rapid or modernized tramway operations, employing features associated with massive or rapid rail systems, are usually defined as light rail transit (Wikipedia, 2005-b). Although tramway and light rail vehicles are “lighter” than the vehicles operated in “heavy rail” systems; the term “light rail” should be actually used for denoting the system capacity that is less than “heavy rail” systems’ (6).

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(6) Systems having capacities between 6.000 and 25.000 passengers per hour in one direction (pphd) are accepted as “light rail” systems (Gray and Hoel, 1992). (eg. LRS of Ankara has a max. capacity of 25.000 pphd (ABB – EGO, 2005).) Tramway systems offer capacities between 2.000 pphd and up to 20.000 pphd on intensive routes (Gray and Hoel, 1992). "Heavy rail" systems offer capacities between 20.000 pphd and 75.000 pphd or more. (eg. Metro of Batıkent in Ankara has a max. capacity of 72.000 pphd. (ABB – EGO, 2005).)

Although tramway system can be considered as a type of light rail transit; there are some differences between tramway and light rail transit system designs. “Tramway tracks are usually built on shared urban space; meaning that tramway tracks share street lanes or pedestrian zones with other vehicles in traffic or pedestrians along the route. Besides, tramway stops tend to be frequent and little effort is made to set up special boarding platforms since urban space is shared and tracks are visually unobtrusive (Figure 4.6-a). However in light rail systems, vehicles tend to run along dedicated tracks, which are generally segregated from vehicular traffic. In this system design, stations are relatively less frequent and vehicles are often boarded from platforms. Besides, LRS tracks are visible and in some cases significant effort is expended to keep vehicular traffic away from tracks (Figure 4.6-b). (Wikipedia, 2005-d)” Advantages and disadvantages of tramways and light rail transit systems are listed in Table 4.4.

Table 4.4 Advantages and disadvantages of tramway and light rail transit

Advantages	Disadvantages
Building a tramway or light rail system is cheaper than to build a heavy rail system, because the infrastructure does not need to be as substantial heavy rail’s and tunnels are usually not obligatory.	Light rail systems tend to be safest when rail tracks are fully separated; however, track separations are not always financially or physically feasible.
Modern tramways and light rail vehicles can handle steeper slopes (up to 8 – 10%) than heavy rail (up to 4%). They can also make sharper turns with min. radii about 15 meters (Bombardier Corp., 2005-a).	Neither steel wheeled tramways nor other light rail vehicles can tolerate steeper slopes more than 10%.
There is no need to build a spatial station or a boarding platform for low floor tramways and light rail vehicles.	Especially tramways occupy urban space above ground and need modifications to traffic and require some right of way managements.

Table 4.4 (continued)

Advantages	Disadvantages
Incase of emergency, tramways and light rail vehicles are easier to evacuate than monorail or other elevated rail/cable systems.	Tramways can be dangerous for pedestrians & cyclists sharing same urban space or for other vehicles sharing same roadways.
Tramways and light rail vehicles work with electric power and fed either from an overhead wire or from a third live rail. So, they spread no emission at the point of use.	
Modern tramways and light rail vehicles have more passenger capacities' than any other bus or "bus like" public transport service.	

Figure 4.6 Examples of tramway and light rail transit services: (a) Modern tramway operated in Istanbul and (b) "Ankaray" light rail system operated in Ankara (Adapted from Bombardier Corp., 2005-a and ABB – EGO, 2005)

- **Monorail:**

  Monorail is a railway technology that uses vehicles operating on a single guideway that is usually elevated. However monorail vehicles can also operate at grade, below grade or in subway tunnels. In contrast to other railway vehicles, a monorail vehicle is significantly wider than the single (central) guideway that supports it. “There are two main types of monorail systems: suspended (Figure 4.7-a) and straddled (Figure 4.7-b). The straddled system, which vehicle covers the guideway on the sides, is a more popular and preferred system (Wikipedia, 2005-c).” Monorail vehicles are powered by electric motors and generally have rubber tires. Monorail vehicle is stabilized and propelled by these tires, rolling along the top and sides of the guideway. Due to powerful traction and guideway adhesion, monorail systems can tolerate steep ground slopes (up to 18%). Moreover, steeper ground slopes may be tolerated by changing the guideway inclination via adjusting pillar heights. Advantages and disadvantages of monorail systems are listed in Table 4.5.

Table 4.5 Advantages and disadvantages of monorail systems

Advantages	Disadvantages
Monorail systems cost less to construct and maintain when compared to underground metro systems.	Monorail systems cost more to construct and maintain than tramways and light rail systems operating at grade.
Because monorail guideway is fully segregated, there is no risk of colliding with traffic or pedestrians.	All monorails require their own fully segregated guideway.
Monorail systems require minimal space both horizontally and vertically. The horizontal space is determined by the vehicle width and the vertical footprints are only pillars.	In case of an emergency, passengers cannot immediately exit from the vehicle because monorails systems are usually elevated. Some monorail systems propose emergency walkways, but this reduces the advantage of minimal sky obstruction.
Due to smaller footprints, they are more attractive than conventional rail tracks elevated on viaducts.	While line switching, monorail vehicles leave one guideway, hanging in-mid-air, until switching is completed. Hence, detaching from the guideway may cause derailing with an additional risk of falling several meters to the ground.

Table 4.5 (continued)

Advantages	Disadvantages
Some monorails are capable of climbing higher gradients up to 18% and making faster turns than tramways since they are clamped to the guideways (MMC Metrail, 2005).	There are no standardized monorail guideway specifications and most tend to be proprietary systems. That may cause technical integration problems when new trains are going to be purchased from different manufacturers.
Since monorail vehicles run on rubber tires through a concrete guide way, they make less noise and vibration than steel wheeled rail systems.	

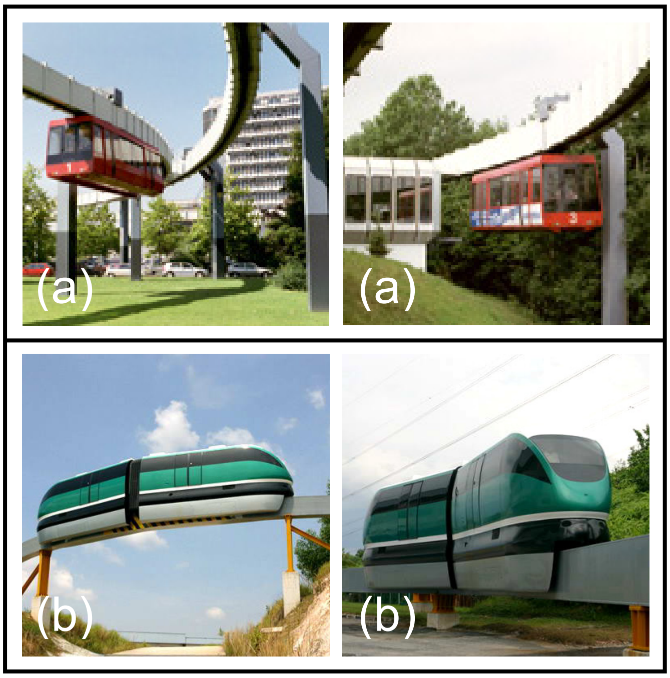

Figure 4.7 Examples of monorail vehicles: (a) H-Bahn suspended monorail operated in Dortmund University – Germany and (b) Metrail straddled monorail on test track (Adapted from H-Bahn Dortmund, 2005 and MMC Metrail, 2005)

4.2.1.1 Evaluating Land and Road Slopes in the Campus for the feasibility of Different Public Transport Modes

Campus land and road slopes are guiding factors for eliminating the public transport modes which cannot tolerate the steep gradients in campus. Besides, land and road slopes should be considered for designing topographically well adjusted routes for the selected modes.

In order to query land slope suitability for different service modes; campus land slope is grouped into several intervals according to the slope limits that can be tolerated by different public transport modes, listed in Table 4.6.

Table 4.6 Slope tolerance limits for different public transportation modes

Modes of Public Transport	Slope (%) Upper Limit (Serviceable with Stops or Stations)	Slope (%) Upper Limit (Max. Possible Traction, No Stops or Stations)
Conventional rail transport vehicles with steel wheels (eg. sub-urban trains)	4 %	N/A
Modern tramways and light rail vehicles with steel wheels (eg. Flexity series from Bombardier)	8 %	10 %
Guided light transit (GLT) systems with rubber tires (eg. GLT from Bombardier or Translohr from LOHR)	13 %	N/A
Monorail, modern trolleybus and guided electrified buses with rubber tires (eg. Metrail from MMC. Metrail or Cristalis and Civis from Iris Bus)	18 %	20 %
Conventional buses with rubber tires, powered by diesel engines (eg. Connecto Euro-3 from Mercedes-Benz)	25 %	55 %
(*) Slope tolerance values are obtained from the technical specifications charts retrieved from relevant manufacturers' websites. (Neufert, 1974), (Bombardier Corp., 2005-a), (Bombardier Corp., 2005-b), (MMC Metrail Corp., 2005) and (Iris Bus Corp., 2005)		

According to Table 4.6, areas having a slope value up to 4 % are assumed to be suitable for conventional rail transport vehicles, such as sub-urban or metro trains. Areas with a slope value up to 8 % are assumed to be suitable for light rail transit vehicles. Areas having a slope value of up to 12 % are assumed to be suitable for rubber tired light transit vehicles. Areas having a slope of up to 18% are assumed to be suitable for rubber tired monorail vehicles and solo or articulated modern trolleybuses. For areas having slope values more than 18 %; public transportation services are possible with conventional diesel powered buses. Figure 4.8 shows suitable and unsuitable service areas in campus by that mode according to its slope tolerance limits.

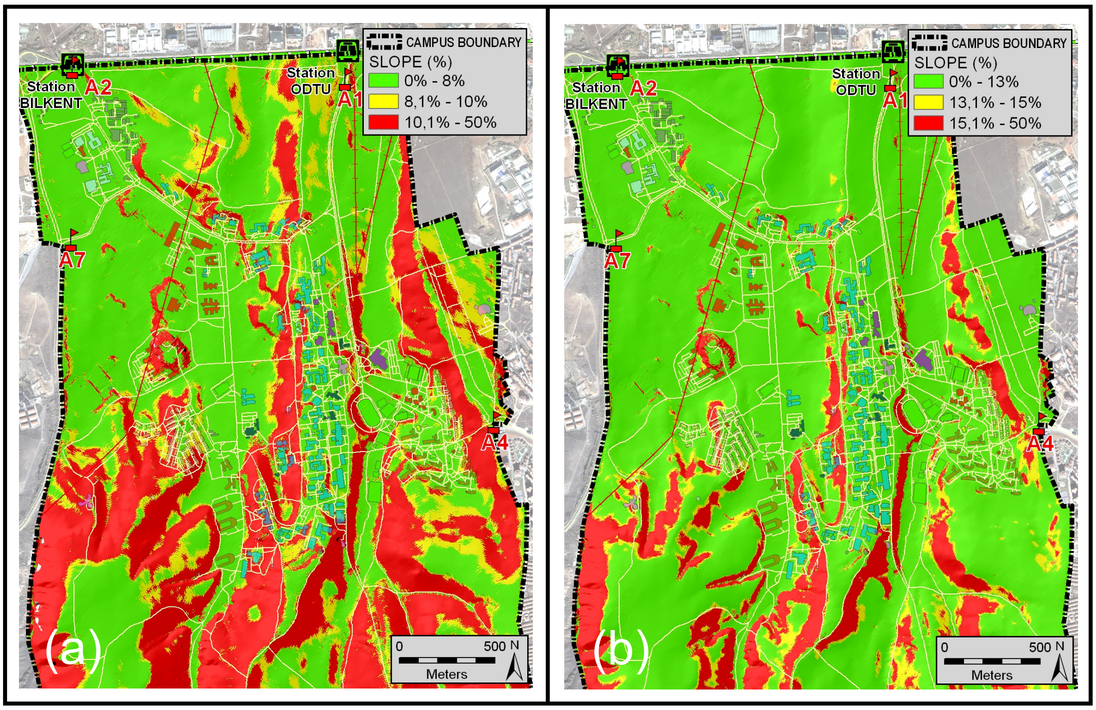

Figure 4.8 Land slope analyses for the feasibility of different public transport modes in campus: (a) tramway and light rail transit, (b) guided light transit (GLT), (c) monorail, trolleybus or guided electrified bus and (d) conventional diesel buses

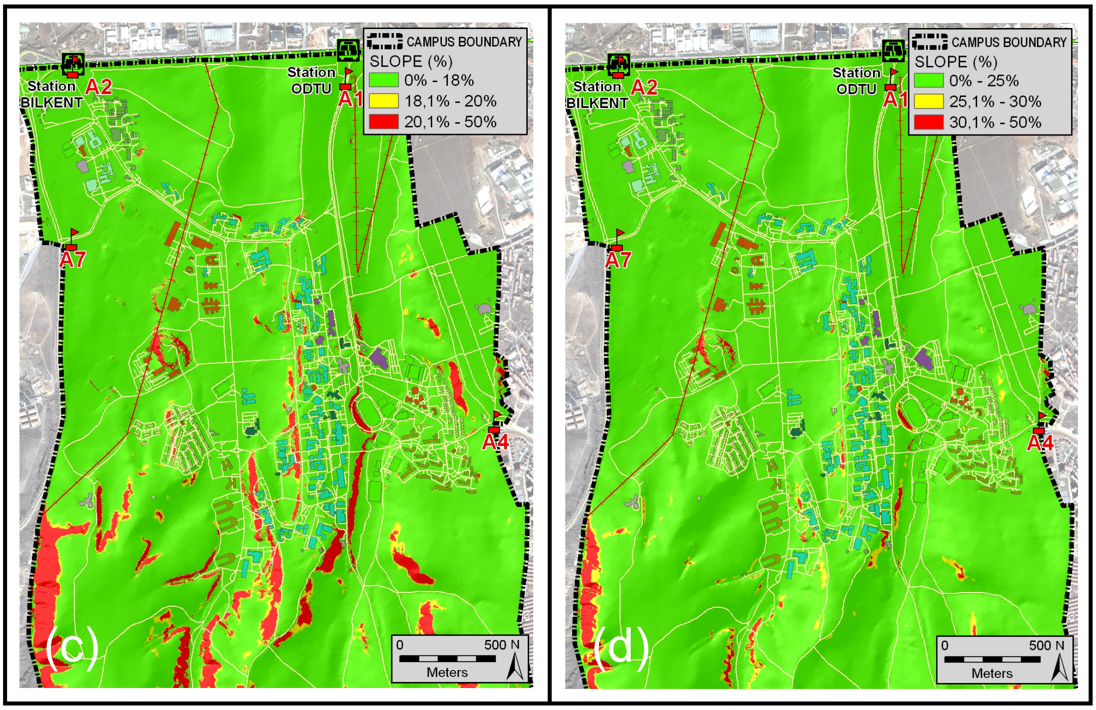

Figure 4.8 (continued)

According to Figure 4.8; first slope interval shown with green color represents first degree topographical suitability, second slope interval shown with orange color represents second degree suitability that denotes mode's maximum slope tolerance limit and lastly red colored third interval represents unsuitable areas in campus with steep slopes for that mode.

Slope characteristics of existing vehicle roads and main pedestrian paths may also be referenced by planners and engineers. For instance, a service route for a selected public transport mode can be proposed on or parallel to a road or path until it covers the spatial trip demand and meets the slope limits for that mode. Therefore, a similar slope suitability query map, which is given in Figure 4.8 for land slope, is also given for campus road slopes in Figure N.1 (Appendix N).

4.2.2 Proposing Routes, Stations – Stops for Different Public Transport Modes

Main steps for planning a new public transport service route can be defined as; system planning, alternative analysis, preliminary engineering and final design (Black, 1995). According to Black (1995); system planning is usually attached to a long ranged transportation master plan. In this step, characteristics of alternative transportation modes are evaluated relative to spatial trip demand and major transit systems defined in the master plan. In the second step; alternative analysis (Black, 1995), a detailed technical evaluation is carried for the selected alternatives relative to the priority corridors or zones. Third and fourth steps; preliminary engineering and final design (Black, 1995), are partially in the scope of this thesis, within Chapter 5. In preliminary engineering step, preferred service alternatives are evaluated in terms of technical and operational feasibility. In most cases, optimal service(s) is/are determined and a group of engineers and architectures prepare the final plans for contractors.

As parallel to the general methodology explained above; campus physical, population and transportation structure is explored and significant campus zones (in terms of trip demand and structural issues) are determined. Besides, characteristics of alterative public transport modes are explored. According to these explorations and analyses; modern trolleybus and guided light transit (GLT) modes are selected as probable public transport services in campus.

Modern trolleybus and GLT systems' construction and vehicles cost less than light rail systems'; besides both modes offer more passenger capacity than buses. Both trolleybuses and GLT vehicles work with zero emission, less noisy electric motors and offer higher service quality, comparable with light rail vehicles. Moreover, both modes tolerate steep slopes and sharp turns like buses. They are also physically less obstructive than light rail systems since GLT needs only one rail for guidance and trolleybuses can be guided by road paints.

According to the information obtained from presidency office, METU is concerning about a monorail system in campus. According to this system, a monorail vehicle, with five cars each having a capacity of 25 passengers is planned to be operated especially for connecting campus to the upcoming metro station(s). Monorail is a modern, flexible and fully automatic, electric powered system that is propelled by rubber tires through a single concrete guide way. Unlike conventional light rail vehicles, monorail trains can tolerate steeper slopes. Besides, monorail guideways can be elevated and they are less obstructive for vehicular and pedestrian traffic. However, monorail systems usually cost more than or at least same as peer light rail systems. In addition, monorail is not a widespread solution yet for urban public transportation unless its advantages are unique and indispensable. However, monorail mode is selected as the third probable service in this study, due to its capability of tolerating steep gradients and because of the campus monorail project.

After determining the probable service modes as modern trolleybus, guided light transit and monorail; modes' route alternatives are designed with the guidance of previous analyses and explorations. Some fundamental service circulation schemas [(7)] (or combinations of them) are also considered in the design process. These are convex polygon, one way ring, nested loops, binary tree (Zorlu, 1999) and spine line. Then, stop or station locations are

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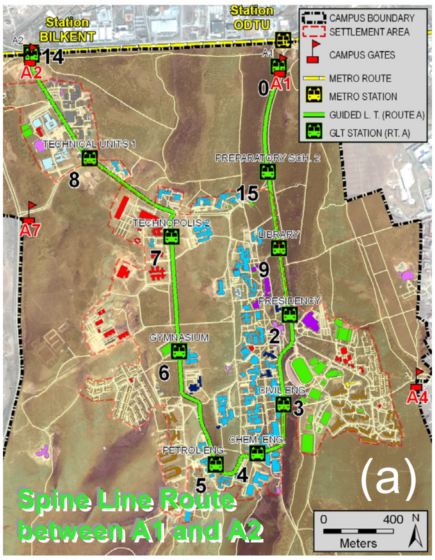
[(7)] "Convex polygon is a robust and compliant circulation system that allows various junction and routing configurations. One way ring is neither a robust nor a well compliant circulation system and in this system travel distance is much more than others. Nested loop is one of the most convenient circulation system that is separated as radio-concentric, the grid and hexagonal loops. Binary tree system requires extreme hierarchical arrangements and this circulation system is arranged to serve especially for inter base trips. (Zorlu, 1999: 101,131,123,136)" Spine line is a node to node, un-circular system that is useful for express connections between nodes or servicing through a demand corridor, which is the "spine".

proposed on the route alternatives of each mode. Proposed service routes and stop/station locations, pertaining to each alternative mode, are evaluated in Chapter 5.

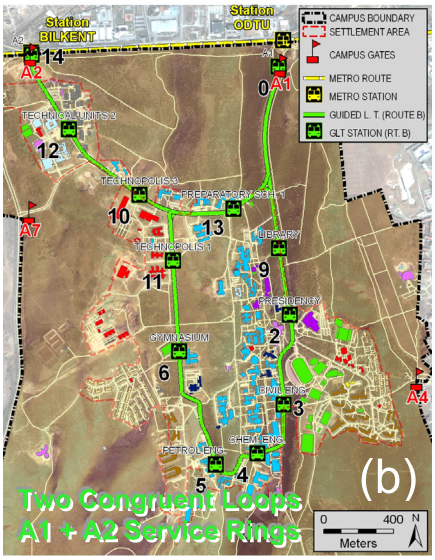
4.2.2.1 Route and Stations for Guided Light Transit

Two service route alternatives are proposed for guided light transit mode and given in Figure 4.9. Same route alternatives are also shown on zone significance and campus slope maps in Figure O.1 (Appendix O).



St. ID	Proposed Service Area for Station
0	A-1 Gate & ODTÜ Metro Station
2	Academic Units & Presidency Office & Cafeteria & CCC. & Shopping Cent. & East (Old) Dorms. & METU Residences (Old)
3	Academic Units & Small Gymnasium & Sports & East (Old) Dorms.
4	Academic Units
5	Academic Units & West (New) Dorms.
6	METU Resid. & Gymnasium (New)
7	METU Tech. & Fac. of Educ. & Fac. of Econ. Adm. Sci. (New B.) & Prep. Sch.
8	METU Foundation School & Techical Units & Faculty of Education (New B.)
9	Academic Units & Library
14	A-2 Gate & Bilkent Metro Station
15	Preparatory School

Figure 4.9 Proposed route and station alternatives for guided light transit: (a) Alternative A and (b) Alternative B



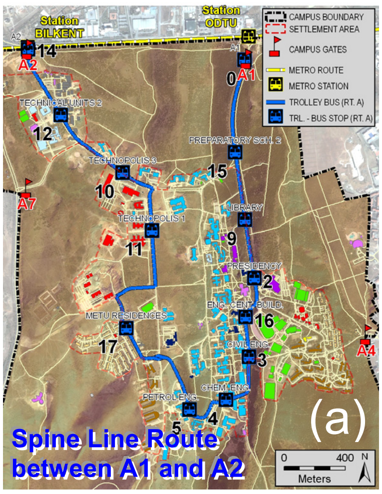
St. ID	Proposed Service Area for Station
0	A-1 Gate & ODTÜ Metro Station
2	Academic Units & Presidency Office & Cafeteria & CCC. & Shopping Cent. & East (Old) Dorms. & METU Residences (Old)
3	Academic Units & Small Gymnasium & Sports & East (Old) Dorms.
4	Academic Units
5	Academic Units & West (New) Dorms.
6	METU Resid. & Gymnasium (New)
9	Academic Units & Library
10	METU Techno. & Fac. of Edu. (New & Old B.)
11	METU Tech. & Fac. of Eco. Adm. Sci. (New)
12	METU Foundation School & Technical Units
13	Prep. Sch. & Fac. of Eco. Adm. Sci. (New B.)
14	A-2 Gate & Bilkent Metro Station

Figure 4.9 (continued)

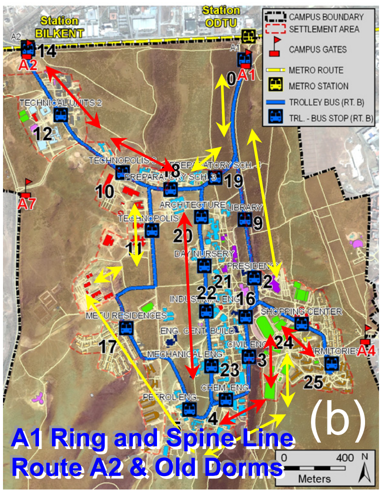
First service route (Figure 4.9-a) is designed with respect to the node to node spine line circulation system. Edges of the spin line route are linked to the metro stations (nodes) located by A1 and A2 gates. In this route, number of proposed GLT stations (vertices of the system) is tried be kept minimum since spine line routes should supply fast and frequent service through a demand corridor while connecting two significant nodes (metro stations). Second service route (Figure 4.9-b) is designed with respect to one way ring and nested loops circulation system. Two congruent one way service rings, one linking to ODTÜ Station at A1 gate and other linking to Bilkent Station at A2 gate, are proposed. By means of this system, campus settlement area serviced twice since it is driven once with each loop. Another advantage of this design is that; since campus trip demand is shared by two services, trips may also be directed to both stations.

4.2.2.2 Route and Stops for Modern Trolleybus

Three service route alternatives, two for working hours during day and one for after evening peak during night, are proposed for trolleybus mode and given in Figure 4.10. These route alternatives are also shown on zone significance and campus slope maps in Figure O.2 (Appendix O).

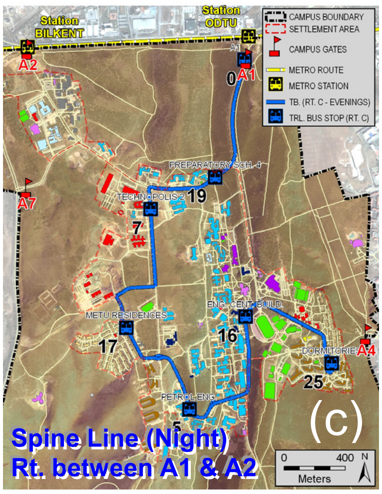


Stop ID	Proposed Service Area for Station
0	A-1 Gate & ODTÜ Metro Station
2	Academic Units & Presidency Office & Cafeteria & CCC. & Shop. Cent. & East (Old) Dorms. & METU Resid. (Old)
3	Acad. Units & Small Gymn. & Sports & East (Old) Dorms.
4	Academic Units
5	Academic Units & West (New) Dorms.
9	Academic Units & Library
10	METU Technopolis & Fac. of Education (New & Old B.)
11	METU Technopolis & Faculty of Economic Administrative Sciences (New Building)
12	METU Foundation School & Technical Units
14	A-2 Gate & Bilkent Metro Station
15	Preparatory School
16	Academic Units & Shopping Center & Sports
17	METU Resid. (New) & METU Tech. (Expansion) & Gym.



Stop ID	Proposed Service Area for Station
0	A-1 Gate & ODTÜ Metro Station
2	Acad. Units & Presidency Office & Cafeteria & CCC. & Shopping Center & East Dorms. & METU Residences
3	Acad. Units & Small Gym. & Sports
4	Academic Units
5	Academic Units & West (New) Dorms.
9	Academic Units & Library
10	METU Technopolis & Fac. of Education (New & Old B.)
11	METU Technopolis & Faculty of Economic Administrative Sciences (New Building)
12	METU Foundation School & Technical Units
14	A-2 Gate & Bilkent Metro Station
16	Academic Units & Shopping Center & Sports
17	METU Resid. (New) & METU Tech. (Expansion) & Gym.
18	Prep. School & Fac. of Edu. (Old B.) & Fac. of Eco. Adm.
19	Preparatory School
20 - 21	Academic Units & Day Nursery
22 - 23	Academic Units
24	Shopping C. & Main Gym. (Old) & Sports & METU Resid.
25	East Dorms. (Old) & METU Residences (Old)

Figure 4.10 Proposed route and stop alternatives for trolleybus services: (a) Alternative A, (b) Alternative B and (c) Alternative C



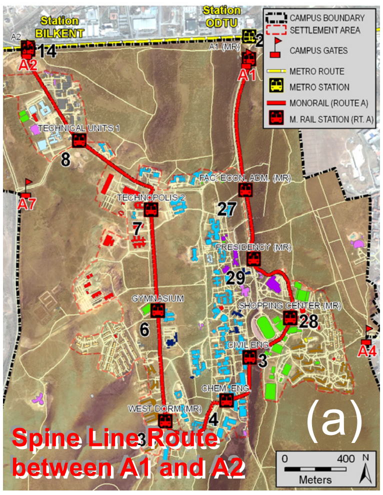
Stop ID	Proposed Service Area for Station
0	A-1 Gate & ODTÜ Metro Station
5	West (New) Dorms. & Southern Academic Units
7	METU Technopolis & Northern Academic Units
16	Central Acad. Units & CCC. & Shopping Center & Sports
17	METU Residences (New)
19	Northern Academic Units
25	East Dorms. (Old) & METU Residences (Old)

Figure 4.10 (continued)

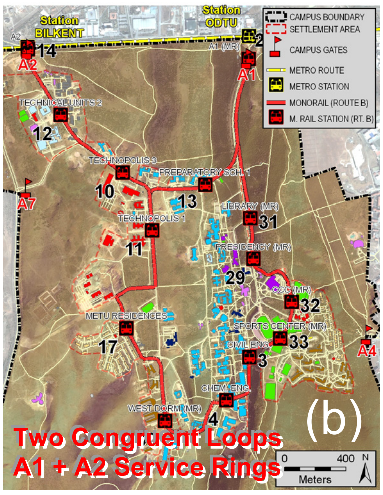
First service route (Figure 4.10-a), is designed with respect to the node to node spine line circulation system, like the first route alternative that is proposed for GLT. Since trolleybus tracks cost less than GLT tracks, spine line route is designed longer and extended towards METU Residences and Technopolis. Nodes of spine line are linked to the metro stations (A-1 and A-2 gates). Second service route (Figure 4.10-b) design principle is based on a combination of one way ring and spine line circulation systems. In this alternative, one service loop encircles the campus trough main roads and then links to the metro station located by A-1 gate (one way ring circulation, shown with yellow arrows); other service (node to node spin line circulation, shown with red arrows) connects east dormitories through Faculties' and Faculty of Education Roads to the Bilkent Station, located by A-2 gate. The biggest advantage of this design is that, eastern zones of the campus are served (eg. shopping center, east dormitories and residences). A third alternative (Figure 4.10-c) is also proposed as "clear cut" route which can be operated after evening peak, during night or in weekends when zonal trip demand significantly changes. Third service route is designed with respect to the spine line circulation. Route connects dormitories and residences to A-1 gate and metro station by tracing some existing trolleybus tracks that are already proposed with second route alternative.

4.2.2.3 Route and Stations for Monorail

Three service route alternatives are proposed for monorail mode and given in Figure 4.11. These route alternatives are also shown on zone significance and campus slope maps in Figure O.3 (Appendix O).

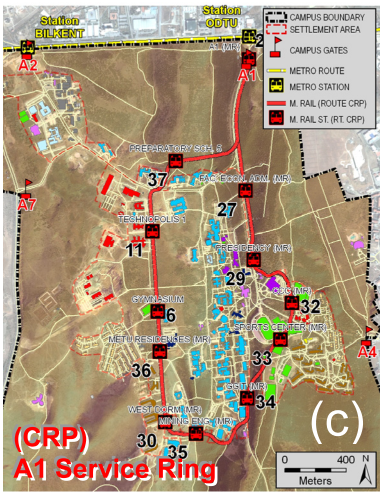


St. ID	Proposed Service Area for Station
3	Academic Units & Small Gym. & Sports
4	Academic Units
6	METU Residences (New) & Gymnasium (New)
7	METU Technopolis & Fac. of Education (Old B.) & Fac. of Econ. Admin. Sci. (New B.) & Preparatory School
8	METU Foun. Sch. & Tech. Units & Fac. of Edu. (New B.)
14	A-2 Gate & Bilkent Metro Station
26	A-1 Gate & ODTÜ Metro Station
27	Faculty of Economic Administrative Sciences (Old B.) & Faculty of Architecture & Preparatory School
28	Shopping Center & Main Gymnasium (Old) & Sports & METU Residences (Old) & East Dorms. (Old)
29	Acad. Units & Presid. Off. & Cafeteria & CCC. & Library
30	West Dorms. (New) & Academic Units



St. ID	Proposed Service Area for Station
3	Academic Units & Small Gym. & Sports
4	Academic Units
10	METU Technopolis & Fac. of Education (New & Old B.)
11	METU Technopolis & Fac. of Eco. Adm. Sci. (New B.)
12	METU Foundation School & Technical Units
13	Preparatory School & Fac. of Eco. Adm. Sci. (New B.)
14	A-2 Gate & Bilkent Metro Station
17	METU Residences (New) & Gymnasium (New)
26	A-1 Gate & ODTÜ Metro Station
29	Acad. Units & Presid. Off. & Cafeteria & CCC. & Library
30	West Dorms. (New) & Academic Units
31	Academic Units & Library
32	Shop. C. & CCC. & Sports & METU Resid. & East Dorms
33	Gymnasiums & Sports & East Dorms. (Old)

Figure 4.11 Proposed route and station alternatives for monorail services: (a) Alternative A, (b) Alternative B and (c) Alternative C



St. ID	Proposed Service Area for Station
6	METU Residences (New) & Gymnasium (New)
11	METU Techno. & Fac. of Eco. Adm. Sci. (New B.)
26	A-1 Gate & ODTÜ Metro Station
27	Faculty of Economic Administrative Sciences (Old B.) & Faculty of Architecture & Preparatory School
29	Academic Units & Presidency Office & Cafeteria & CCC. & Library
30	Academic Units & West Dorms. (New)
32	Shopping Center & CCC. & Sports & METU Residences (Old) & East Dorms. (Old)
33	Gymnasiums & Sports & East Dorms. (Old)
34	Academic Units
35	Academic Units
36	METU Residences (New) & West Dorms. (New)
37	Preparatory School & Faculty of Education (Old B.)

Figure 4.11 (continued)

First service route (Figure 4.11-a) is designed with respect to the node to node spine line circulation system. In the first proposal, it is aimed to keep the number of stations as minimum since monorail stations are usually special elevated structures, requiring additional investment. First service route connects A-1 and A-2 gates and so the metro stations, trough a campus demand corridor. Second route alternative (Figure 4.11-b) is designed with respect to one way ring and nested loops circulation system. Two congruent service rings, one linking to ODTÜ Station at A1 gate and other linking to Bilkent Station at A2 gate, are proposed to loop the campus. However, this efficient bidirectional servicing may be possible with track sharing and interchanging (cheaper solution) or with constructing double tracks that also enables high capacity service (expensive solution). The third alternative service route is obtained from the presidency office. This route is proposed by the academic committee, from the Department of City and Regional Planning, to the Presidency of METU as an opinion regarding to the campus monorail project. The common advantage of all three routes is that, due to monorails' higher slope tolerance, vertical thresholds trough the stadium (on the east) and by the Aerospace Engineering (on the west) can be bypassed on elevated tracks (over pillars). So that western and eastern zones are also served with monorail stations without distorting the service routes.

CHAPTER 5

EVALUATING FEASIBILITY OF PROPOSED PUBLIC TRANSPORT SERVICES

In this chapter, proposed route (and pertaining stop/station) alternatives of the probable service modes are evaluated for determining the feasibility of these services in campus. Feasibility of each alternative service is evaluated from two main aspects; physical characteristics and service coverage areas. Route lengths, number of stops/stations, elevation profiles and slope characteristics of the routes are analyzed for physical evaluation. Then, service coverage areas are determined with the aid of network analysis, based on the pedestrian accessibility from/to service stops/stations. Since this thesis is not a complete transportation planning study, evaluation of operational factors and feasibility analyses regarding to service management are not included in the scope of this chapter. At the end of this chapter, results of the feasibility analyses are discussed and suitable service routes and related service modes are determined from different viewpoints with different service strategies.

5.1. Physical Evaluation of the Proposed Public Transport Services

In this part of the study, public transport services, proposed in Chapter 4, are evaluated according to their physical characteristics. First, lengths of alternative service routes and the number of stops/stations on these routes are queried for three probable services: guided light transit, trolleybus and monorail. Then, elevation profiles and slope characteristics of alternative service tracks are analyzed relative to the slope tolerance limits defined for each service mode.

5.1.1. Evaluating Route Lengths and Number of Stations – Stops

In public transport service planning, although service routes are designed to cover the spatial trip demand through or around them; actually services are only available from the stops or stations, located on these routes. Therefore, service coverage area is usually proportional with the number of stop/stations on that route, depending on the limits of pedestrian accessibility from/to these stops/stations. But on the other side; as the number of stops/stations increases, average distance between stops/stations decreases and average operational speed (8) decreases on that route. Also, stations of some transport modes (eg. monorail, subway etc.) require special architecture and increase the overall setup cost. When the average operational speed decreases on that route, travel time increases and door-to-door (9) accessibility decreases. All these are chaining cases, based on the design principles of service routes. Therefore, as Black also stated (1995); (while ignoring the capacity concerns,) a public transport service should establish an optimum balance between the following factors for efficient operation: length of the service route, number of stops/stations on that route, average operational speed and average distance between stops/stations.

On the other side, spacing between stops/stations directly affects to the walking time. As spacing increases, walking time to/from stops/stations increases and door-to-door accessibility decreases. Service operators define

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(8) "Average operational speed depends on the total travel time that is spent while covering the service route from one end to other end; including the delays at stops/stations (Black, 1995:121)."

(9) "Door-to-door speed is the average speed for traveling from origin to destination. It also includes the time spent for walking to stop/station and for waiting the service vehicle. This is the most important measure because it is believed that most travelers make modal chooses based on door-to-door time (Black, 1995: 122)."

the probability of walking to a stop/station from a specified distance with the cumulative normal distribution curve (White, 1976:102). According to this curve, probability of walking decreases less than 0,5 after 500 meters and reaches down to 0 (zero) at 900 meters (White, 1976:102). Therefore, stops/stations on the service routes should be located with a maximum service radius about 500 meters, which corresponds to a 5 minute walking time for an adult. However, this spacing may change according to the scale of study and type of transport mode. Black (1995) stated that, any stop/station spacing between 350 and 800 meters is considerable for trolleybus, guided bus, light rail or monorail modes with an operational speed between 20 and 30 kilometer per hour.

In this study, it is assumed that optimal stop/station spacing should not be more than 500 meters (~250 m. service radius per stop) and less than 400 meters (~200 m. service radius per stop), based on the design principle: proposing 2 or 3 minutes effective service rings for each stop/station on that service route. In Table 5.1; route lengths; number of stops/stations; average stop/station spacing; operational speed and average travel time estimations are given for three alternative modes' eight different service tracks. Some proposed public transport services in Table 5.1 (GLT B, Trolleybus B and Monorail B) offer two service routes on their track infrastructure. Therefore, actually 11 service routes are explored in Table 5.1 for eight alternative service infrastructure. Besides, trolleybus service "Trolley C" is proposed as an alternative route, tracked on "Trolley B" infrastructure, after working hours or in weekends.

Table 5.1 Physical characteristics of alternative service routes in campus

Physical Characteristics	Probable Public Transport Modes										
	GLT Route Alternatives			Trolleybus Route Alternatives				Monorail Route Alternatives			
	A (*) (A1 to A2)	B (**)		A (*) (A1 to A2)	B (**)		C (*) (A1 to Dorm)	A (*) (A1 to A2)	B (**)		C (*) (A1 Ring)
		A1 Ring	A2 Ring		A1 Ring	A2 to Dorm			A1 Ring	A2 Ring	
Total Route (Track) Length (meter)	**5.480**	**6.270**		**5.930**	**8.960**		**5.340**	**6.040**	**7.120**		**5.540**
A1 Route / A2 Route		4.880	5.360		5.260	4.780			5.830	6.300	
Total Number of Stops/Stations	11	12		13	20		7	11	14		12
A1 Rt. Stops / A2 Rt. Stops		9	11		11	13			11	13	
Avg. Distance between Stops (meter)	498	523		456	448		763	549	509		462
A1 Rt.'s Av.Dist. / A2 Rt.'s Av.Dist.		542	487		478	368			530	485	
Avg. Delay Time at Stop/Station	30 Seconds per Stop/Station										
Vehicle Speed	30 km. / hour (500 meters / minute)							40 km. / hour (666 meters / minute)			
Total Travel Time (All Route) ('minute ''second)	16' 28"	~ 15' (avg.)		18' 22"	~ 16' (avg.)		14' 12"	14' 34"	~ 15' (avg.)		14' 19"
A1 Rt. T. Time / A2 Rt. T. Time		14' 16"	16' 13"		16' 01"	16' 03"			14' 15"	16' 08"	
Avg. Operational Speed (kilometer/hour)	**20,0**	**20,5**	**19,8**	**19,4**	**19,7**	**17,9**	**22,6**	**24,9**	**24,6**	**23,7**	**23,2**
Number of Loops per hour	**3,6**	~ 4,0 (avg.)		**3,3**	~ 3,8 (avg.)		**4,2**	**4,1**	~ 4,0 (avg.)		**4,2**
# of A1 Loops / # of A2 Loops		**4,2**	**3,7**		**3,8**	**3,7**			**4,2**	**3,8**	

(*) Following service tracks are operated with one route: GLT A, Trolleybus A, Trolleybus C, Monorail A and Monorail C.
(**) Following service tracks are operated with two routes: GLT B with two congruent service rings, one links to A1 and other links to A2; Trolleybus C with one service ring that links to A1 and one node-to-node service route that connects A2 to east dorms; Monorail B with two congruent service rings, one links to A1 and other links to A2.
(***) "." is thousand separator, "," is decimal separator, ' stands for minute, '' stands for seconds

According to Table 5.1, required track lengths (infrastructure) to be constructed for proposed services, vary between min. 5.480 m. (GLT A) and max. 8.960 m. (Trolleybus B). On the other side, the shortest service route is the A2 to East Dormitories route on Trolleybus B track (4.780 m.); however it offers the least operational speed (17,9 km./h.) since there are 13 stops on this route. Average distances between stops/stations vary between 368 m. (A2 to Dorm. route on Trolleybus B) and 549 m. (Monorail A); while excluding the night/weekend (express) route Trolleybus C which has 763 m average spacing. According to these measures, average distances between service stops/stations can be considered as favorable for all proposed alternatives. In terms of operational speeds; since trolleybus stops tend to be more frequent, trolleybus mode offers less operational speed then GLT or Monorail. On the other side, Monorail offers the highest operational speeds in all alternatives (up to 4,2 service loops per hour) due monorail's higher initial speed (40 km./h.), since vehicles run on fully segregated guideways. However, building these segregated guideways makes the monorail to be the most expensive mode within all alternatives.

Obviously, these findings are not enough for selecting one or more of these service alternatives as suitable since these findings must be evaluated together with the pedestrian accessibility based service area analysis, carried in the second part of this study.

5.1.2. Evaluating Slope Characteristics of Routes

Slope characteristics of the service tracks may be critical for the feasibility of public transport services. First of all, speed and (uphill) slope are inversely proportional factors; meaning that as the average (uphill) slope of the service tracks increase, average operational speed of that service decreases relative to the slope tolerance limits defined for that mode. On the other side, since some public transport modes need technical service infrastructure (eg.

guided light transit, monorail etc.), ground slope must also be considered for the amount of construction costs, in addition to the operational efficiency. On the other side, owing to today's modern construction techniques, steep ground slope is not an unsurpassable threshold for the establishment of a service track. However, steep slope is still a negative factor, which may increase the initial construction costs since special construction techniques might be used while dealing with problematic topography and steep slope.

In Chapter 4, campus land and roads are queried according to the slope tolerance limits of different public transport modes, given in Table 4.6. With the aid of this spatial query, due to their higher slope tolerance limits, guided light transit (GLT) (up to 13%), trolleybus and monorail (up to 18%) modes are detected as the modes, allowing the biggest theoretical service area in campus (while ignoring the conventional diesel buses). At the end of Chapter 4, alternative service tracks are designed for these modes by considering the spatial trip demand and also the ground slope. In this part of the study, slope characteristics of these service tracks analyzed and compared via some summary statistics.

In Table 5.2, following basic indicators are given for the eight alternative service tracks; regarding to GLT, trolleybus and monorail: maximum and average slopes on service tracks; length of problematic segments and their ratio to the rest. The term "problematic" is used for defining the segments of service tracks, having steeper slopes than the slope tolerance limits defined for that mode. In addition to these indicators, a basic slope index is developed to reflect the amount of problematic segments on that service track. In order to calculate this index, service tracks are divided into sub segments having lengths about 10 meters. Then, average percentage slope of each segment is extracted from the campus slope map, generated in Chapter 3. After calculating the average slope of each segment; problematic service segments are queried. Then, slope values of these segments are subtracted from the slope tolerance limit of the relevant mode. Calculated residue of each problematic segment is squared and all squared residues are summed. Finally, value of the total residue is divided by the total number of segments on that service track and resulting index values is normalized by multiplying with 1000. Formula of the slope index is given as: ***Slope Index = [1000 x ((Σ for "i" to "m" ((Slope Value of the Problematic Segment "i") – (0,9 x Slope Tolerance Value of Transport Mode))*** ^{2} ***) / Number of All Segments "n")].*** *("m" stands for number of all problematic segments.)*

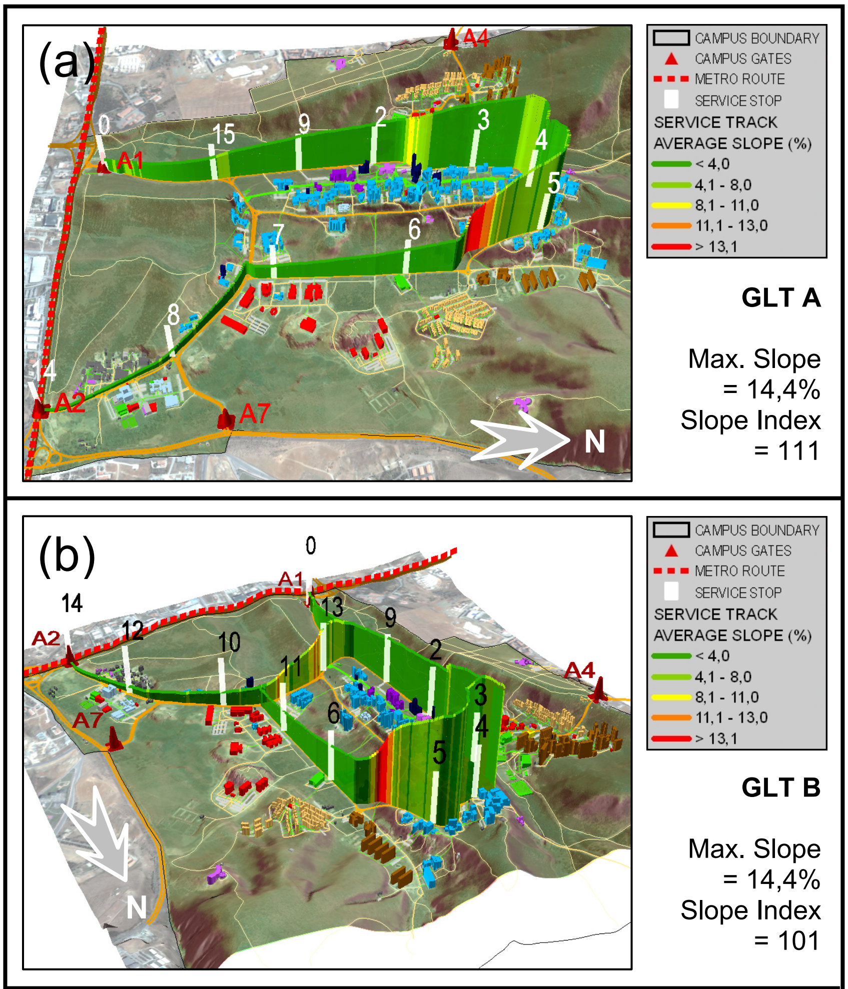
Table 5.2 Slope characteristics of alterative service tracks in campus

Slope Characteristics	Probable Public Transport Modes							
	GLT		Trolleybus			Monorail		
	Track A	Track B	Track A	Track B	Track C	Track A	Track B	Track C
(**) **Mode's Slope Tolerance Limit** (%)	*13 x (0,9) = 11,7* **~ 11**		*18 x (0,9) = 16,2* **~ 16**					
Average Slope of the Service Track (%)	3,1	3,4	2,9	3,3	3,7	3,24	3,36	4,18
Maximum Slope of the Service Track (%)	**14,4**	**14,4**	**19,0**	**19,0**	**19,0**	**22,9**	**22,9**	**29,9**
Length of the Service Track (meter)	5.480	6.270	5.930	8.960	5.340	6.040	7.120	5.540
Length of the Problematic Segments (meter)	**120**	**150**	**60**	**80**	**60**	**50**	**50**	**80**
(*) **Ratio of the Problematic Segments to the All Service Track** (x1000)	**21,9**	**23,9**	**10,1**	**8,9**	**11,2**	**8,3**	**7,0**	**14,4**
(*) **Squared Slope Residuals of the Problematic Segments**	**61,1**	**63,0**	**22,9**	**23,4**	**22,9**	**70,6**	**70,6**	**466,1**
(*) **Slope Index of the Service Track** (x1000)	**111**	**101**	**39**	**26**	**43**	**117**	**99**	**843**

(*) Small value is better.
(**) Modes' slope tolerance limits are multiplied by an assumed efficiency factor of 0,9 (decreased by 10%) since vehicles may not operate with full efficiency in real world conditions.
(***) "." is thousand separator, "," is decimal separator, all slope values are percentage.

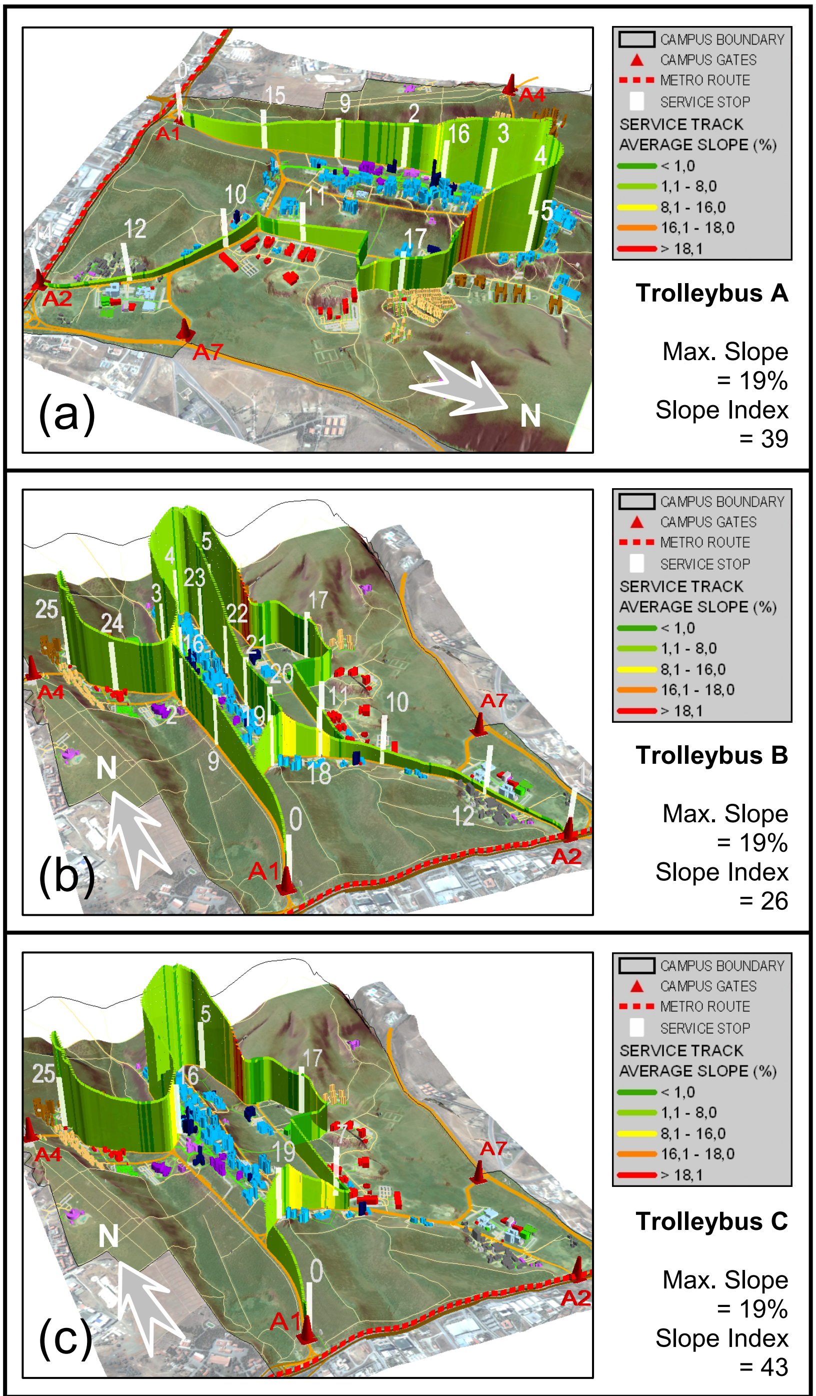
According to Table 5.2, average slopes of the service tracks vary between 2,9% (Trolleybus A) and 4.18% (Monorail C). Although average slope of a service track affects to the average operational speed; average slopes calculated in Table 5.2 are not very critical values for the efficiency of these services. However, maximum slopes of these service tracks should be considered as more critical than the average slopes; if the steepest segment's slope exceeds the tolerance limit of that mode. According to Table 5.2, all three trolleybus tracks share the same steepest slope of 19% while the steepest segment slopes for Monorail A and B tracks are 23% and for Monorail C is 30%. Since both modes are assumed to have an operational slope tolerance limit of 16%; construction of monorail tracks can be considered as more problematic than trolleybus tracks due to steeper maximum slope. On the other side, Monorail tracks A and B include the least amount of problematic segments on their network. In addition, although the Monorail C track has the steepest slope of 30%, it has only 80 meters problematic track which is a reasonable value in the middle. Main reason of this case is that monorail tracks coincide with steep ground slope only in two locations (Figure 5.3); between Civil Engineering and METU Stadium; and between Mining Engineering and Western Dormitories. GLT tracks have the maximum amount of problematic segments, 120 meters for GLT A and 150 meters for GLT B, since the operational slope tolerance limit for GLT vehicles is 11%. According to the slope index values, Trolleybus tracks have significant advantage due to their higher slope tolerance limits and so small amount of squared residue. Index values of GLT A, B and Monorail A, B tracks are around the average and can be considered as reasonable. However, Monorail C track has a significantly higher index value than others because this track coincides with the problematic topography by the Civil Engineering K5 Building with steep slopes up to 30% (Figure 5.3).

In order to clarify the findings of the slope analyses, elevation profiles and slope maps are produced and problematic segments are marked for GLT, Trolleybus and Monorail track alternatives, respectively in Figures 5.1, 5.2 and 5.3.



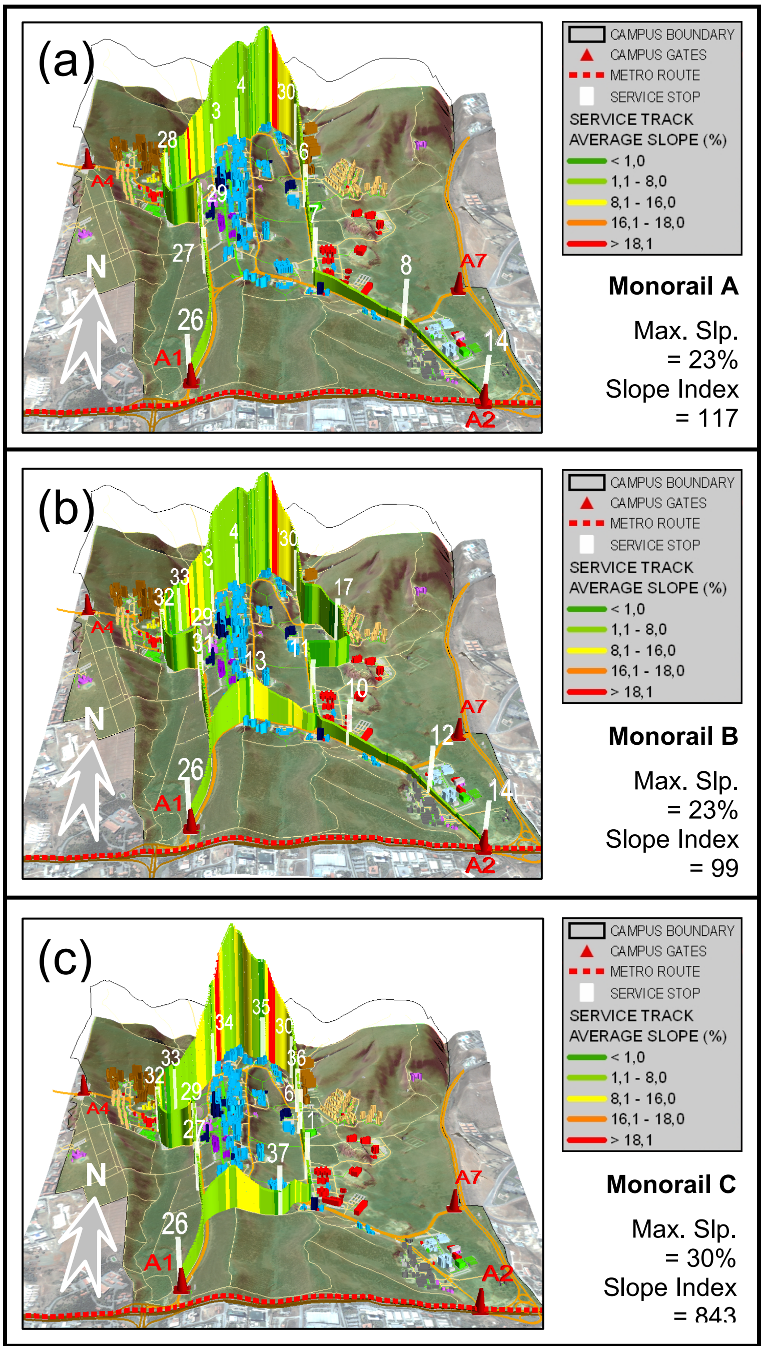
All figures are schematic and do not have constant scales. Campus topography is exaggerated four times in the Z axis. Service tracks are extruded in the Z axis proportional to the squared elevations of segments. White marks represent the locations of proposed stations and each station is labeled with its unique ID.

Figure 5.1 Elevation profiles and slope maps for the alternative service tracks of guided light transit: (a) “GLT A” and (b) “GLT B”



All figures are schematic and do not have constant scales. Campus topography is exaggerated four times in the Z axis. Service tracks are extruded in the Z axis proportional to the squared elevations of segments. White marks represent the locations of proposed stops and each stop is labeled with its unique ID.

Figure 5.2 Elevation profiles and slope maps for the alternative service tracks of trolleybus: (a) “Trolleybus A”, (b) “Trolleybus B” and (c) “Trolleybus C”



All figures are schematic and do not have constant scales. Campus topography is exaggerated four times in the Z axis. Service tracks are extruded in the Z axis proportional to the squared elevations of segments. White marks represent the locations of proposed stations and each station is labeled with its unique ID.

Figure 5.3 Elevation profiles and slope maps for the alternative service tracks of monorail: (a) "Monorail A", (b) "Monorail B" and (c) "Monorail C"

Consequently, Trolleybus track alternatives A, B and C, can be selected as the well adjusted service tracks relative to the ground slope. Although GLT tracks have the least maximum slope, they have higher slope index values because of their relatively small slope tolerance limits. Construction of Monorail tracks A and B can also be considered in spite of their higher maximum slope if they offer good service coverage in campus. However, special construction techniques must be applied in order to bypass the problematic segment (with 30% slope) in Monorail C track.

5.2. Pedestrian Accessibility Analysis and Service Coverage Areas for the Proposed Public Transport Services

“The goal of any transport system can be defined as enabling access to facilities; rather than mobility. So, to evaluate the efficiency of a transport system, in terms of delivering people to the facilities, some accessibility measures are needed. (O’Sullivan et al., 2000)” A definition of accessibility is given by Dalvi (1978) as; accessibility is the ease of reaching to a facility (destination) from a particular location (origin), using a particular transport system (transport mode). Koenig (1980) goes on this definition and adds the terms “time budget”, “isochrones” and “total amount of accessible facilities” to the original definition. Within this perspective, accessibility is measured with the total amount of available facilities from an origin by a transport mode within a limited time budget. Besides, isochrones are the equal accessibility rings which are used to define the extents of accessible areas from a specific location for a given time. Isochrones are commonly used for defining the service areas of fixed locations; facilities as public transport stops/stations, shopping centers, firehouses etc.

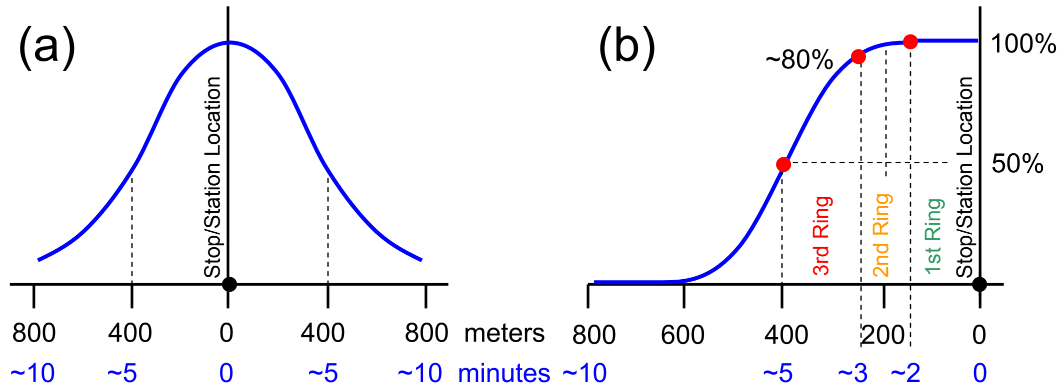
In this part of the study, service areas of proposed public transport routes are calculated with the aid of service isochrones, shaped relative to the results of pedestrian accessibility analysis. At the end of these analyses, it is aimed to calculate the total amount of population and building floor area that are covered by the service area of each route, as an indicator of efficiency.

In order to perform the service area analysis; estimated service area of a public transport route is defined with the following formula, adapted from McGinley's study (2001). ***Estimated Service Amount of a Route = [Σ from t = 1 to 3 Σ from i to m (Accessibility Ring of a Stop within a Given "t") Σ from j to n ((Population and Floor Area of an Accessible Facility within the Accessibility Ring of Stop "m") x (K_t))].*** In this formula, "t" stands for the time intervals of accessibility rings (2, 3 and 5 minutes isochrones), "m" is the number of stops/stations on the route, "n" is the number of accessible facilities (academic buildings, residences, dormitories etc.) and "K_t" is the intensity factor representing the probability of service usage in different time intervals (100% usage up to 2 minutes, 80% usage up to 3 minutes etc.).

According to this formula, it is assumed that the overall service area of a public transport route can be drawn by aggregating the service areas (isochrones) of all stops/stations on that route. Therefore, the efficiency of each stop/station must be determined at first, in order to calculate the overall route efficiency. In this study, the measure of service coverage is defined as the total number of people that can access to a stop/station within a given time interval. In addition to the accessible population; the number of accessible buildings and their total floor areas are also considered as the subsidiary measures for service coverage.

In order to perform the accessibility analyses; vehicular roads, pedestrian paths and all other tracks in campus that can be used by pedestrians are digitized by splitting each road segment at intersections. However, some network costs must be defined before performing the accessibility analyses for stops/stations. Since accessibility is measured for a given time, rather than absolute distances (Koenig, 1980); walking time for accessing to a stop/station is considered as the network cost. In order to determine the walking time on campus road network, each digitized road segment, bigger than 15 meters, is divided into sub-segments varying about 10 meters. Average ground slope of each road segment is extracted from the campus slope map that is generated in Chapter 3. After determining the average slope of each segment, average walking speed on each segment is calculated with the following hiker function, adapted from Tobler (1993). ***Average Pedestrian Walking Speed (km./hour) = 5,2 x Exp (– 2 x Abs (Average Slope of Segment) / 100).*** In this formula, walking speed of 5,2 km./hour is taken as the maximum speed of a pedestrian walking on a zero inclined road, referenced from the study of Ladetto et al. (2000). Since average walking speeds and lengths of all road segments are calculated; average travel times are calculated (in seconds) for all segments by proportioning the segment length to the walking speed. After defining the network cost as time; a simple “arc node” network topology is built for performing the service area analyses via the Network Analyst Extension of ESRI ArcView 3.2.

In order to perform the service area analyses; probability of walking to a public transport stop/station should be determined. According to White (1976), while ignoring the operational issues as service quality, capacity etc., service radius a stop/station is defined as 800 or maximum 900 meters. Besides, in an ideal case that assumes the passenger distribution as homogeneous on space, the distribution of passengers accessing to a stop/station from different locations can be defined with a “normal distribution curve” (Figure 5.4-a). Therefore, the probability of walking to a stop/station from various distances can be referenced from the “cumulative normal distribution curve” that derives from the normal distribution (Figure 5.4-b).



Normal Distribution Curve

Service Area of a Stop/Station is defined with the distribution amount of passengers accessing from different distances (White, 1976).

Cumulative Normal Distribution Curve

Probability of walking to a Stop/Station for an individual from different distances (White, 1976). Derived from the Normal Distribution Curve

(*) Both graphs represent ideal cases by assuming that passenger distribution is homogeneous on space and services are always available from stops, ignoring the wait time at stops/stations and other operational factors. However in practice, flatness and skewness of both graphs would change.

(**) Values 100%, 80% and 50%, marked with red dots, are the estimated service intensity multipliers (K_t) respectively for the 0 (zero) to 2, 2 to 3 and 3 to 5 minutes service rings.

Figure 5.4 Service area of a stop/station and probability of walking (Adapted from White, 1976)

In this study, maximum service radius for a proposed stop/station is considered about 400 meters (nearly 5 minutes walking time) in campus, since 800 meters is suggested for the services in city scale. However, according to Figure 5.4-b, the probability of using a stop/station for an individual is not constant through 400 meters. Therefore, overall service area of a stop/station is defined with three accessibility rings. First ring represents 2 minutes accessibility from/to stops/stations; second ring for 2 to 3 minutes and third ring for 3 to 5 minutes accessibility.

Accessibility analyses are performed with the Network Analyst of ESRI ArcView 3.2. In the first step, accessible road segments around a stop/station are detected for the following time intervals: 0 (zero) to 2, 2 to 3 and 3 to 5 minutes. In the second step, accessible facilities that are intersecting to the edges of road segments are selected. In the third step, following attributes are queried and aggregated from the accessible facilities: number of accessible facilities, total floor area, overall population and population groups within the accessible buildings. In the fourth and last step, calculated amounts of service measures (eg. population, total floor area etc.) are decreased by 80% and 50% for the second and third service rings in order to reflect the decreasing probability of service usage, defined in Figure 5.4-b. Then final amounts of service measures are summed to determine the estimated service area of that stop/station. By repeating this routine for all stops/stations on a route and summing each result; overall service coverage of that route is estimated.

A schema, showing the steps for determining the overall service area, is given in Figure 5.5 with “GLT B” route. Total population, population groups, floor areas and number of buildings covered by the estimated service area of each proposed route alternative are given in Table 5.3. Besides, a table presenting the results of service area and accessibility analyses for each stop/station is given in Appendix P.

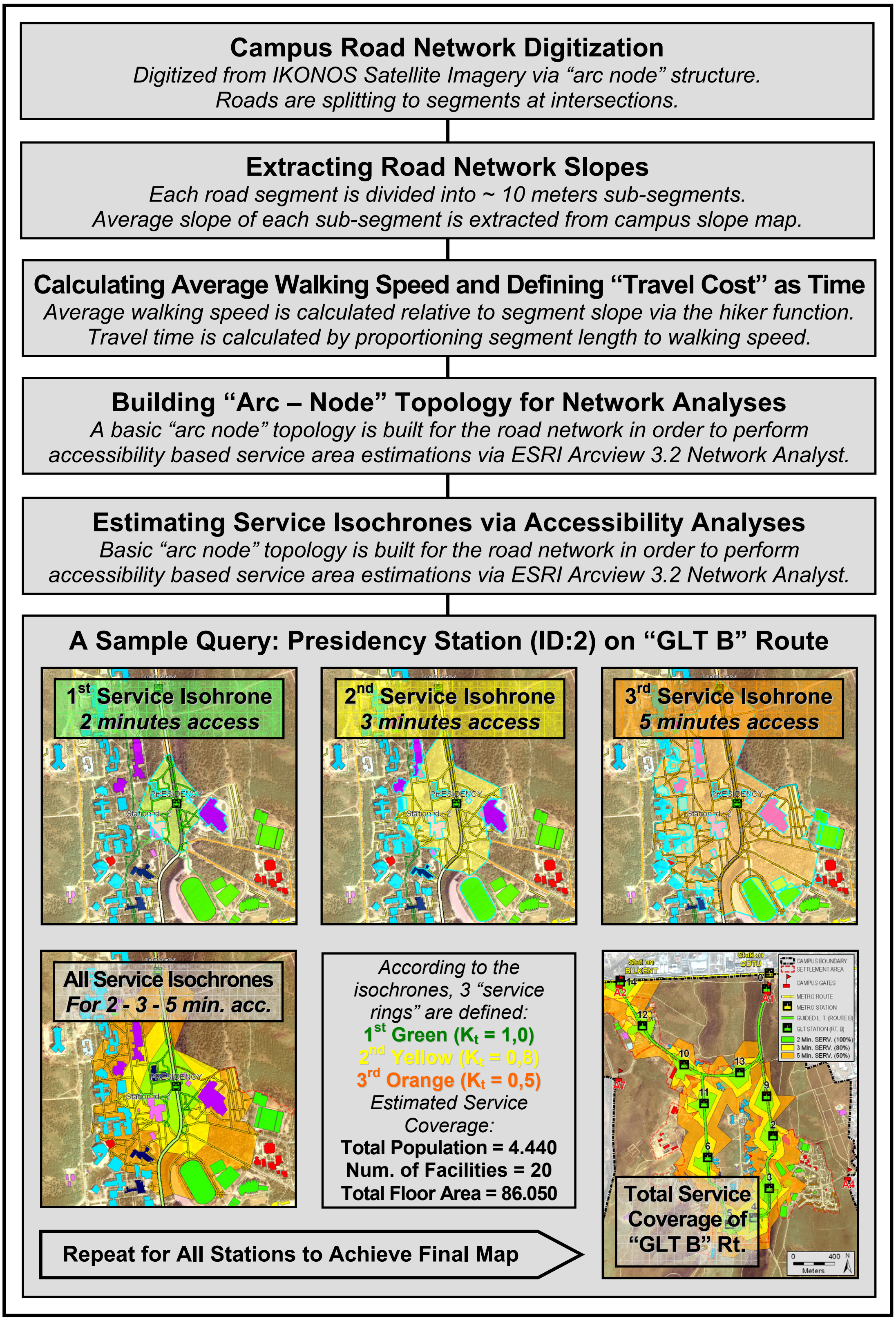


Figure 5.5 Steps for determining the overall service area of a route

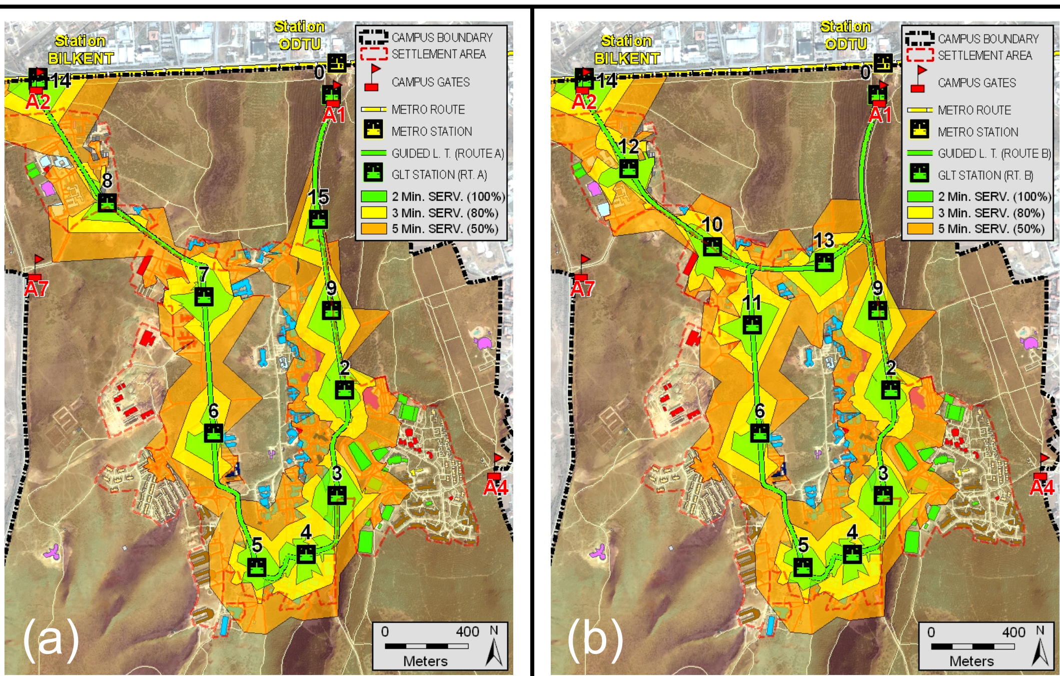
Table 5.3 Service area characteristics of the proposed route alternatives in campus

Service Area Characteristics	Probable Public Transport Modes							
	GLT Route Alternatives		Trolleybus Route Alternatives			Monorail Route Alternatives		
	A	B	A	B	C	A	B	C
Population of All Students	22.540	28.260	29.710	55.180	13.760	18.380	27.000	16.900
Population of All Staff	7.070	8.720	9.740	16.050	4.440	6.610	9.440	6.090
Pop. of Dorms. & Residences	1.250	1.250	1.760	8.170	5.920	3.620	5.830	6.400
Total Population Covered	**30.860**	**38.230**	**41.210**	**79.400**	**24.120**	**28.610**	**42.270**	**29.390**
Total Number of Facilities Covered	167	204	253	430	147	182	280	190
Total Floor Area (TFA) Covered	**505.280**	**584.880**	**691.550**	**1.211.840**	**384.290**	**535.270**	**737.860**	**581.070**
Number of Stops/Stations	11	12	13	20	7	11	14	12
Service Track Length (meter)	5.480	6.270	5.930	8.960	5.340	6.040	7.120	5.540
Ratio of Total Pop. Covered to the Number of Stops/Stations	**2.800**	**3.190**	**3.170**	**3.970**	**3.450**	**2.600**	**3.020**	**2.450**
Ratio of TFA Covered to the Number of Stops/Stations	**45.940**	**48.740**	**53.200**	**60.600**	**54.900**	**48.660**	**52.700**	**48.420**
Ratio of Total Pop. Covered to the Service Track Length	**5,6**	**6,1**	**6,9**	**8,9**	**4,5**	**4,7**	**5,9**	**5,3**
Ratio of TFA Covered to the Service Track Length	**92**	**93**	**117**	**135**	**72**	**89**	**104**	**105**

(*) Service coverage analyses are carried with the following assumptions: Service coverage efficiency of a stop/station can be estimated by the accessible population and total floor area covered from that stop/station. Operational factors as service capacity, timetables, vehicle quality and personal preferences are ignored. All population is attending in the buildings that they are registered in the study database.
(**) Service coverage analyses are performed based on the study database with the following attributes: Pop. of all students= 22.177 Pop. of all Staff= 7.403 Pop. of Dorms. & METU Residences= 8.749 Number of all buildings/facilities= 338 Total floor area of all buildings/facilities= 680.380 m^2
(***) "." is thousand separator, "," is decimal separator, all slope values are percentage.

5.2.1. Evaluating Route and Stations of Guided Light Transit

Service area estimations for two route alternatives of guided light transit (GLT) are performed according to the pedestrian network based accessibility analyses steps, defined in Figure 5.5. Estimated service area of each station and overall service areas of each GLT route alternative are given in Figure 5.6. Besides, service area characteristics of two alternative routes are summarized in the same figure, based on Table 5.3. In addition, results of service area and accessibility analyses for each station that is proposed on each route alternative is given in Appendix P with the id of relevant station.



Overall Service Area of “GLT A”	
Total Population Covered	**30.860**
Students’ Population	22.540
Staff’s Population	7.070
Dorms. & METU Residences	1.250
Total Floor Area Covered (m^2)	**505.280**
Total Pop. / Number of Stations	**2.800**
Tot. Pop. / Service Track Length	**5,6**

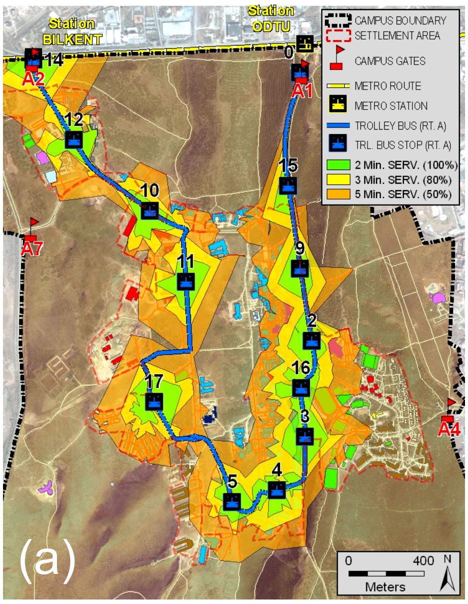
Overall Service Area of “GLT B”	
Total Population Covered	**38.230**
Students’ Population	28.260
Staff’s Population	8.720
Dorms. & METU Residences	1.250
Total Floor Area Covered (m^2)	**584.880**
Total Pop. / Num. of Stations	**3.190**
Tot. Pop. / Service Track Length	**6,1**

Figure 5.6 Overall service areas for guided light transit route alternatives: (a) “GLT A” and (b) “GLT B”

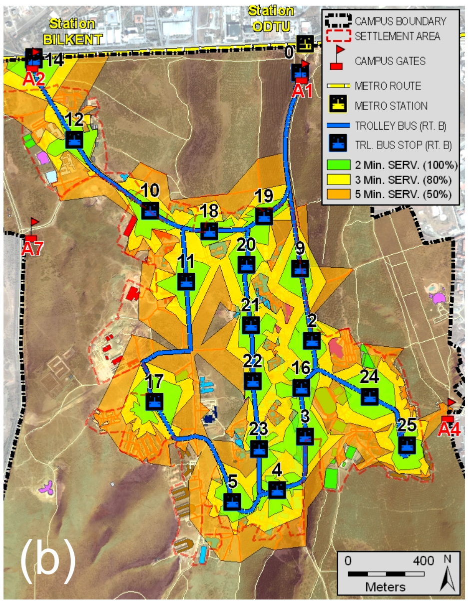
According to Figure 5.6, “GLT B” route reaches to a total population about 38.000 from its stations while “GLT A” reaches about 31.000 people (nearly 20% less than “GLT B”), based on the service area analyses performed for each station on these routes. Similarly, accessible floor area of the facilities from “GLT B” route is about 59 hectare while it is about 51 hectare from “GLT A” route (nearly 15% less than “GLT B”). Although, “GLT B” route is nearly %15 longer than “GLT A” route about 800 meters and will cost more to build; “GLT B” route has better efficiency ratios than “GLT A”, indicated by total population to number of stations and total population to service track length. Two main reasons for achieving these results can be explained as following; station 13 on “GLT B” covers preparatory school better than station 15 on “GLT A” and stations 10 & 12 cover Faculty of Education, METU Foundation School and Technical Units better than station 8 on “GLT A”. However, neither of these routes reaches to the population living in the east dormitories and residential zones within five minutes. On the other side, both routes hardly reach to the west dormitories and residences zones in five minutes. According to these findings, it can be considered as “GLT B” alternative is preferable to “GLT A”.

5.2.2. Evaluating Route and Stops of Modern Trolleybus

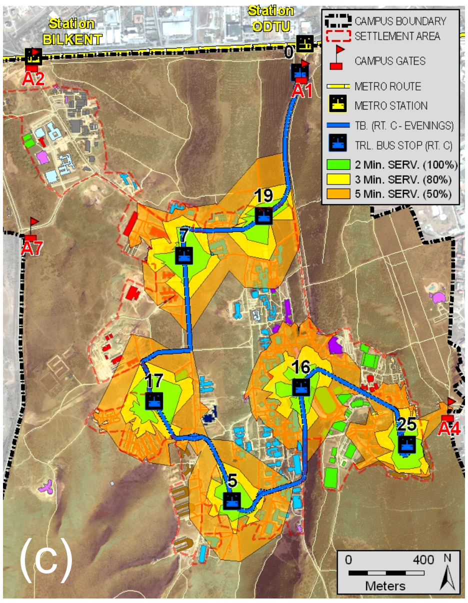
Service area estimations for three route alternatives of modern trolleybus are performed according to the pedestrian network based accessibility analyses steps, defined in Figure 5.5. Estimated service area of each stop and overall service areas of each trolleybus route alternative are given in Figure 5.7. Besides, service area characteristics of three alternative routes are summarized in the same figure, based on Table 5.3. In addition, results of service area and accessibility analyses for each stop that is proposed on each route alternative is given in Appendix P with the id of relevant stop.



Overall Service Area of “Trolleybus A”	
Total Pop. Covered	**41.210**
Students’ Population	29.710
Staff’s Population	9.740
Dorms. & METU Residences	1.760
Tot. Floor Area Covered (m^2)	**691.550**
Tot. Pop. / Num. of Stops	**3.170**
Tot. Pop. / Service Track Len.	**6,9**



Overall Service Area of “Trolleybus B”	
Total Pop. Covered	**79.400**
Students’ Population	55.180
Staff’s Population	16.050
Dorms. & METU Residences	8.170
Tot. Floor Area Covered (m^2)	**1.211.840**
Tot. Pop. / Num. of Stops	**3.970**
Tot. Pop. / Service Track Len.	**8,9**



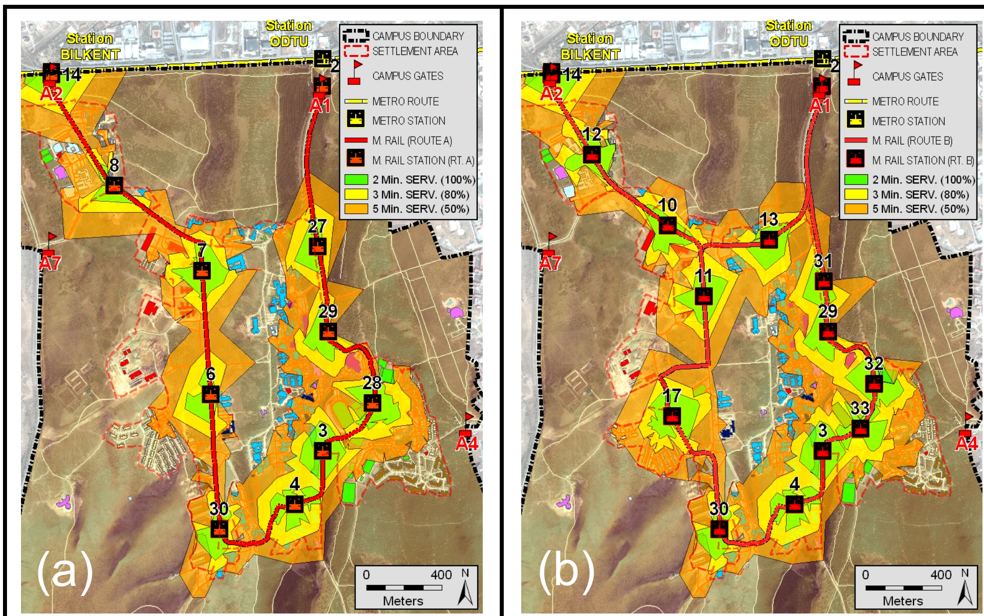
Overall Service Area of “Trolleybus C”	
Total Pop. Covered	**24.120**
Students’ Population	13.760
Staff’s Population	4.440
Dorms. & METU Residences	5.920
Tot. Floor Area Covered (m^2)	**384.290**
Tot. Pop. / Num. of Stops	**3.450**
Tot. Pop. / Service Track Len.	**4,5**

Figure 5.7 Overall service areas for trolleybus route alternatives: (a) “Trolleybus A”, (b) “Trolleybus B” and (c) “Trolleybus C”

According to Figure 5.7, “Trolleybus B” route reaches to a total population about 79.000 from its stations while “Trolleybus A” route, which is nearly 50% shorter than “Trolleybus B”, reaches only 41.000 people based on the service area analyses performed for each station on these routes. Similarly, accessible floor area covered by “Trolleybus B” route is about 80% bigger than the amount offered by “Trolleybus A” route (nearly 70 hectare for “Trolleybus A” and 120 hectare for “Trolleybus B”). Although “Trolleybus B” has the longest service track within all alternatives evaluated in this study, due to its higher service coverage, it offers the best efficiency ratios in terms of total population covered to the number of stops (3.970) and total population covered to the service tracks length (8,9). Main reasons for achieving these results can be explained as following; since trolleybus service needs only trolleybus overhead network to be operated and can be easily (re)routed like conventional buses, an additional node to node service route is proposed between A-2 Gate and east dormitories zones; with the aid of this route, faculties in the core campus ring are covered twice (with the additional stops: 20, 21, 22, 23) and east residences, dormitories zones are served (with the stops: 24, 25). In addition to “Trolleybus A and B” routes, “Trolleybus C” route is proposed by tracking the technical infrastructure of “Trolleybus B” as a third alternative that can be operated after the evening peak until midnight and on holidays. “Trolleybus C” route reaches to a population about 6.000 from its stops (7, 5 and 25) that corresponds nearly 75% of the population living in residences and dormitories while “Trolleybus B” route reaches nearly 100% and “Trolleybus A” reaches only 20% of that population. On the other hand, all three alternative routes can hardly cover the west dormitories zone in five minutes with the stop id 5. Besides, in terms of serving west residences zones, all three alternatives offer a better coverage with the stop id 7 than the stop id 6, located on all GLT routes. According to these findings, it can be considered as “Trolleybus B” alternative is preferable to “Trolleybus A”; besides “Trolleybus C” route can be preferred to be operated by sharing “Trolleybus B” infrastructure in the evenings and on holidays.

5.2.3. Evaluating Route and Stations of Monorail

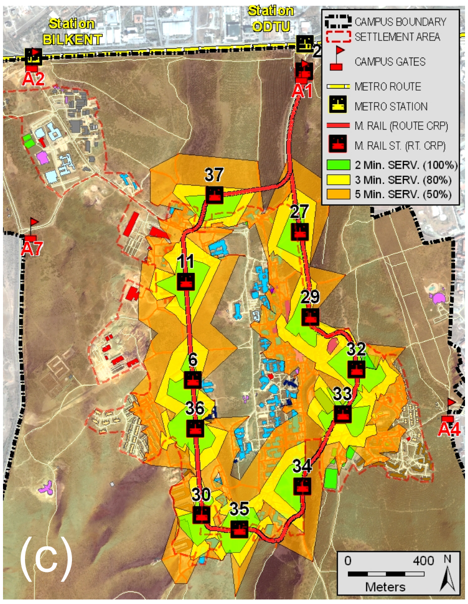
Service area estimations for three route alternatives of monorail are performed according to the pedestrian network based accessibility analyses. Estimated service area of each station and overall service areas of each monorail route alternative are given in Figure 5.8. Besides, results of service area and accessibility analyses for each station that is proposed on each route alternative is given in Appendix P with the id of relevant station.



Overall Service Area of “Monorail A”	
Total Pop. Covered	**28.610**
Students’ Population	18.380
Staff’s Population	6.610
Dorms. & METU Residences	3.620
Tot. Floor Area Covered (m^2)	**535.270**
Tot. Pop. / Num. of Stops	**2.600**
Tot. Pop. / Service Track Len.	**4,7**

Overall Service Area of “Monorail B”	
Total Pop. Covered	**42.270**
Students’ Population	27.000
Staff’s Population	9.440
Dorms. & METU Residences	5.830
Tot. Floor Area Covered (m^2)	**737.860**
Tot. Pop. / Num. of Stops	**3.020**
Tot. Pop. / Service Track Len.	**5,9**

Figure 5.8 Overall service areas for monorail route alternatives: (a) “Monorail A”, (b) “Monorail B” and (c) “Monorail C”



Overall Service Area of "Monorail C"	
Total Pop. Covered	**29.390**
Students' Population	16.900
Staff's Population	6.090
Dorms. & METU Residences	6.400
Tot. Floor Area Covered (m^2)	**581.070**
Tot. Pop. / Num. of Stops	**2.450**
Tot. Pop. / Service Track Len.	**5,3**

Figure 5.8 (continued)

According to Figure 5.7, "Monorail B" route reaches to a total population about 42.000 from its stations while "Monorail B and C" routes reach about 29.000 (nearly 35% less than "Monorail B") based on the service area analyses performed for each station on these routes. Similarly, accessible floor area of the facilities from "Monorail B" route is about 74 hectare while it is about 54 hectare from "Monorail A" and 58 hectare from "Monorail B". In terms of efficiency ratios; although "Monorail B" route is nearly 20% longer than "Monorail A and C" alternatives, it offers the best ratios within three alternatives (total population covered to the number of stations is 3.020 and total population to the service track length is 5,9). "Monorail A and C" route alternatives offer closer values around 2.500 in terms of population ratio to the number of stations, however "Monorail C" (5,3) alternative is more efficient than "Monorail A" (4,7) in terms of population ratio to service track length. The main advantage of "Monorail A" route is that, it links to both campus gates (A-1 and A-2); however stations 8 and 27 located on this route cannot completely serve to METU Foundation School, Technical Units and preparatory school within the defined time budget of five minutes. The advantages of “Monorail C” route to “Monorail A” can be defines as; this route completely covers preparatory school with its station id 37 and offers better service to east residences and dormitories zones with its two stations id’s 32 and 33. However, “Monorail C” route only links to campus main gate (A-1) and misses the Bilkent Metro Station located at A-2 Gate, Technical Units and METU Foundation School. On the other side, “Monorail B” route links to both campus gates and also covers the zones which “Monorail A and C” routes cannot reach. In addition, similar to “Trolleybus B” but significantly shorter than this route, “Monorail B” route is the only alternative, linking both campus gates and completely covering west dormitories (with its station id 30) while partially covering west residences and dormitories zones (with its stations 32 and 33). According to these findings, it can be considered as “Monorail B” route is preferable to “Monorail A and C” alternatives.

5.3. Discussing the Results of Analyses and Determining Suitable Public Transport Services

After completing the feasibility analyses for all alternative public transport services; a summary table is given in order to discuss and determine the suitable service mode(s) and route(s) in campus by comparing the results of each analysis performed in this chapter. Service modes and routes which are sharing the first three ranks according to the results of different analyses are given in this summary table (Table 5.4).

Table 5.4 Summarizing the results of feasibility analyses

Results of Feasibility Analyses	Probable Public Transport Modes and Routes Sharing the First Three Ranks		
	1st Rank	2nd Rank	3rd Rank
Track Length (*) (meter)	Trolleybus C *5.340*	GLT A *5.480*	Monorail C *5.540*
Number of Stops/Stations (*)	Trolleybus C *7*	GLT A Monorail A *11*	Monorail C GLT B *12*
Number of Loops per Hour	Monorail C Trolleybus C *4,2*	Monorail A *4,1*	Monorail B *4,0*
Maximum Slope of Track (*) (%)	GLT A & B *19*	Trolley A & B & C *19*	Monorail A & B *23*
Length of Problematic Segments (*) (meter)	Monorail A & B *50*	Trolleybus A & C *60*	Trolleybus B Monorail C *80*
Track Slope Index (*)	Trolleybus B *26*	Trolleybus A *39*	Trolleybus C *43*
Total Population Covered	Trolleybus B *79.400*	Monorail B Trolleybus A *~42.000*	GLT B *38.230*
Dormitories' and METU Residences' Population Covered	Trolleybus B *8.170*	Monorail C *6.400*	Trolleybus C Monorail B *~5.900*
Total Floor Area Covered (m^2)	Trolleybus B *1.211.840*	Monorail B *737.860*	Trolleybus A *691.550*
Total Population Covered / Number of Stops/Stations	Trolleybus B *3.970*	Trolleybus C *3.450*	GLT B Trolleybus A *~3.200*
Total Population Covered / Total Track Length	Trolleybus B *8,9*	Trolleybus A *6,9*	GLT B *6,1*

(*) Small value is better
(**) "." is thousand separator, "," is decimal separator, all slope values are percentage.

According to Table 5.4, it is clear that there is not a perfect public transport mode and route, taking the first rank in all analyses. However, some modes and routes can be defined as suitable choices according to different construction and service strategies.

In Table 5.4, “Trolleybus B” alternative achieves to be the service taking the first ranks in many analyses. Due to mode’s higher slope tolerance limit, as much as monorail; “Trolleybus B” offers the smallest slope index value. Besides, “Trolleybus B” alternative offers an accessible population about 80.000, which is two times more than its nearest alternative: “Monorail B”. In this study, covering METU Residences and dormitories zones, without distorting the service route, has been a problematic issue. However, “Trolleybus B” routes (A-1 Ring and A-2 to Dorms Rt.) cover these zones and offer an accessible population about 8.000. On the other hand, “Trolleybus B” route has 20 stops and the longest track, about 9 km. However, these values are acceptable since “Trolleybus B” alternative offers the best values for the ratios of covered population to the track length and to the number of stops. Other unique advantages of “Trolleybus B” alternative is that; “Trolleybus C” route can be operated via “Trolleybus B” infrastructure after the evening peak, at night and weekends. Besides; initial setup costs for trolleybus services are cheaper than the costs of other alternatives, GLT and especially monorail. Therefore, “Trolleybus B” alternative is selected as the suitable public transport service mode and route in the METU Campus.

On the other side; “Monorail B” and “Trolleybus A” alternatives are also considerable for the public transport services in campus. According to Table 5.4, “Monorail B” alternative offers an accessible population about 42.000 and shares the second rank with “Trolleybus A” alternative. Besides, “Monorail B” stations are accessible for about 5.900 persons in METU Residences and dormitories zones. Although “Monorail B” track has a maximum slope of 23%; it has only 50 meters problematic segments at two locations: near by METU Stadium and west dormitories. Since monorail vehicles have higher initial speeds due to their fully segregated guideways; in Table 5.4, first three ranks of “number of loops” field, denoting for higher operational speeds, are shared by monorail alternatives. It is estimated that “Monorail B” alternative completes 4 loops on its tracks; which is 3,8 for

“Trolleybus B”. Another advantage of “Monorail B” alternative to “Trolleybus B” is that monorail vehicles usually offer higher passenger capacity than trolleybuses. However monorail is the most expensive mode to setup in campus. The other alternative, “Trolleybus A” offers an accessible population about 42.000; however “Trolleybus A” route clearly cannot compete with “Trolleybus B” and “Monorail B” in terms of covering the population in dormitories and residential zones. On the other hand, “Trolleybus A” has the second and the third ranks in terms of the following efficiency indicators: covered total population ratio to the track length (6,9) and number of stations (3200) meaning that “Trolleybus A” is still an efficient and cheaper solution for supplying the demand arising from core campus; except for dormitories and residential zones.

Consequently, “Trolleybus B” alternative is selected as the first degree suitable public transport service in campus, according to the feasibility analyses carried. Besides, “Monorail B” and “Trolleybus A” services are determined as second degree suitable alternatives that can be considered in campus. On the other hand, although these public transport modes and routes are selected as suitable services in campus; more detailed feasibility analyses would be necessary to determine the optimal public transport service in campus. Therefore, service mode and route alternatives selected by this study, must be evaluated in terms of constructional, operational and economic factors, in addition to the feasibility analyses carried in this study.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

In this chapter, the conclusions of the conducted study are described together with the recommendations for further studies related with GIS and transportation planning.

6.1. Conclusions

The main aim of this study was to determine a new public transport mode and route for the METU campus with the aid of GIS by considering the conditions after the new metro route.

In this study, it is also aimed to show that GIS can be a useful tool for constructing transport planning database and exploring, analyzing planning data. Besides, this study aims to develop a methodology for determining the potential service area of a stop or station and then to estimate the overall service area of a route with the aid of accessibility analysis performed on pedestrian road network.

Within this framework, three different public transport modes; guided light transit, trolleybus and monorail systems are selected initially. Then, eight different service tracks are proposed for these selected transport modes. Finally, alternative service routes, stops and stations are mutually evaluated with the aid of GIS in order to determine the suitable service(s) in METU campus.

Based on campus land use analyses performed in Chapter 3, it is detected that gross built-up area of the campus has reached up to 155 hectare in 2004 while it was only about 65 hectare in the 1970's. According to this basic measure, METU campus has widened for more than two fold with the new spatial extensions, especially constructed on the western side of campus.

According to campus land slope analyses performed in Chapter 3, it is not possible to track any apparent path having smaller gradients in the west to east direction (or vice versa) because of the problematic topography in the horizontal axis. Therefore, all public transport route alternatives, evaluated in this study, dealt with the bevels by the METU Stadium and the Department of Aerospace Engineering in order to serve east and west dormitories zones. For "Trolleybus B" alternative, this problem is solved with an additional feeder route, proposed between A-2 Gate and east dormitories. On the other side, although monorail is the most expensive solution and it is sometimes perceived as a "futuristic" transport solution, it is the only service mode that can serve educational zones and both dormitories zones at the same time (eg. "Monorail B") since it can bypass the problematic topography with its fully segregated guideways, elevated on pillars which partially enables to adjust the track inclination relative to the slope tolerance limit of the monorail vehicles. However, "Monorail C" track would still need an important topographic adjustment in order to bypass the steep ground slope (30%) near by the K-5 Building of Civil Engineering.

In Chapter 4, multi criteria decision analysis (MCDA) is performed in order to determine the important zones in campus for designing service routes and determining stop/station locations on these routes. In order to achieve zonal significance map, multi linear normalization is carried for reclassifying the zonal values derived from different maps. Then, simple criteria weighting is applied in the zone significance level formula in order to evaluate zonal trip demand, structural distribution (TFA) and density (FSI). According to MCDA results; zones to be considered with first and second degree significance are detected as following: METU Foundation School (zone 0); Department of Basic English (zone 5); METU Technopolis (zone 6); Faculty of Economic & Administrative Sciences, Architecture and Social Sciences (respectively zones 12, 27 and 28); Departments of Chemistry, Electric & Electronic Engineering and Civil Engineering (respectively zones 34, 35 and 36); finally dormitories and student guesthouses, zone 20 on the southwest and zones 43, 45 on the southeast. However, it is possible to assign different weight factors to these zonal indicators in different studies depending on the aim and methodology of that study. Consequently, different weight factors will change the final zonal significance map that will be considered in that study. Therefore, weight factors that are used in this study are not constant values and they may change in different studies.

In Chapter 5, feasibility of each route alternative is evaluated from two main aspects; physical characteristics and service areas, pedestrian accessibility. After evaluating all service proposals, “Trolleybus B” alternative achieves to be better than other services from the following aspects. Due to its higher slope tolerance, “Trolleybus B” offers the smallest slope index value. Moreover, “Trolleybus B” service routes reach to a population about 80.000 from their stop, which is two times more than its nearest alternatives: “Monorail B” and “Trolleybus A”. Besides, “Trolleybus B” service reaches to METU Residences and dormitories zones and offers an accessible population about 8.000. Other unique advantage of “Trolleybus B” alternative is that; “Trolleybus C” route can be operated on “Trolleybus B” infrastructure in the evenings and at nights or on holidays.

“Monorail B” and “Trolleybus A” alternatives are considered as second degree suitable public transport services for the campus. Both “Monorail B” and “Trolleybus A” alternatives offer an accessible population about 42.000. Besides, “Monorail B” reaches to a population about 5.900 that live in the

METU Residences and dormitories zones. However, “Monorail B” track would deal with the problematic topography, having ground slopes up to 23%, near by the METU Stadium and west dormitories. On the other hand, “Trolleybus A” alternative has the second and third ranks in the following efficiency indicators: ratio of total population to the track length (6,9) and the number of stations (3200). Based on these findings, “Trolleybus A” alternative is still an efficient and cheaper solution for supplying the trip demand arising from campus; except for supplying the demand arising from dormitories and residential zones.

As a result of this study, “Trolleybus B” alternative is selected as the first degree suitable public transport service in campus. Besides, “Monorail B” and “Trolleybus A” services are selected as second degree suitable alternatives that can be considered in campus.

6.2. Recommendations

In this study, much time was spent to construct the study database in GIS. Data pertaining to campus land use, topography, population and transportation structure are obtained from different sources and then imported into the study database. The oldest dataset in the study database dates back to year 2003 while the newest 2005. Therefore, “up-to-date” database of this study can be used by other GIS studies, concerning to METU Campus.

In Chapter 3, campus population is distributed into the campus buildings which are initially registered in the study database. In this process, if the exact spatial distribution of the population is not known (eg. for the departments having multiple buildings), population is distributed proportional to the total floor area of these buildings. Then, population of each analyses zone is calculated by summing the populations of all buildings in that zone.

However, in an ideal case, populations in the campus buildings should be exactly known and populations of the analyses zones should be calculated from this data. Therefore, if the spatial distribution of the campus population is exactly known, spatial trip demand can be estimated more precisely. Besides, zonal significance map, estimated in Chapter 4, might change relative to this new distribution.

In Chapter 4, multi criteria decision analysis (MCDA) is carried for producing a reference map, denoting significant zones, that is to be considered while designing service routes and selecting stop/station locations. In this analysis, multi linear normalization is carried for reclassifying the zonal trip demand, structural distribution (TFA) and structural density (FSI) of the zones. Then, simple criteria weights are given to these zonal indicators within the significance level formula. However, in different studies, it is possible to assign different weights to these zonal indicators depending on the aim and methodology of that study. The publication of Malczewski (1999), regarding to GIS and MCDA, can be referenced in order to explore different types of criteria weighting (eg. ranking, rating, pairwise comparison etc.). On the other hand, in a comprehensive transportation study, structural indicators of the analyses zones will not be necessary to be evaluated via MCDA, if the origin destination (O/D) matrix is known and spatial trip demand is “accurately” estimated based on transportation survey data.

Campus land and road slopes are guiding factors for eliminating the public transport modes which cannot tolerate the steep gradients in campus. Besides, land and road slopes should be considered for designing topographically well adjusted service routes. Therefore, in Chapter 4, campus land and road slopes are spatially queried according to the slope limits that can be tolerated by different public transport modes. Findings of these queries can be used by other studies, in order to determine the suitable campus land and road segments for the mode and route alternatives evaluated in these studies. Besides, METU is concerning about a monorail test track in campus. In the beginning, this track is planned to be constructed between A-1 Gate and Presidency. In the long run, this system may be extended to cover whole campus. Therefore, spatial findings of these slope queries can also be utilized for evaluating the slope suitability of this monorail project and its probable extensions.

In this study, indicator of the efficiency for a service area is accepted as the number of persons that can access to that stop/station within a given time. However, it would be better to estimate the number of passengers that can access to that stop/station, rather than the number of persons. In order to estimate the potential ridership of that stop/station or route, operational characteristics of that service as vehicle capacity, intensity, timetables and service quality should also be considered. Besides, passenger accessibility analyses should be carried for door-to-door accessibility which also includes wait time at the stops/stations. On the other hand, in order to determine the operational factors as service intensity, timetables and capacity of vehicles; route capacity should be estimated relative to the spatiotemporal trip demand in campus.

Although “Trolleybus B”, “Monorail B” and “Trolleybus A” alternatives are selected as suitable public transport services by this study; more detailed feasibility analyses must be performed to determine the most efficient service for METU Campus. Meaning that service mode and route alternatives selected by this study, are evaluated by considering some physical factors and accessibility based service area analyses; however, these service proposals must also be evaluated for operational and economic factors. Besides, slope characteristics of these service tracks should be reevaluated by civil engineers for constructional factors.

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APPENDIX A

FLOWCHART OF THE STUDY

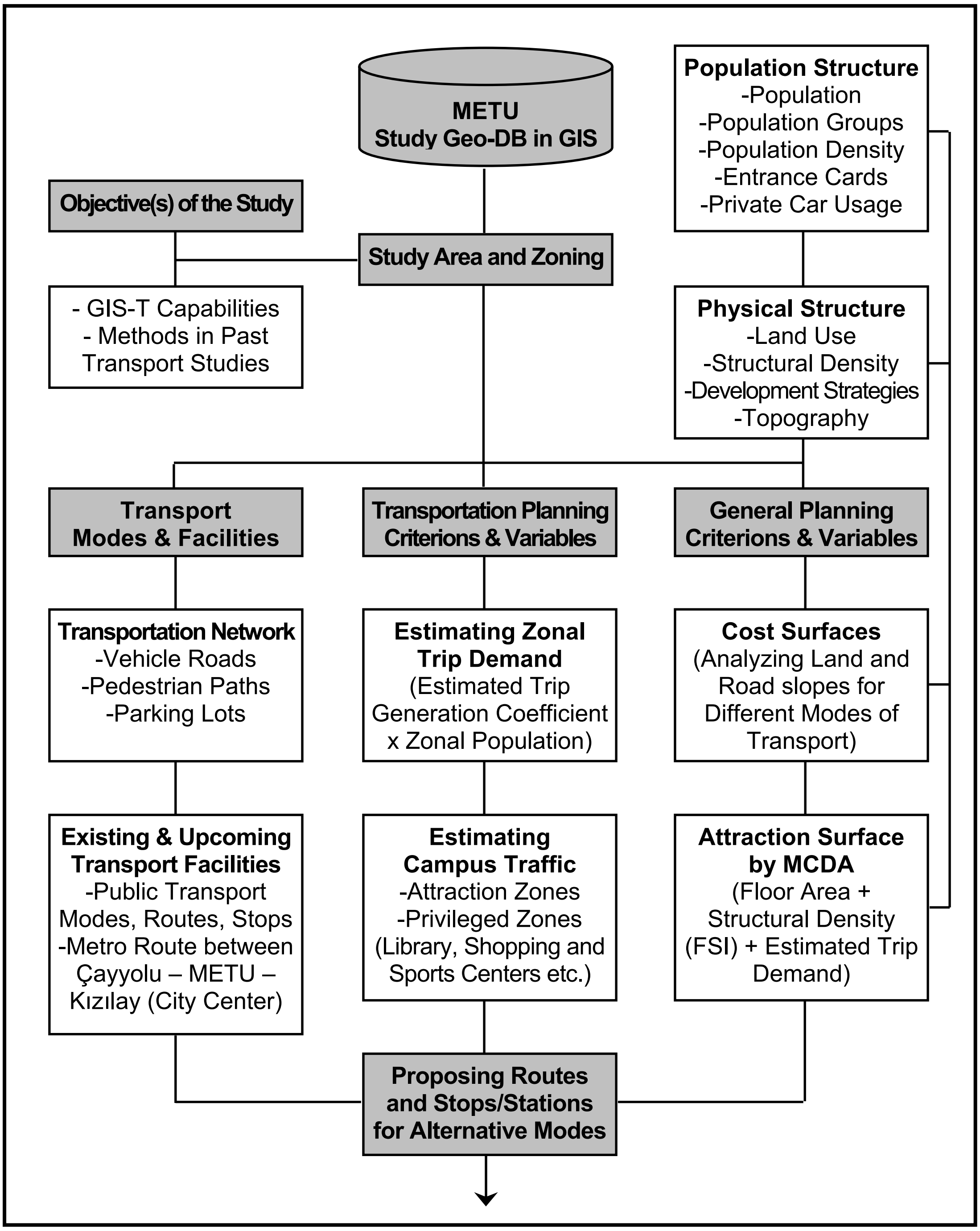


Figure A.1 Flowchart of the Study

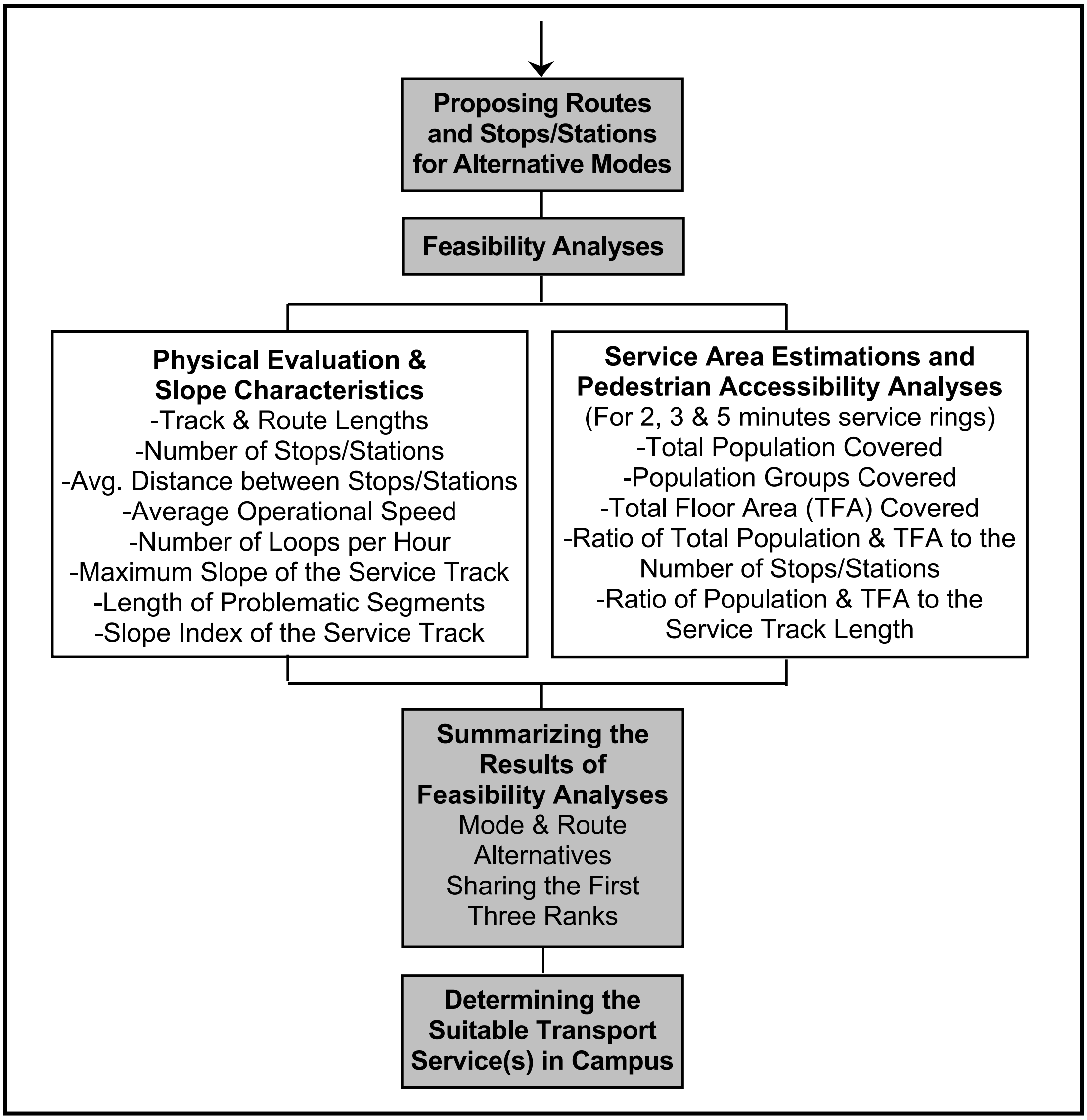


Figure A.1 (continued)

Flowchart of the study, presented in Figure A.1, partially refers to the methodology of analytical transportation planning defined by Lane et al (1971) and utilizes from the flowchart of transportation planning in GIS-T environment described by Khan and Armstrong (2001).

APPENDIX B

CATEGORIES OF VEHICLE ROADS, PEDESTRIAN PATHS AND PARKING LOTS IN THE CAMPUS

As a part of the study database, transportation infrastructure elements as; vehicle roads, pedestrian paths and parking lots are digitized as road centrelines and registered into the database. These transportation infrastructure elements in the campus are graded into 11 categories (Table B.1).

Table B.1 Categories of roads, paths and parking lots in the campus

Transportation Infrastructure Element Category			
ID	**Name**	**Level**	**Scope**
1 – 02	1st degree roads (Highways)	Turkey and Ankara	Ankara – Eskişehir Highway
2 – 01	2nd degree roads (Main Streets)	Ankara	Anadolu Boulevard
2 – 02	3rd degree roads (Streets)	Ankara and METU campus	Main streets of METU like 23rd street between gates A1 and A4 and 22nd street between preparatory school and gate A7.
2 – 03	4th degree roads (Sub Streets)	METU campus	Streets of METU like faculties' road and Technopolis – ODTÜKent road which are connecting loops to the main streets.
2 – 04	5th degree roads (Sub Streets)	METU campus	All other supplementary roads
2 – 05	6th degree roads (Dirt Tracks and Pathways)	METU campus	All paved and unpaved tracks, pathways and fire roads in the forest
8 – 50	1st degree pedestrian roads	METU campus	Campus main pedestrian alley lying between preparatory school and chemical engineering
8 – 10	2nd degree pedestrian roads	METU campus	Pedestrian road connecting students' dormitories to cafeteria and main pedestrian alley.
8 – 00	3rd degree pedestrian roads	METU campus	All other pedestrian roads enabling on foot access.
9 – 50	Double sided parking lots	METU campus	Capacity about 62 to 86 cars per 100 meter lot segment (Neufert, 1974).
9 – 00	One sided parking lots	METU campus	Capacity about 31 to 43 cars per 100 meter lot segment (Neufert, 1974).

APPENDIX C

LAND USE OF THE CAMPUS ACCORDING TO THE ANALYSIS ZONES

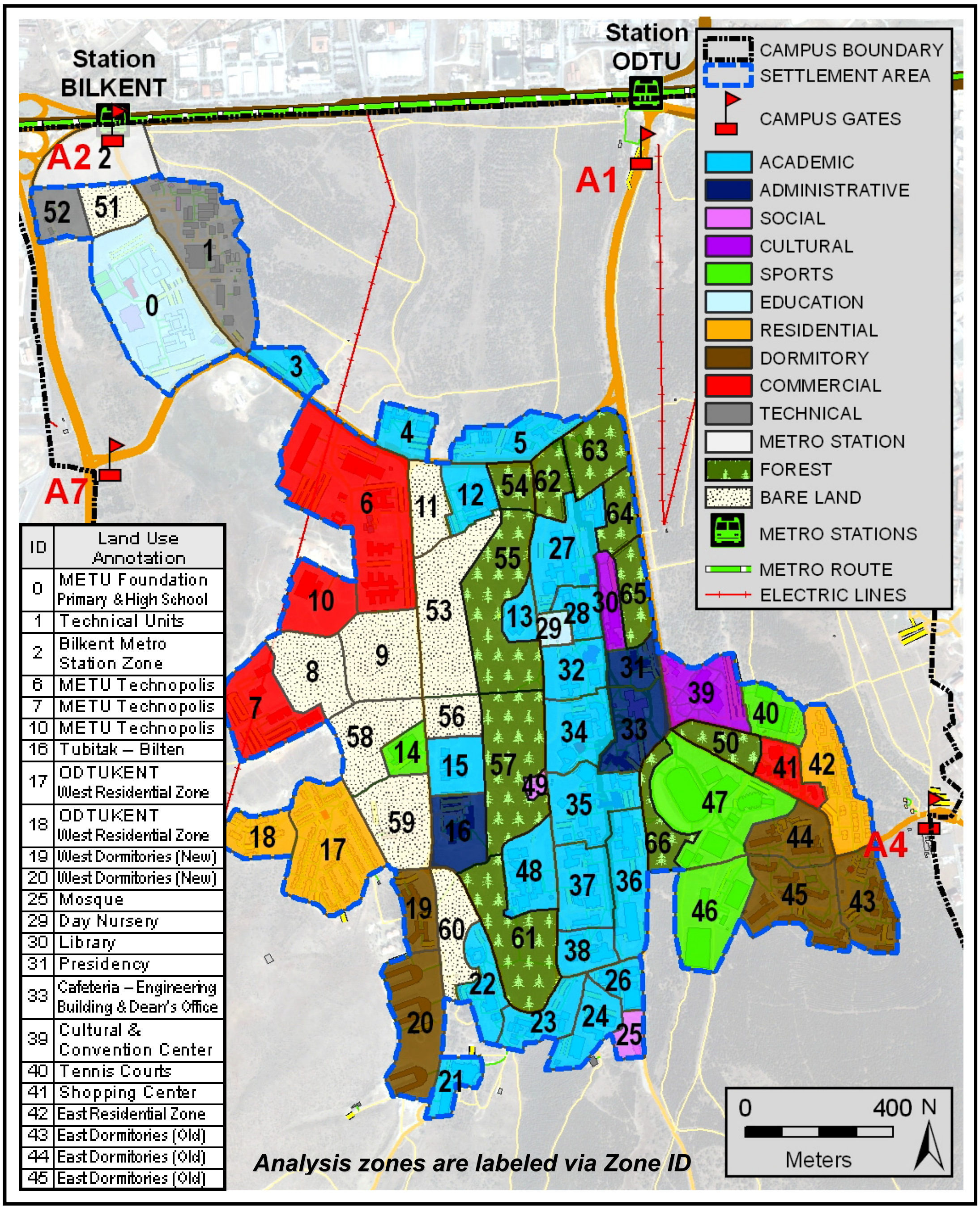


Figure C.1 Land use of the METU Campus according to the analysis zones

Land use category of each zone is determined according to the dominant land use category, having the largest floor area in the relevant zone. However, land use category of the zones having base space indices smaller than 3 %, are accepted as forest or bare land according to the land cover of the relevant zone. Totally, 67 study zones are grouped into 13 land use categories as; academic, administrative, social, cultural, sports, education, residential, dormitory, commercial, technical, metro station field, forest and bare land (Figure C.1).

APPENDIX D

TOTAL FLOOR AREA OF THE STRUCTURES WITHIN EACH ZONE AND FLOOR SPACE INDICES

Total floor area of the structures within each zone, an indicator of the built up distribution in campus, is presented in Figure D.1-a. Floor space indices of analysis zones, an indicator of the structural density in campus, are presented in Figure D.1-b.

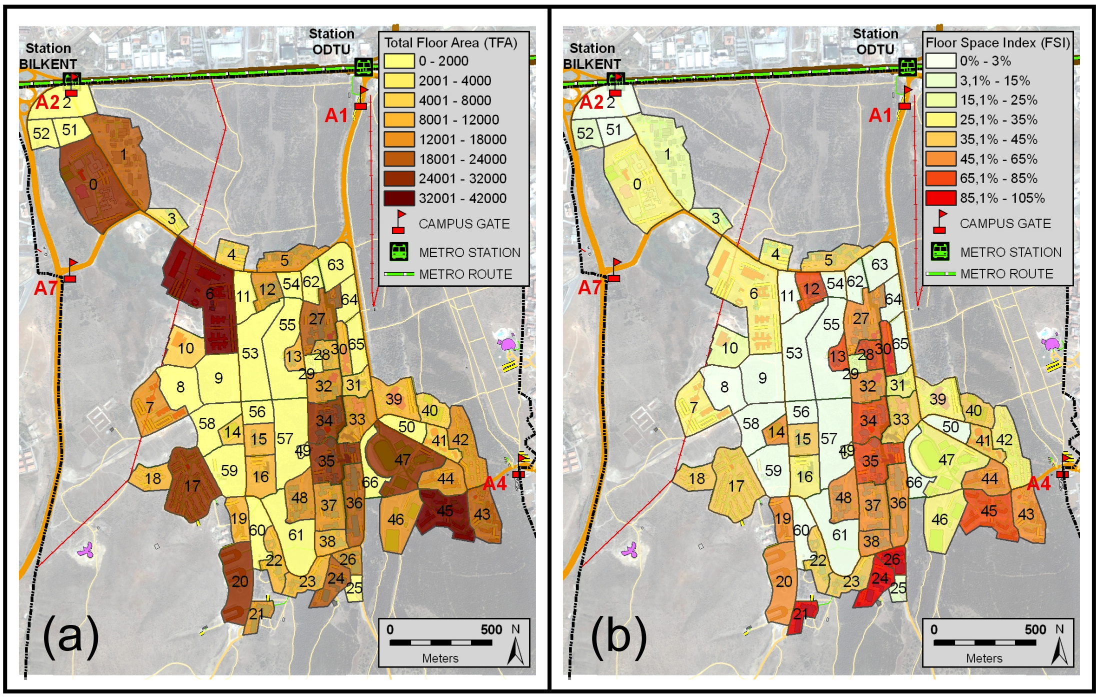


Figure D.1 (a) Total floor area of the structures within each zone and (b) floor space indices of the analysis zones

APPENDIX E

SPATIAL ATTRIBUTES AND INDICATORS OF THE ANALYSIS ZONES

Table E.1 Spatial attributes and indicators of the analysis zones

Zone Id	Land Use Category	Zone Area (m²)	# of Structures in the Zone	Total Base Area (TBA) (m²)	Base Space Index (BSI) (%)	Total Floor Area (TFA) (m²)	Floor Space Index (FSI) (%)	Average # of Floors
0	Education	102.636	11	21.134	20,6	30.598	29,8	1,4
1	Technical	79.563	42	15.214	19,1	18.100	22,7	1,2
2	Metro Station	44.071	1	0	0	0	0	0
3	Academic	15.111	2	1.699	11,2	2.562	17,0	1,5
4	Academic	18.553	3	2.714	14,6	6.192	33,4	2,3
5	Academic	30.426	9	6.143	20,2	12.547	41,2	2,0
6	Commercial	120.397	12	18.522	15,4	35.759	29,7	1,9
7	Commercial	44.510	6	5.134	11,5	13.230	29,7	2,6
8	Bare Land	38.766	0	0	0	0	0	0
9	Bare Land	48.177	0	0	0	0	0	0
10	Commercial	31.362	1	3.542	11,3	7.085	22,6	2,0
11	Bare Land	22.864	0	0	0	0	0	0
12	Academic	21.706	1	6.226	28,7	14.697	67,7	2,4
13	Academic	12.216	1	2.051	16,8	9.323	76,3	4,5
14	Sports	13.239	1	3.361	25,4	6.721	50,8	2,0
15	Academic	23.408	1	3.462	14,8	8.773	37,5	2,5
16	Administrative	29.272	3	2.970	10,1	8.360	28,6	2,8
17	Residential	68.565	38	12.628	18,4	26.715	39,0	2,1
18	Residential	22.581	6	2.802	12,4	8.405	37,2	3,0
19	Dormitory	20.919	2	3.317	15,9	9.791	46,8	3,0
20	Dormitory	52.043	3	9.287	17,8	28.006	53,8	3,0
21	Academic	14.421	2	5.017	34,8	13.560	94,0	2,7
22	Academic	24.777	3	4.403	17,8	9.876	39,9	2,2
23	Academic	24.808	7	3.940	15,9	9.173	37,0	2,3
24	Academic	24.458	4	5.727	23,4	20.840	85,2	3,6
25	Social	9.309	2	608	6,5	754	8,1	1,2

Table E.1 (continued)

Zone Id	Land Use Category	Zone Area (m²)	# of Structures in the Zone	Total Base Area (TBA) (m²)	Base Space Index (BSI) (%)	Total Floor Area (TFA) (m²)	Floor Space Index (FSI) (%)	Average # of Floors
26	Academic	13.607	4	6.199	45,6	14.229	104,6	2,3
27	Academic	44.620	6	10.752	24,1	22.969	51,5	2,1
28	Academic	14.658	3	3.649	24,9	9.616	65,6	2,6
29	Education	8.046	2	1.428	17,8	1.428	17,8	1,0
30	Cultural	14.939	1	3.493	23,4	11.004	73,7	3,2
31	Administrative	15.911	1	1.422	8,9	4.874	30,6	3,4
32	Academic	25.236	4	5.320	21,1	15.416	61,1	2,9
33	Administrative	32.854	4	4.958	15,1	14.424	43,9	2,9
34	Academic	33.475	6	7.768	23,2	24.863	74,3	3,2
35	Academic	41.418	12	9.818	23,7	28.782	69,5	2,9
36	Academic	37.999	4	10.180	26,8	21.991	57,9	2,2
37	Academic	33.457	6	7.972	23,8	16.033	47,9	2,0
38	Academic	18.040	6	3.833	21,2	9.491	52,6	2,5
39	Cultural	37.436	2	6.553	17,5	9.801	26,2	1,5
40	Sports	20.766	5	7.385	35,6	7.385	35,6	1,0
41	Commercial	18.576	7	4.374	23,5	7.642	41,1	1,7
42	Residential	43.190	17	6.633	15,4	14.307	33,1	2,2
43	Dormitory	36.298	12	5.872	16,2	18.768	51,7	3,2
44	Dormitory	28.661	4	4.313	15,0	14.702	51,3	3,4
45	Dormitory	49.521	10	10.211	20,6	40.823	82,4	4,0
46	Sports	47.943	7	11.671	24,3	14.594	30,4	1,3
47	Sports	79.920	10	23.571	29,5	26.789	33,5	1,1
48	Academic	30.814	5	7.230	23,5	14.065	45,6	1,9
49	Social	3.504	3	544	15,5	544	15,5	1,0
50	Forest	17.816	0	0	0	0	0	0
51	Bare Land	19.418	0	0	0	0	0	0
52	Technical	19.033	5	731	3,8	731	3,8	1,0
53	Bare Land	64.468	0	0	0	0	0	0
54	Forest	13.904	0	0	0	0	0	0
55	Forest	68.256	1	84	0,1	84	0,1	0
56	Bare Land	17.348	0	0	0	0	0	0
57	Forest	63.195	2	0	0	0	0	0
58	Bare Land	37.958	0	0	0	0	0	0

Table E.1 (continued)

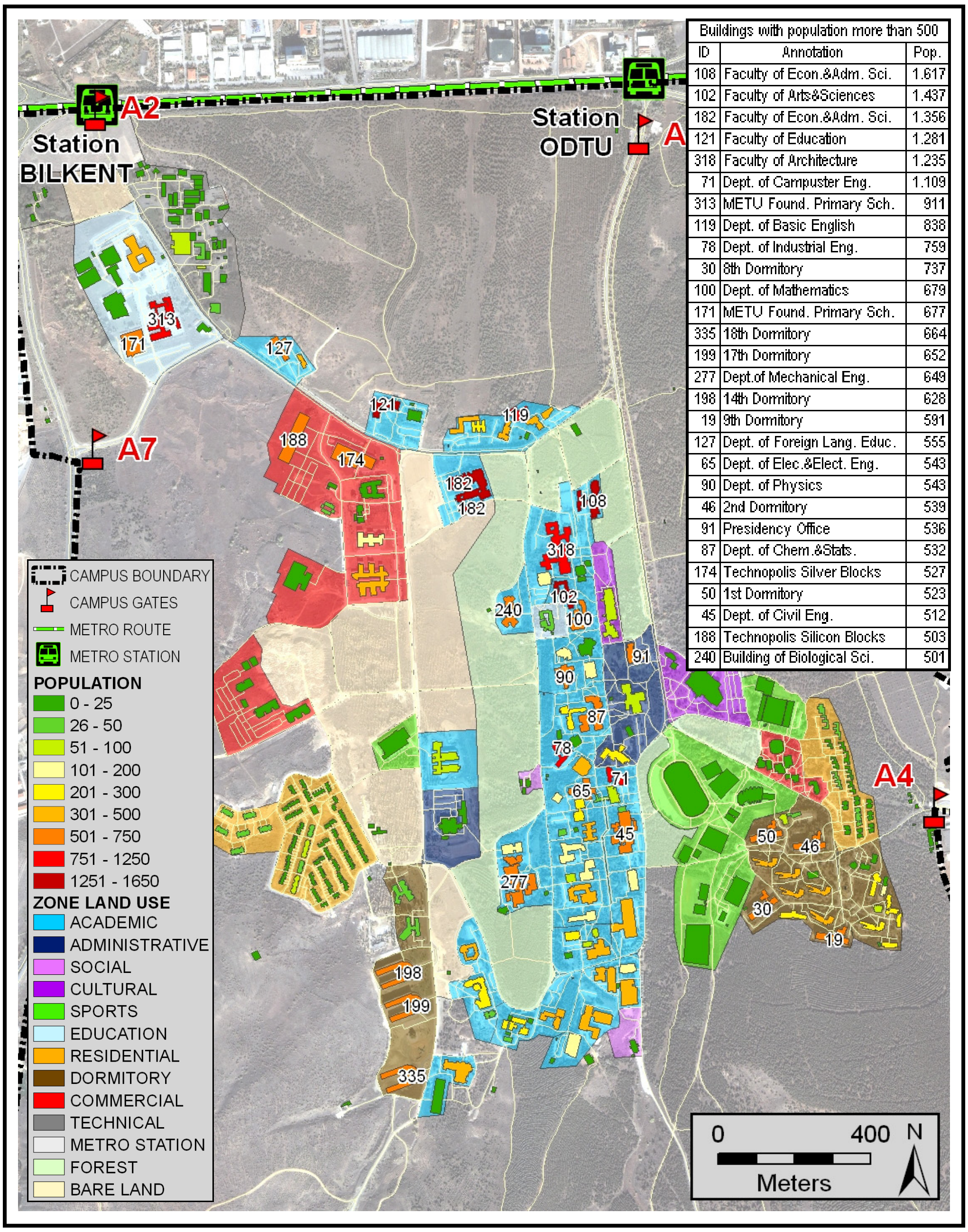
Zone Id	Land Use Category	Zone Area (m²)	# of Structures in the Zone	Total Base Area (TBA) (m²)	Base Space Index (BSI) (%)	Total Floor Area (TFA) (m²)	Floor Space Index (FSI) (%)	Average # of Floors
59	Bare Land	40.803	3	608	1,5	608	1,5	0
60	Bare Land	28.082	1	52	0,2	52	0,2	0
61	Forest	57.410	1	0	0	0	0	0
62	Forest	17.507	2	34	0,2	34	0,2	0
63	Forest	29.310	1	497	1,7	497	1,7	0
64	Forest	18.073	0	0	0	0	0	0
65	Forest	21.299	0	0	0	0	0	0
66	Forest	19.832	0	0	0	0	0	0

* The sign "." is thousands separator and "," is decimal separator.

In Table E.1; TBA stands for total base area and TFA stands for total floor area of the buildings and structures within a zone, similarly BSI stands for base space index and FSI stands for floor space index of a zone. BSI was calculated by dividing relevant zone's TBA to the zone's area, similarly FSI was calculated by dividing TFA to the zone's area. Average number of floors in each zone is calculated by dividing zone's FSI to the BSI.

APPENDIX F

DISTRIBUTION OF THE CAMPUS POPULATION ACCORDING TO THE CAMPUS BUILDINGS



ID	Annotation	Pop.
108	Faculty of Econ.&Adm. Sci.	1.617
102	Faculty of Arts&Sciences	1.437
182	Faculty of Econ.&Adm. Sci.	1.356
121	Faculty of Education	1.281
318	Faculty of Architecture	1.235
71	Dept. of Campuster Eng.	1.109
313	METU Found. Primary Sch.	911
119	Dept. of Basic English	838
78	Dept. of Industrial Eng.	759
30	8th Dormitory	737
100	Dept. of Mathematics	679
171	METU Found. Primary Sch.	677
335	18th Dormitory	664
199	17th Dormitory	652
277	Dept.of Mechanical Eng.	649
198	14th Dormitory	628
19	9th Dormitory	591
127	Dept. of Foreign Lang. Educ.	555
65	Dept. of Elec.&Elect. Eng.	543
90	Dept. of Physics	543
46	2nd Dormitory	539
91	Presidency Office	536
87	Dept. of Chem.&Stats.	532
174	Technopolis Silver Blocks	527
50	1st Dormitory	523
45	Dept. of Civil Eng.	512
188	Technopolis Silicon Blocks	503
240	Building of Biological Sci.	501

Figure F.1 Distribution of the campus population according to the campus buildings

APPENDIX G

DISTRIBUTION OF THE STUDENTS’, STAFF’S AND DORMITORIES’ – RESIDENCES’ POPULATION ACCORDING TO THE ANALYSIS ZONES

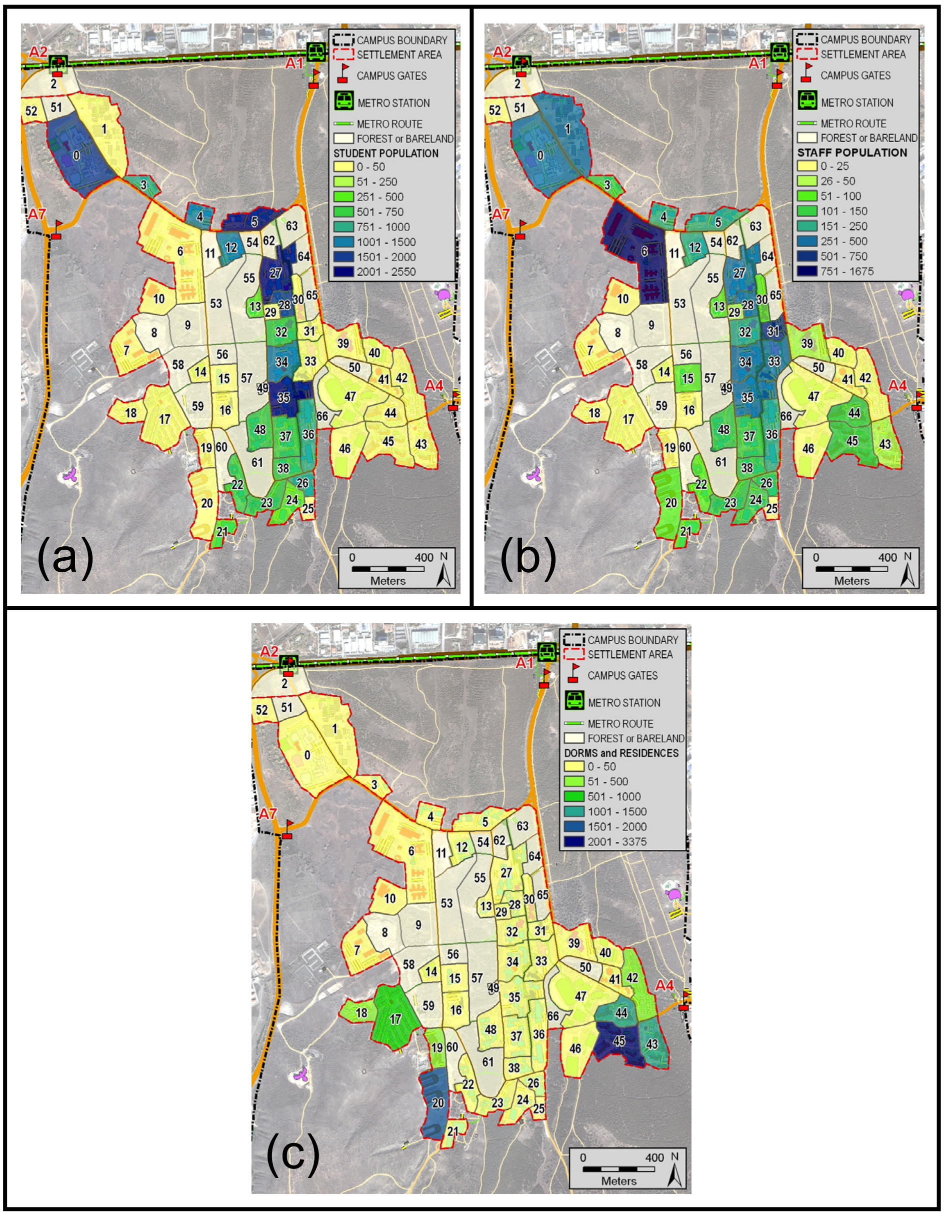


Figure G.1 Distribution of the (a) students’ population, (b) staff’s population, (c) dormitories’ and residences’ population according to the analysis zones

Spatial distribution of the all students in the campus, comprising from 20.372 METU students and 1.805 METU Foundation Primary and High School students, is presented in Figure G.1-a. Spatial distribution of the staff, including 2.593 academics and 2.835 university, 1660 METU Tecnhopolis, 299 METU Foundation School personnel, is presented in Figure G.1-b. Figure G.1-c presents the estimated population inhabiting in the residential zones and the capacity of the dormitories in the campus. Figure G.1-c also presents the population amount that would generate home or dorm based regular trips in morning and evening peak hours for workdays.

APPENDIX H

DISTRIBUTION OF POPULATION DENSITIES ACCORDING TO THE ANALYSIS ZONES

Population densities in the zones are spatially distributed according to the analysis zones (Figure H.1).

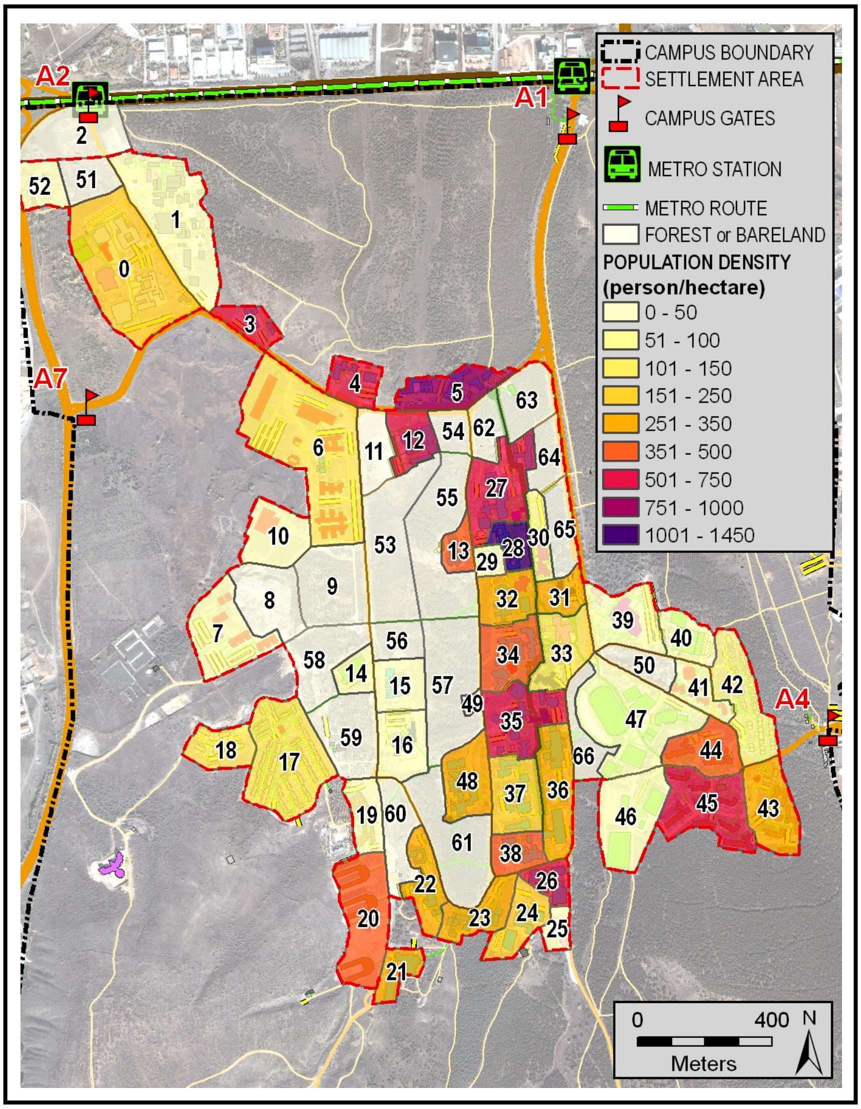


Figure H.1 Distribution of the population densities according to the analysis zones

Population densities in the zones are also calculated for the following groups: students' density (Figure H.2-a), staff's density (Figure H.2-b) and campus inhabitants' density, only for the residential and dormitories zones (Figure H.2-c).

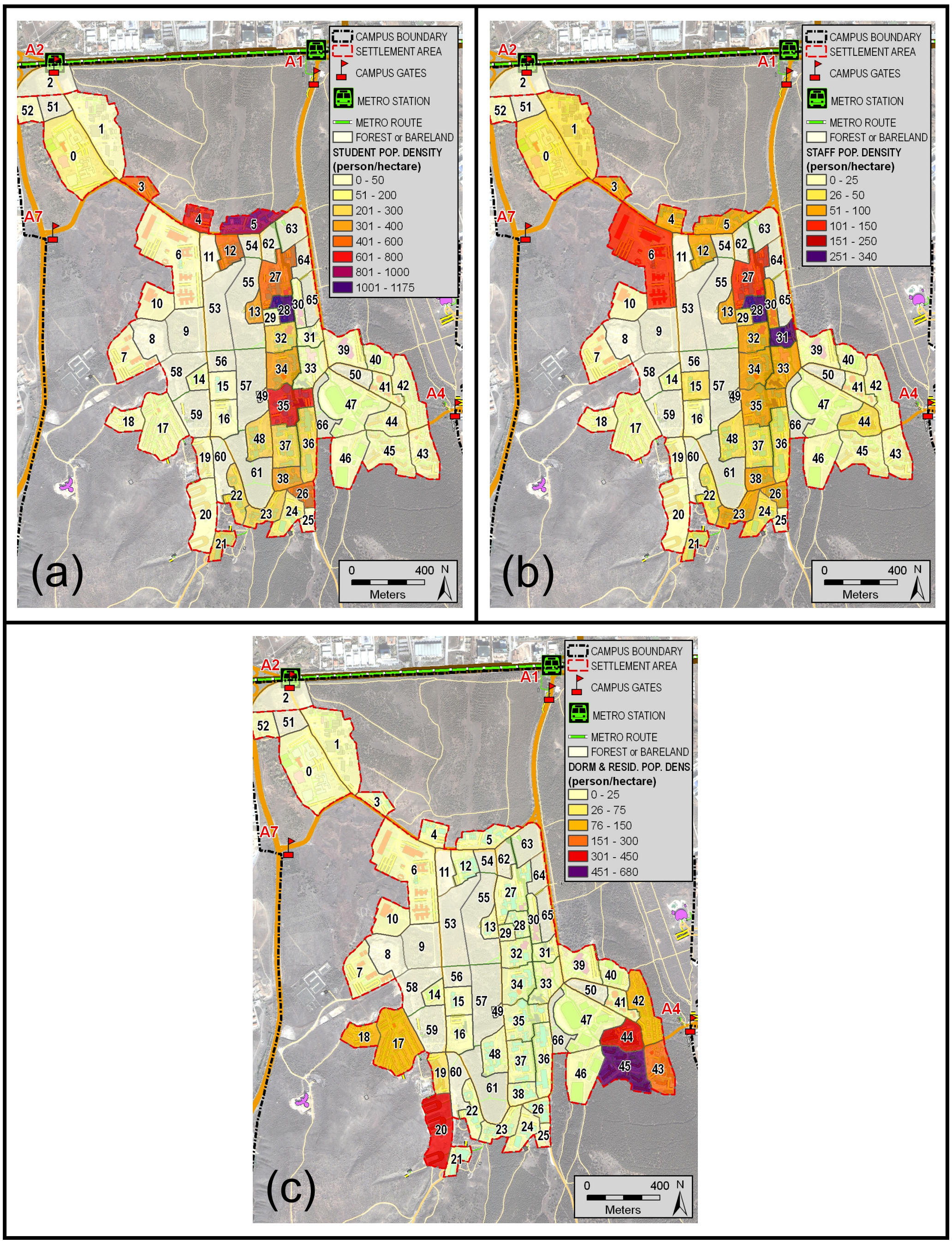


Figure H.2 Distribution of the (a) students' population density, (b) staff's population density, (c) dormitories' and residences' population density according to the analysis zones

APPENDIX I

POPULATION CHARACTERISTICS OF THE ANALYSIS ZONES

Table I.1 Population characteristics of the analysis zones

Analysis Zone			All Students		All Staff		Dormitories and Residences		Total	
ID	Land Use Category	Area (m²)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)
0	Education	102.636	1.805	176	300	29	0	0	2.105	205
1	Technical	79.563	0	0	350	44	0	0	350	44
2	Metro Station	44.071	0	0	0	0	0	0	0	0
3	Academic	15.111	786	520	109	72	0	0	895	592
4	Academic	18.553	1.137	613	153	82	0	0	1.290	695
5	Academic	30.426	2.476	814	235	77	0	0	2.711	891
6	Commercial	120.397	0	0	1675	139	0	0	1.675	139
7	Commercial	44.510	0	0	0	0	0	0	0	0
8	Bare Land	38.766	0	0	0	0	0	0	0	0
9	Bare Land	48.177	0	0	0	0	0	0	0	0
10	Commercial	31.362	0	0	0	0	0	0	0	0
11	Bare Land	22.864	0	0	0	0	0	0	0	0
12	Academic	21.706	1.205	555	151	70	0	0	1.356	625
13	Academic	12.216	422	345	79	65	0	0	501	410
14	Sports	13.239	0	0	12	9	0	0	12	9
15	Academic	23.408	0	0	71	30	0	0	71	30
16	Administrative	29.272	0	0	15	5	0	0	15	5
17	Residential	68.565	0	0	1	0	705	103	706	103
18	Residential	22.581	0	0	0	0	252	112	252	112
19	Dormitory	20.919	0	0	18	9	72	34	90	43
20	Dormitory	52.043	0	0	72	14	1.872	360	1.944	374
21	Academic	14.421	342	237	68	47	0	0	410	284
22	Academic	24.777	633	255	91	37	0	0	724	292
23	Academic	24.808	596	240	131	53	0	0	727	293
24	Academic	24.458	385	157	109	45	0	0	494	202
25	Social	9.309	0	0	0	0	0	0	0	0
26	Academic	13.607	775	570	128	94	0	0	903	664

Table I.1 (continued)

Analysis Zone			All Students		All Staff		Dormitories and Residences		Total	
ID	Land Use Category	Area (m²)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)
27	Academic	44.620	2.516	564	489	110	0	0	3.005	673
28	Academic	14.658	1.711	1.167	405	276	0	0	2.116	1.444
29	Education	8.046	0	0	26	32	0	0	26	32
30	Cultural	14.939	0	0	91	61	0	0	91	61
31	Administrative	15.911	0	0	536	337	0	0	536	337
32	Academic	25.236	589	233	210	83	0	0	799	317
33	Administrative	32.854	40	12	310	94	0	0	350	107
34	Academic	33.475	1.319	394	259	77	0	0	1.578	471
35	Academic	41.418	2.542	614	411	99	0	0	2.953	713
36	Academic	37.999	885	233	174	46	0	0	1.059	279
37	Academic	33.457	708	212	107	32	0	0	815	244
38	Academic	18.040	606	336	127	70	0	0	733	406
39	Cultural	37.436	0	0	32	9	0	0	32	9
40	Sports	20.766	0	0	0	0	0	0	0	0
41	Commercial	18.576	0	0	3	2	0	0	3	2
42	Residential	43.190	0	0	0	0	389	90	389	90
43	Dormitory	36.298	0	0	43	12	1.086	299	1.129	311
44	Dormitory	28.661	0	0	129	45	1.026	358	1.155	403
45	Dormitory	49.521	0	0	112	23	3.356	678	3.468	700
46	Sports	47.943	0	0	14	3	0	0	14	3
47	Sports	79.920	0	0	22	3	0	0	22	3
48	Academic	30.814	699	227	106	34	0	0	805	261
49	Social	3.504	0	0	0	0	0	0	0	0
50	Forest	17.816	0	0	0	0	0	0	0	0
51	Bare Land	19.418	0	0	0	0	0	0	0	0
52	Technical	19.033	0	0	12	6	0	0	12	6
53	Bare Land	64.468	0	0	0	0	0	0	0	0
54	Forest	13.904	0	0	0	0	0	0	0	0
55	Forest	68.256	0	0	0	0	0	0	0	0
56	Bare Land	17.348	0	0	0	0	0	0	0	0
57	Forest	63.195	0	0	0	0	0	0	0	0
58	Bare Land	37.958	0	0	0	0	0	0	0	0
59	Bare Land	40.803	0	0	1	0	0	0	1	0
60	Bare Land	28.082	0	0	0	0	0	0	0	0

Table I.1 (continued)

Analysis Zone			All Students		All Staff		Dormitories and Residences		Total	
ID	Land Use Category	Area (m^2)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)	Pop. (person)	Pop. Density (person per hectare)
61	Forest	57.410	0	0	0	0	0	0	0	0
62	Forest	17.507	0	0	0	0	0	0	0	0
63	Forest	29.310	0	0	0	0	0	0	0	0
64	Forest	18.073	0	0	0	0	0	0	0	0
65	Forest	21.299	0	0	0	0	0	0	0	0
66	Forest	19.832	0	0	0	0	0	0	0	0

* Pop. stands for population. 1 hectare = 10.000 m^2. The sign "." is thousands separator. Population density in 1 hectare is calculated by dividing zone's population to the zone's area in hectares.

In Table I.1, population sub field, under the all students column, stands for the overall population of the student groups within each zone comprising from 20.372 university students at the levels of undergraduate, graduate, postgraduate education and 1.805 students registered to the METU Foundation Primary and High School. Similarly, population sub field of all staff column presents the zonal distribution of the staff population comprising from 2.593 academics, 2.835 administrative and other university staff, 1.660 METU Technopolis staff and 299 METU Foundation School staff. Dormitories and residences field presents the zonal distribution of the people living in the residential and dormitories zones. Although their population is reflected to the total population field, they should be evaluated separately since they are permanently living in the residential zones with their families or living in the student dormitories and guesthouses.

Average zonal population in the built up area of the campus is determined as 648 persons. 20 zones, with no population and having land use types of forest and bare land, are ignored. Within the 47 analysis zones, 23 zones have population values bigger than the average. Within these 23 zones, 8 zones, comprising a population of 14.061 persons, are located in the area known as core campus along the main pedestrian alley. In addition, Department of Basic English, known as preparatory school (zone 5), is another important zone with an overall population of 2.711 persons; located on the northern side of the core campus. Also, all the dormitories zones, except for the one containing research assistants' guesthouses, exhibit population values grater than the average. With an overall population about 7400 persons, dormitories zones would generate temporal trip intensity towards the central academic zones especially in the morning and evening peaks since they are located at the southeastern and southwestern zones of the campus. METU Technopolis (zone 6), METU Foundation School (zone 0) and Faculty of Education with its two zones (zones 3 and 4), exhibit population values greater than the average and formed trip attraction zones that could shape the public transport service routes towards the northwestern zones of the campus.

Average students' population is detected as 472 students, within the 47 zones where 20 zones' land use is either academic or education. About 50% of the students' population (10.926 students) is located within the core campus ring, encircling the main pedestrian alley. About 25% of the students' population (5.604 students) is located on the northern side of the core campus ring, where the Department of Basic English (zone 5), Faculty of Education (zome 4) and Faculty of Economic and Administrative Sciences (new building, zone 12) are located. However, this rate increases up to 33% when the students of METU Foundation School (1.805 students in zone 0) are added. About 12% of the students' population (2.731 students) is located on the southern segment of the campus and only 5% of the students' population (1.121 students in the zones 13 and 48) is located on the west, in two zones, adjacent to the core campus ring.

Average staff’s population in the zones is detected as 110 persons. Zonal distribution of the staff’s population is decentralized more than the students’ population because, about 80% of the analysis zones exhibit staff populations more than 10 persons, however only %40 of the zones exhibit students’ population within. 43% of the staff (3.145 persons) is working within the core campus ring. Besides, 32% of the staff (2.325 persons) is working in the northwestern segment of the campus, including Technopolis (zone 6), METU Foundation School (zone 0) and the technical units (zone 1). However, with the new Technopolis buildings under construction, staff population of the METU Technopolis will increase and move towards the zones 7, 8, 9 and 10; hence trip generation and attraction potential of these zones should be accounted while proposing new public transport routes.

Another factor, affecting public transport proposals, is the population of the inhabitants living in the METU Residences and the students staying in the dormitories. A population of 1.000 persons is estimated in the ODTÜKent (zones 17 and 18) and a population of 400 persons is estimated in the east residential zone (zone 42). According to the capacity of the METU student dormitories and guesthouses, about 1.950 students are staying in the west dormitory zone (zone 20) and nearly 5.500 students are staying in the eastern dormitories zones (zones 43, 44 and 45) within the academic year.

There is a temporary population that could not be estimated in this study since no data is available. However, temporal population, attracted from outside of the campus and attracted from the different zones of the campus, can be mapped over the following zones: METU Technopolis (zones 6, 7 and 10), library (zone 30), presidency office (zone 31), cultural and convention center (zone 39), shopping center and banks (zone 41) and sports halls, fields (zones 14, 40, 46 and 47).

APPENDIX J

EXISTING TRANSPORT FACILITIES IN CAMPUS

Table J.1 Existing transport facilities in campus

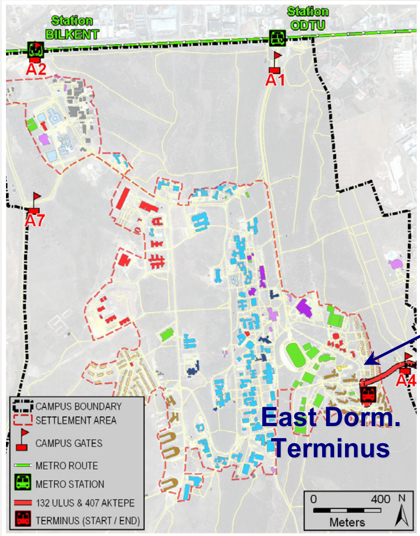
Transport Mode		Annotation		
		Route ID	**Route**	**Route Timetable**
Public Transport	EGO Bus Services	132	METU (Gate A4) – 100. Yıl – Karakusunlar – Kızılay – Ulus	From 06:30 to 23:00, approximately in every 15 minutes, 76 trips per day
Public Transport	EGO Bus Services	196 (1,2)	METU (Gate A1) – National Library – Tunus St.	From 07:30 to 17:45, approximately in every 60 minutes, 10 trips for one direction per day
Public Transport	EGO Bus Services	197 (1,2)	METU (Gate A1) – National Library – Sıhhıye Bridge	From 07:30 to 17:45, approximately in every 60 minutes, 10 trips for one direction per day
Public Transport	EGO Bus Services	198	METU (Gate A1) – National Library – Kızılay (Güvenpark)	From 08:30 to 23:00, in every 30 minutes, 30 trips for one direction per day
Public Transport	EGO Bus Services	District Services (1,2)	Additional EGO Bus Services to the Districts of Ankara (10 additional bus routes are available)	Between 07:00 and 09:00 from districts to campus. At 17:45 from campus to districts. 26 trip per day
Public Transport				
Public Transport	Bus (Privately Operated)	407	METU (Gate A4) – 100. Yıl – Karakusunlar – AŞTİ – Beşevler – Aktepe	From 06:30 to 22:30, in every 15 minutes, 64 trips per day
Public Transport	Minibus (Privately Operated)	M-10	METU (Gate A1) – National Library – Kızılay (Güvenpark)	From 07:00 to 24:00, service intervals are proportional to the passenger density
Public Transport	Minibus (Privately Operated)	M-20	METU (Gate A1) – AŞTİ – Ulus	
Public Transport	Minibus (Privately Operated)	M-30	METU (Gate A4) – Çetin Emeç Boulevard – Ayrancı	

Table J.1 (continued)

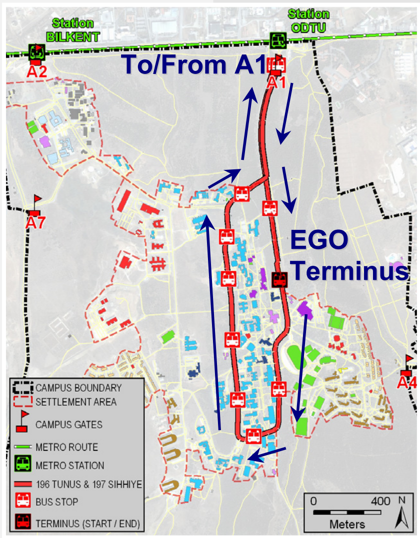
Transport Mode		Annotation			
		Route ID		Route	Route Timetable
Public Transport	METU Transport Services	Staff Services (1)		METU Bus Services to the Districts of Ankara for METU Staff (46 bus routes are available)	Between 06:20 and 07:55 from districts to campus. At 17:45 from campus to districts. 46 trip for one direction per day
		Campus Rings	911 (1)	Red Ring	From 09:00 to 16:45, in every 15 minutes, 31 trip per day
			912 (1)	Yellow Ring	From 09:00 to 16:45, in every 15 minutes, 31 trip per day
			921 (1,2)	Blue Ring	At 08:25, from west dormitories zone, 1 trip per day
			922 (1,2)	Orange Ring	At 08:25, from west dormitories zone, 1 trip per day
			931 (2)	Dormitories Ring (Operates between west dormitories and east dormitories)	For weekdays, from 18:35 to 23:30, approximately in every 60 minutes, 6 trips for one direction per day For weekend, at 09:30, 13:00 and 16:00, 3 trips for one direction per day
			941 (2)	AŞTİ Ring (Operates between campus and AŞTİ)	At 09:00, 12:00, 13:00 and 15:00, 4 trips for one direction per day
Individual Transport	Taxi	Available with a call to the taxi depot located at the east dormitories zone			Between 07:00 and 24:00
	Private Cars	Totally 10.790 motorized vehicles are registered with campus entrance cards in 2005. Moreover, nearly 90% of these entrance cards are assigned for private cars.			

(1) Service is available for working days.
(2) Service is available within the academic year, between months September and June.

Table J.2 Routes and stops of available bus services in campus for different periods of day

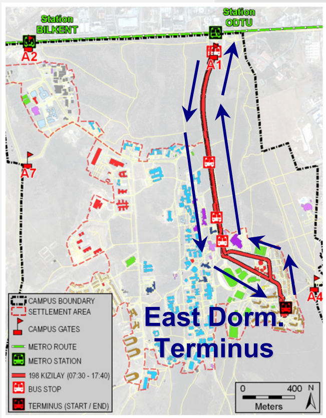
<table>
<tr><th rowspan="2">BUS Service</th><th colspan="3">Daily Service Routes and Available Stops in Campus</th></tr>
<tr><th>Morning Peak</th><th>During Day</th><th>Evening Peak & At Night</th></tr>
<tr><td>EGO Route ID: 132 From 06:30 to 23:00
METU (A4) – Karakusunlar – Kızılay – Ulus
Route ID: 407 From 06:30 to 22:30
METU (A4) – AŞTİ – Beşevler – Aktepe</td><td colspan="2">Starts 06:30


To/From A4</td><td>Bus services #132 and #407 are only <u>available from the bus stop located in east dormitories zone</u>. Both use gate A4 for departure/arrival.

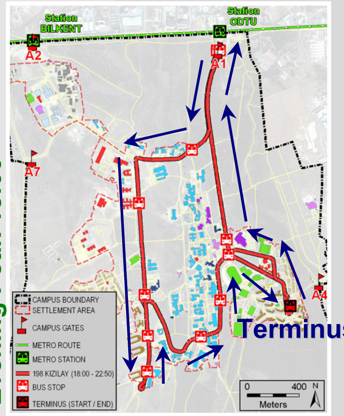
Available Until
23:00 (# 132)
22:30 (# 407)</td></tr>
<tr><td>EGO Route ID: 196 From 07:30 to 17:45
METU (A1) – National Library – Tunus St.
EGO Route ID: 197 From 07:30 to 17:45
METU (A1) – National Library – Sıhhiye Bridge</td><td colspan="2">Starts 07:30

</td><td>Bus services #196 and #197 depart from the terminus located by the presidency, then track through faculties' road (core campus ring) and reach gate A1. <u>Stops at gate A1 and Terminus are available for both get on and get off. Stop by the Fac. of Adm. is only available for get off. Other stops are only available for get on.</u> (Available for working days in acad. year)

Available Until
Evening Peak
17:45 (# 196 & 197)</td></tr>
</table>

Table J.2 (continued)

<table>
<tr><th rowspan="2">BUS Service</th><th colspan="3">Daily Service Routes and Available Stops in Campus</th></tr>
<tr><th>Morning Peak</th><th>During Day</th><th>Evening Peak & At Night</th></tr>
<tr><td>EGO Route ID: 198 From 08:30 to 23:00
METU (A1) – Kızılay (Güvenpark)</td><td colspan="3">Starts 08:30


Available Until 18:00 (# 198a)
Bus service #198a departs from the Terminus located in the east dorms, then tracks through shopping center, Cult. Conv. Cent. (CCC) and reaches gate A1. <u>Stops at A1 & Terminus are available for get on/off. Stop by the CCC. is for get on. Others are only for get off.</u>

Starts After Evening Peak 18:00


Available Until 23:00 (# 198b)
Bus service #198b departs from the Terminus located in the east dorms, then tracks through shopping center, CCC. and reaches gate A1. <u>Stops at A1 & Terminus are available for get on/off. Stop by the CCC. is for get on. Other stops, Prep. Sch., Technopolis, ODTÜKent, West Dorms and those until Terminus are for get off.</u></td></tr>
<tr><td>EGO
District Services</td><td colspan="3">07:00 – 09:00 (Morning Peak)
<u>Services depart from districts</u>

17:45 (Evening Peak)
<u>Services depart from the stops by presidency</u>

Balgat – Dostlar Sitesi (*) / Dikmen – Keklikpınarı / Oran – Yıldız / Yenimahalle / Subayevleri – Y.Beyazıt / Batıkent / Natoyolu – Ege Mah. / Bağcılar – Küçükesat / Keçiören – Etlik / Eryaman – Fatih – Sincan
(* Available only in morning peak / All services are available for working days in acad. year)</td></tr>
</table>

Table J.3 Routes and stops of available minibus services in campus for different periods of day

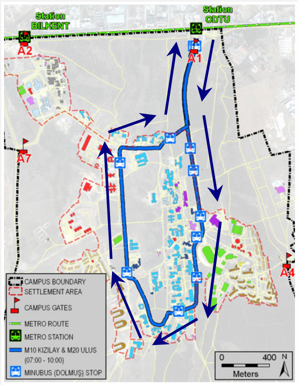
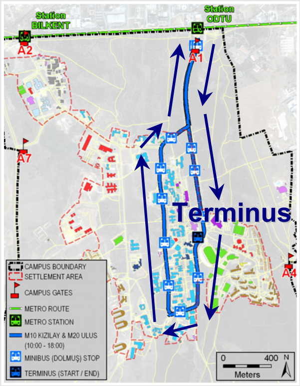
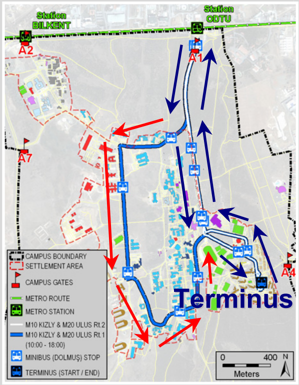
MINIBUS Service	Daily Service Routes and Available Stops in Campus		
	Morning Peak	During Day	Evening Peak & At Night
Minibus Route ID: M-10 From 07:00 to 24:00 METU (A1) – Kızılay (Güvenpark) Minibus Route ID: M-20 From 07:00 to 24:00 METU (A1) – Ulus			
	Starts 07:00 **Available Until 10:00**	**Starts After Morning Peak 10:00** **Available Until 18:00**	**Starts After Evening Peak 18:00** **Available Until 24:00**
	During morning peak, services #M-10 & #M-20 make a loop through the (blue) route given above. <u>Services are available from all stops on this route (both for get on & get off). Passengers may prefer any of these stops to get a minibus.</u> Both services use A1 for departure/arrival.	Essentially, #M-10 & #M-20 are available from all stops (both for get on & get off) except for the stops located by Library & Fac. of Adm. <u>However in practice, stop by the cafeteria is the terminus point and #M-10 & #M-20 minibuses reach full capacity at this stop.</u> Both #M-10 and #M-20 minibuses use A1 gate.	After evening peak, two routes are used by #M-10 & #M-20. If there are Tehnopolis and/or ODTÜKent passengers, red route is prioritized. Else, blue route is used. <u>Services depart/arrive from/to the stop located in west dorms (terminus) and use A1 gate. Services are available (get on) from terminus, shopping cent., CCC. & A1. Other stops</u> are only for get off.

Table J.3 (continued)

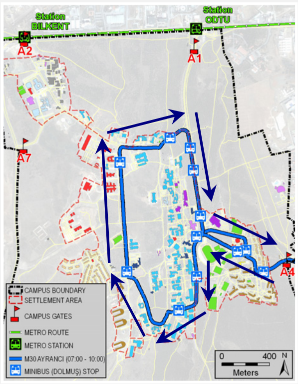
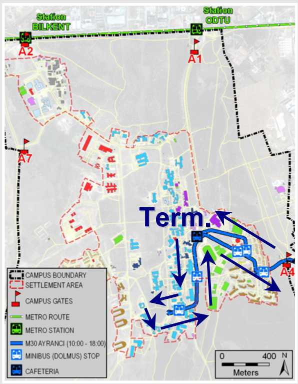
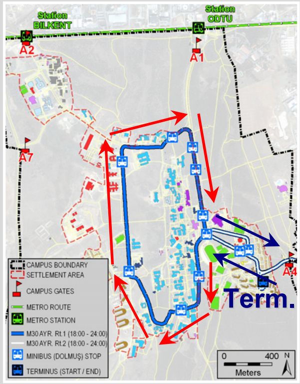
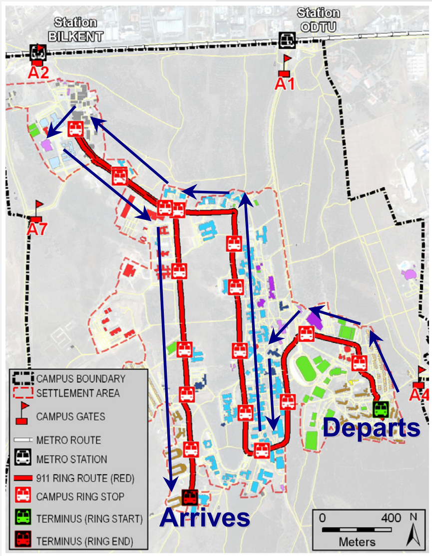
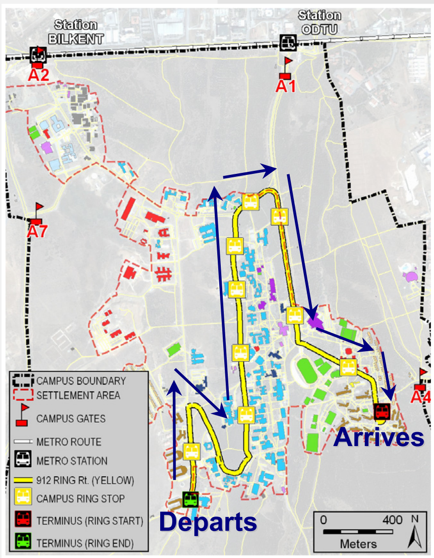
MINIBUS Service	Daily Service Routes and Available Stops in Campus		
	Morning Peak	**During Day**	**Evening Peak & At Night**
Minibus Route ID: M-30 From 07:00 to 24:00 METU (A4) – Ayrancı District			
	Starts 07:00 **Available Until 10:00**	**Starts After Morning Peak 10:00** **Available Until 18:00**	**Starts After Evening Peak 18:00** **Available Until 24:00**
	During morning peak, service #M-30 makes a loop through the (blue) route given above. Service is available from all stops on this route (both for get on & get off). Passengers may prefer any of these stops to get a minibus. Service uses A4 for departure/arrival.	Essentially, #M-30 is available from all stops (both for get on & get off) except for the stops located by Civil Eng. & Chem. Eng. However in practice, stop by the cafeteria is the terminus point and #M-30 minibuses reach full capacity at this stop. #M-30 minibuses use A4 gate.	After evening peak, two routes are used by #M-30. If there are Tehnopolis and/or ODTÜKent passengers, red route is prioritized. Else, blue route is used. #M-30 departs/arrives from/to the stop located in west dorms (terminus) and uses A4 gate. Service is available (get on) from terminus, shopping cent., CCC. & A1. Other stops are only for get off.

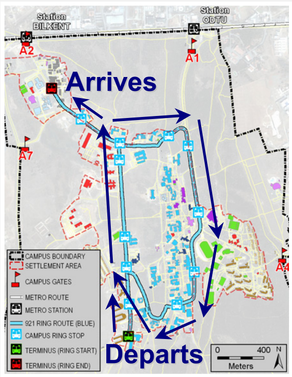
Table J.4 Routes and stops of available campus ring services in different periods of day

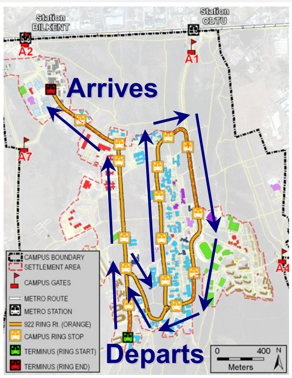
<table>
<tr><th rowspan="2">RING Service</th><th colspan="3">Daily Service Routes and Available Stops in Campus</th></tr>
<tr><th>Morning Peak</th><th>During Day</th><th>Evening Peak & At Night</th></tr>
<tr><td>RED Ring Route ID: 911
Between 09:00 & 16:45
Departs from East (Old) Dorms.
Arrives to West (New) Dorms.</td><td colspan="3">Starts 09:00


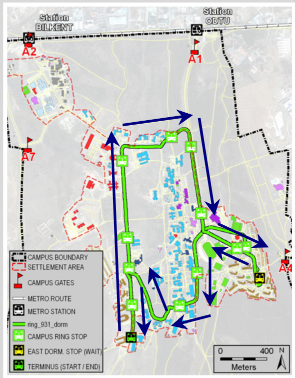
RED Ring service #911 departs from the stop located in the east (old) dormitories zone, then tracks through shopping center, CCC., Civil Eng., Faculties' Road, Prep. School, Fac. of Education, Technical Units, METU Technopolis, METU Residences and finally arrives to the west (new) dormitories zone. <u>All stops on this route are available for get on & get off.</u>
Available Until 16:45</td></tr>
<tr><td>YELLOW Ring Route ID: 912
Between 09:00 & 16:45
Departs from West (New) Dorms.
Arrives to East (Old) Dorms.</td><td colspan="3">Starts 09:00


YELLOW Ring service #912 departs from the stop located in the west (new) dormitories zone, then tracks through Food Eng., Geology Eng., Faculties' Road, day nursery, Prep. School, Presidency, shopping center and finally arrives to the east (old) dormitories zone. <u>All stops on this route are available for get on & get off.</u>
Available Until 16:45</td></tr>
</table>

Table J.4 (continued)

<table>
<tr><th rowspan="2">RING Service</th><th colspan="3">Daily Service Routes and Available Stops in Campus</th></tr>
<tr><th>Morning Peak</th><th>During Day</th><th>Evening Peak & At Night</th></tr>
<tr><td>BLUE Ring Route ID: 921
Available at 08:25
Departs from West (New) Dorms.
Arrives to Technical Units</td><td>

Only Available in the Morning at 08:25</td><td colspan="2">BLUE Ring service #921 departs from the stop located in the west (new) dormitories zone, then makes a loop through; METU Residences & Technopolis, Prep. School, Fac. of Adm., Presidency, Civil Eng., Chem. Eng, Food Eng. and again Technopolis; finally arrives to the Technical Units. <u>All stops on this route are available for get on & get off.</u> (Available for working days in academic year)</td></tr>
<tr><td>ORANGE Ring Route ID: 922
Available at 08:25
Departs from West (New) Dorms.
Arrives to Technical Units</td><td>

Only Available in the Morning at 08:25</td><td colspan="2">ORANGE Ring service #922 departs from the stop located in the west (new) dormitories zone, then makes a loop through the core campus by following the route; Food. Eng., Mechanical Eng., day nursery, Prep. School, Fac. of Adm., Presidency, Civil Eng., Chem. Eng and again Food Eng., finally arrives to the Technical Units by following Technopolis Road. <u>All stops on this route are available for get on & get off.</u> (Available for working days in academic year)</td></tr>
<tr><td>DORMS. Ring Route ID: 931
Between 18:35 & 23:30
Loops between West (New) Dorms.
& East (Old) Dorms.</td><td colspan="2">DORMITORIES Ring service #931 departs from the stop located in the west (new) dormitories zone and makes a loop between west and east (old) dormitories zones. <u>All stops on this route are available for get on & get off.</u> (Available only in academic year / Available only for three times in a day, at 09:30, 13:00 and 16:00, at weekends and in legal holidays)</td><td>

Starts 18:35 Available Until 23:30</td></tr>
</table>

APPENDIX K

CAMPUS DAILY TRAFFIC RELATIVE TO THE PROBABLE MOVEMENTS OF POPULATION GROUPS

Different population groups use different zones of campus. Thus, campus daily traffic and zonal interactions in different periods of day are explored in relation to the probable movements and trips of these groups (Table K.1).

Table K.1 Campus daily traffic relative to the probable movements of population groups in different periods of day

Population Groups or Relevant Zones		**Periods of (Working) Days**			
		Morning Peak (08:00 – 10:00)	**During Day (10:00 – 16:00)**	**Evening Peak (16:00 – 18:00)**	**Evening & Night (18:00 – 24:00)**
University	All Prep. School & Und. Graduate Students (*)	Educational zones attract ~14.500 (max.) students from dormitories & city. (Home or dorms. based regular trips***)	Students in educational zones may generate trips to other zones during day. (eg. to library or to cafeteria, shopping center in midday for lunch.)	Educational zones redirect ~14.500 (max.) students to dormitories & city. (Home or dorms. based regular trips***)	N/A
	All Graduate & Postgraduate & Integrated Prog. & Private Stds. (**)	Educational zones attract ~5.500 (max.) students from dormitories & city. (Home or dorms. based regular trips***)		Educational zones redirect ~5.500 (max.) students to dormitories & city. (Home or dorms. based regular trips***)	N/A
	Staff (*) All Academic & Administrative & Other Personnel	Educ., Admin., Socio-Cult. & Tech. zones attract ~5.500 (max.) personnel from METU Resid. & city. (Home based regular work trips***)	Staff generates trips to cafeteria, social building & shopping center in midday for lunch. (Regular inner campus trips)	Educ., Admin., Socio-Cult. & Tech. zones redirect ~5.500 (max.) personnel to METU Resid. & city. (Home based regular work trips***)	N/A

Table K.1 (continued)

Population Groups or Relevant Zones		Periods of (Working) Days			
		Morning Peak (08:00 – 10:00)	During Day (10:00 – 16:00)	Evening Peak (16:00 – 18:00)	Evening & Night (18:00 – 24:00)
METU Technopolis	Staff (*)	Techopolis zone (id: 6, 7, 10) attracts ~1.500 (max.) personnel from city. (Home based regular work trips***)	N/A	Techopolis zone (id: 6, 7, 10) redirects ~1.500 (max.) personnel to city. (Home based regular work trips***)	N/A
METU Foundation Primary & High School	Students & Staff (*) All Prim. – High Sch. Stds. & Instructors & Administ. – Other Staff	METU Found. School zone (id: 0) attracts ~1.500 (max.) students & ~500 (max.) personnel from city. (Home based regular trips***)	N/A	School zone redirects (id: 0) ~1.500 (max.) students & ~500 (max.) personnel to city. (Home based regular trips***)	N/A
METU Residences	METU Staff & their families (*)	~1.500 (max.) persons, living in METU Residences (zone id: 17, 18, 42), generate trips to other zones of campus & city. (Home based regular trips***)	Some inhabitants may generate trips to other zones of campus & city. (eg. with shopping, leisure or other purposes.) (Trips attracted by other zones of campus & city)	~1.500 (max.) persons return to METU Residences (zone id: 17, 18, 42) from other zones of campus & city. (Home based regular trips***)	Some inhabitants may generate trips to other zones of campus & city. (eg. with shopping, leisure or other purposes.) (Trips attracted by other zones of campus & city)
METU Dormitories & Student Guesthouses	Students living in East Dormitories (*) / Students living in West Dorms. (*)	~7.500 (max.) students, living in dorms & guesthouses (zone id: 19, 20, 43, 44, 45), generate trips to educational zones of campus. (Dorm based regular trips***)	Some students may generate trips to other zones of campus & city (eg. with shopping, leisure or other purposes.) (Irregular trips attracted by other zones of campus & city)	~7.500 (max.) students return to dorms & guesthouses (zone id: 19, 20, 43, 44, 45) from educational zones of campus. (Dorm based regular trips***)	Some students may generate trips to other zones of campus & city (eg. with shopping, leisure or other purposes.) (Irregular trips attracted by other zones of campus & city)

Table K.1 (continued)

<table>
<tr><th colspan="2" rowspan="2">Population Groups or Relevant Zones</th><th colspan="4">Periods of (Working) Days</th></tr>
<tr><th>Morning Peak (08:00 – 10:00)</th><th>During Day (10:00 – 16:00)</th><th>Evening Peak (16:00 – 18:00)</th><th>Evening & Night (18:00 – 24:00)</th></tr>
<tr><td rowspan="2">Visitors & Temporary Population</td><td>Visitors</td><td colspan="3">Facilities offered in METU Campus, Cult. Conv. Cent. (id: 39) & Technopolis (id: 6, 7, 10) & Sports Centers (id: 14, 40, 46, 47) etc., attract temporary population from city. However intensity cannot be estimated. (Irregular trips attracted by campus)</td><td>N/A</td></tr>
<tr><td>Parents of chld. in day nursery & stds. in METU Found. School</td><td>Trips are attracted by the following zones;
Zone ID: 0 & 29</td><td>N/A</td><td>Trips are attracted by the following zones;
Zone ID: 0 & 29</td><td>N/A</td></tr>
</table>

(*) People in this group exhibit first order, intensive relations with campus (eg. full attendance in campus for working days). Their trips are assumed as continuous & regular for working days.

(**) People in this group exhibit second order, less intensive relations with campus (eg. partial attendance in campus for working days). Their trips are also assumed as regular but not continuous for all working days.

(***) "In analytical transportation studies, trip generation edge for regular home based trips is always home side since both origin & destination is home. Term "regular" means; any person generating a daily trip in the morning, either with work or educational purpose, will generate a similar daily trip in the evening in reverse direction, to return back home. (Gülgeç, 1998:84, 85)" additionally in this study; dormitories and METU Residences.

(****) Entrance to campus is available from gates A1, A4 and A7 until 24:00. After midnight, only the main gate A1 is available for entrance. Besides, public transport services use gates A1 and A4 for entrance, however there is no public transport service using A7 entrance.

(*****) Numbers marked with "~" approximation sign and "(max.)" term are given to denote the maximum possible trips from that group, in the relevant time period, based on group's population.

APPENDIX L

TRIP GENERATION AMOUNTS OF THE ANALYSIS ZONES

Each analysis zone's trip demand is calculated by multiplying estimated trip generation coefficients with relevant groups' populations, registered in that zone. Table L.1 lists the amount of trips, which are generated by each population group and also the total trips, according to the analysis zones.

Table L.1 Trips generation amounts of the analysis zones

Analysis Zone		Trip Demand = (Population x Trip Generation Coefficient)			
ID	Land Use Category	All Students'	All Staff's	Dorms' and Residences'	Total
0	Education	3.610	602	0	4.212
1	Technical	0	1.400	0	1.400
2	Metro Station	0	0	0	0
3	Academic	2.673	436	0	3.109
4	Academic	3.523	612	0	4.135
5	Academic	8.477	940	0	9.417
6	Commercial	0	3.380	0	3.380
7	Commercial	0	0	0	0
8	Bare Land	0	0	0	0
9	Bare Land	0	0	0	0
10	Commercial	0	0	0	0
11	Bare Land	0	0	0	0
12	Academic	3.607	604	0	4.211
13	Academic	1.149	316	0	1.465
14	Sports	0	48	0	48
15	Academic	0	284	0	284
16	Administrative	0	60	0	60
17	Residential	0	4	1.875	1.879
18	Residential	0	0	670	670
19	Dormitory	0	72	216	288
20	Dormitory	0	288	5.616	5.904
21	Academic	1.086	272	0	1.358
22	Academic	2.045	364	0	2.409

Table L.1 (continued)

Analysis Zone		Trip Demand = (Population x Trip Generation Coefficient)			
ID	Land Use Category	All Students'	All Staff's	Dorms' and Residences'	Total
23	Academic	1.848	524	0	2.372
24	Academic	1.208	436	0	1.644
25	Social	0	0	0	0
26	Academic	2.372	512	0	2.884
27	Academic	7.608	1.956	0	9.564
28	Academic	4.934	1.620	0	6.554
29	Education	0	104	0	104
30	Cultural	0	364	0	364
31	Administrative	0	2.144	0	2.144
32	Academic	1.770	840	0	2.610
33	Administrative	84	1.240	0	1.324
34	Academic	4.142	1.036	0	5.178
35	Academic	7.477	1.644	0	9.121
36	Academic	2.788	696	0	3.484
37	Academic	2.208	428	0	2.636
38	Academic	1.921	508	0	2.429
39	Cultural	0	128	0	128
40	Sports	0	0	0	0
41	Commercial	0	12	0	12
42	Residential	0	0	1.035	1.035
43	Dormitory	0	172	3.248	3.420
44	Dormitory	0	516	3.078	3.594
45	Dormitory	0	448	10.068	10.516
46	Sports	0	56	0	56
47	Sports	0	88	0	88
48	Academic	2.178	424	0	2.602
49	Social	0	0	0	0
50	Forest	0	0	0	0
51	Bare Land	0	0	0	0
52	Technical	0	48	0	48
53	Bare Land	0	0	0	0
54	Forest	0	0	0	0
55	Forest	0	0	0	0
56	Bare Land	0	0	0	0
57	Forest	0	0	0	0
58	Bare Land	0	0	0	0
59	Bare Land	0	4	0	4

Table L.1 (continued)

Analysis Zone		Trip Demand = (Population x Trip Generation Coefficient)			
ID	**Land Use Category**	**All Students'**	**All Staff's**	**Dorms' and Residences'**	**Total**
60	Bare Land	0	0	0	0
61	Forest	0	0	0	0
62	Forest	0	0	0	0
63	Forest	0	0	0	0
64	Forest	0	0	0	0
65	Forest	0	0	0	0
66	Forest	0	0	0	0

* Trip demand in each zone is calculated by multiplying relevant group population with its estimated trip generation coefficient. The sign "." is thousands separator. For comparison, zone IDs are unique and common in all tables, defining attributes of analysis zones.

APPENDIX M

DISTRIBUTION OF THE TRIPS GENERATED BY STUDENTS, STAFF AND DORMITORIES – RESIDENCES ACCORDING TO THE ANALYSIS ZONES

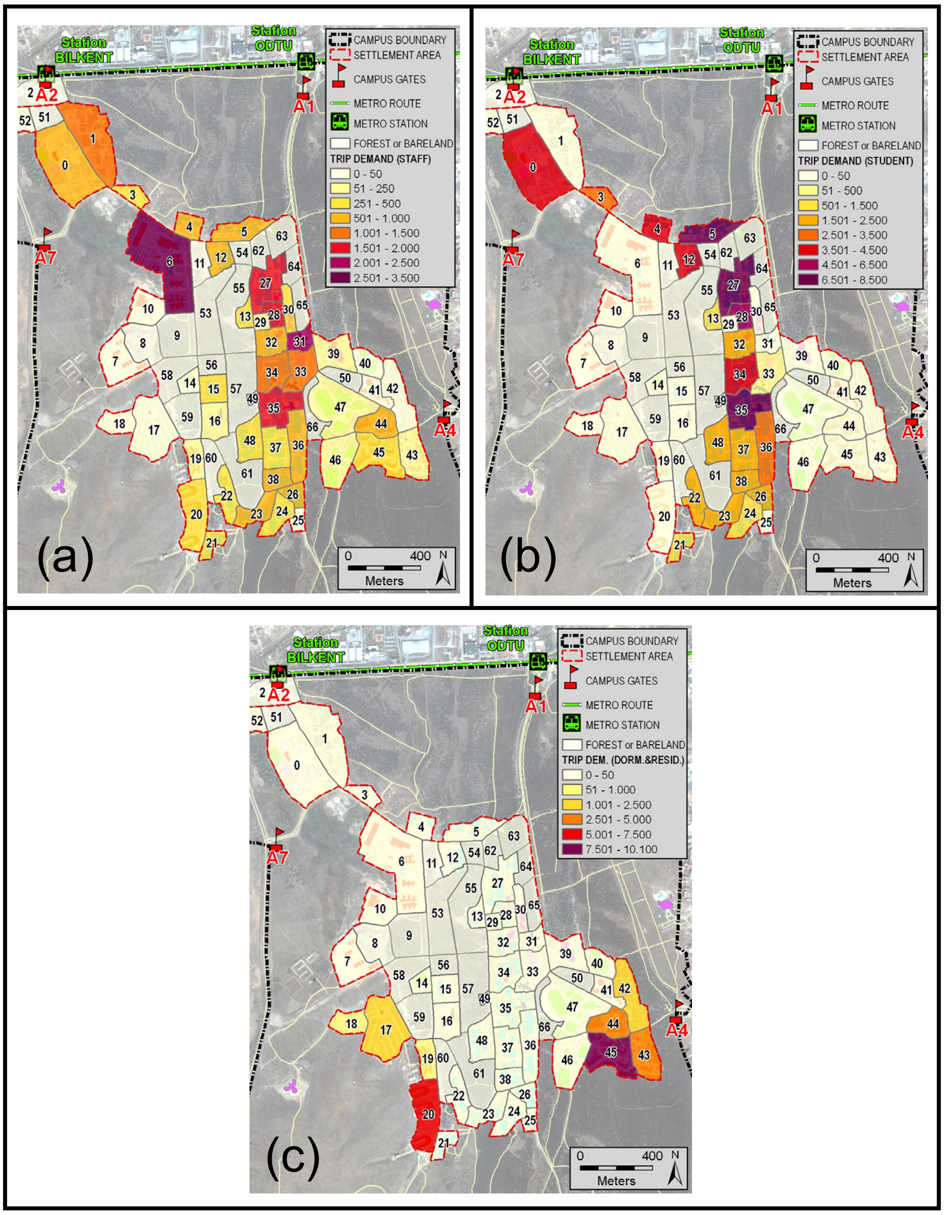


Figure M.1 Distribution of the trips generated by (a) students, (b) staff and (c) dormitories – residences according to the analysis zones

APPENDIX N

ROAD SLOPE ANALYSES FOR THE FEASIBILITY OF DIFFERENT PUBLIC TRANSPORT MODES IN CAMPUS

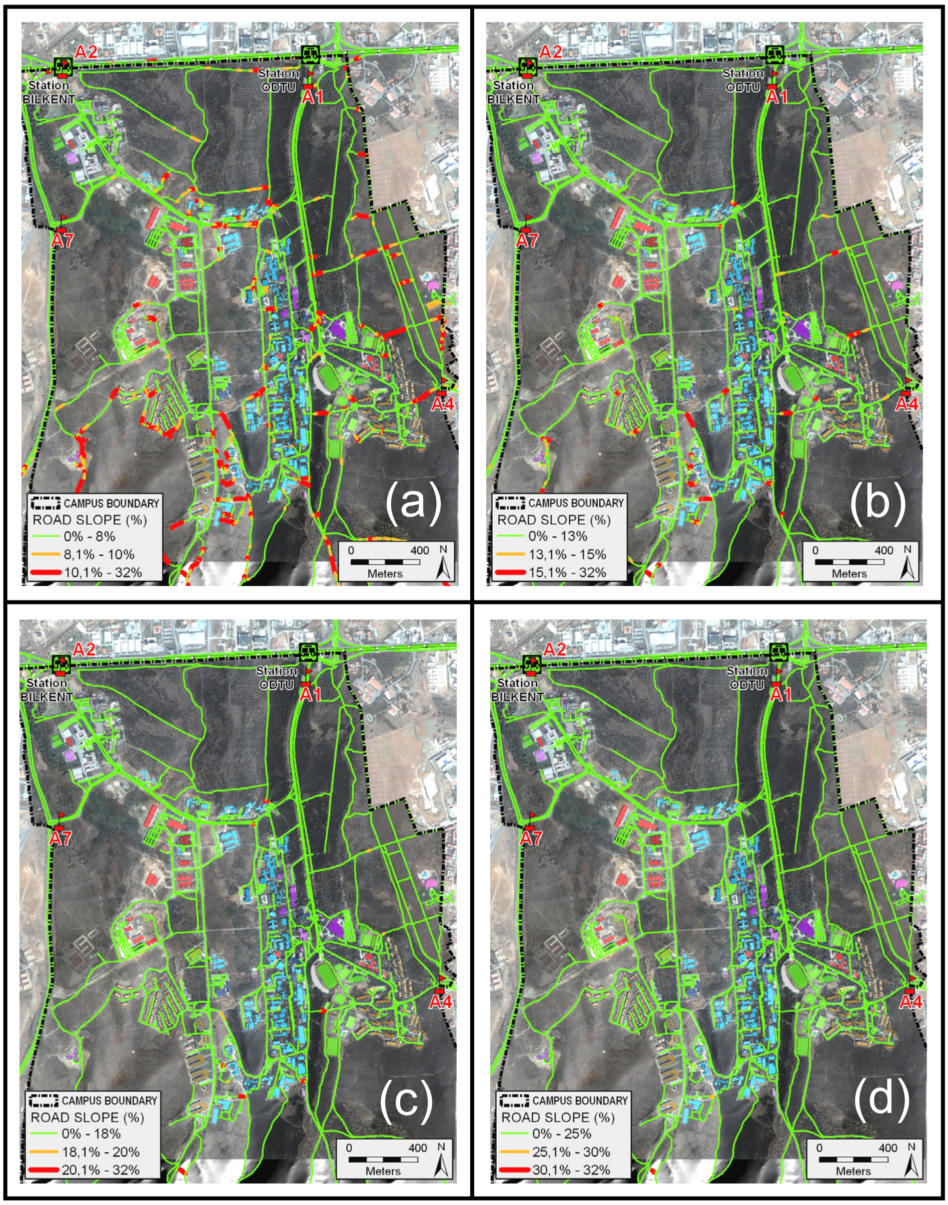


Figure N.1 Road slope analyses for the feasibility of different public transport modes in campus: (a) tramway and light rail transit, (b) guided light transit (GLT), (c) monorail, trolleybus or guided electrified bus and (d) conventional diesel buses

According to Figure N.1; first slope interval shown with green color represents first degree topographical suitability, second slope interval shown with orange color represents second degree suitability that denotes mode’s maximum slope tolerance limit and lastly red colored third interval represents unsuitable roads and paths in campus with steep slopes for that mode.

APPENDIX O

PROPOSED ROUTES AND STOPS – STATIONS FOR DIFFERENT MODES OF PUBLIC TRANSPORT, OVERLAID WITH SIGNIFICANT ZONES AND SLOPE MAP

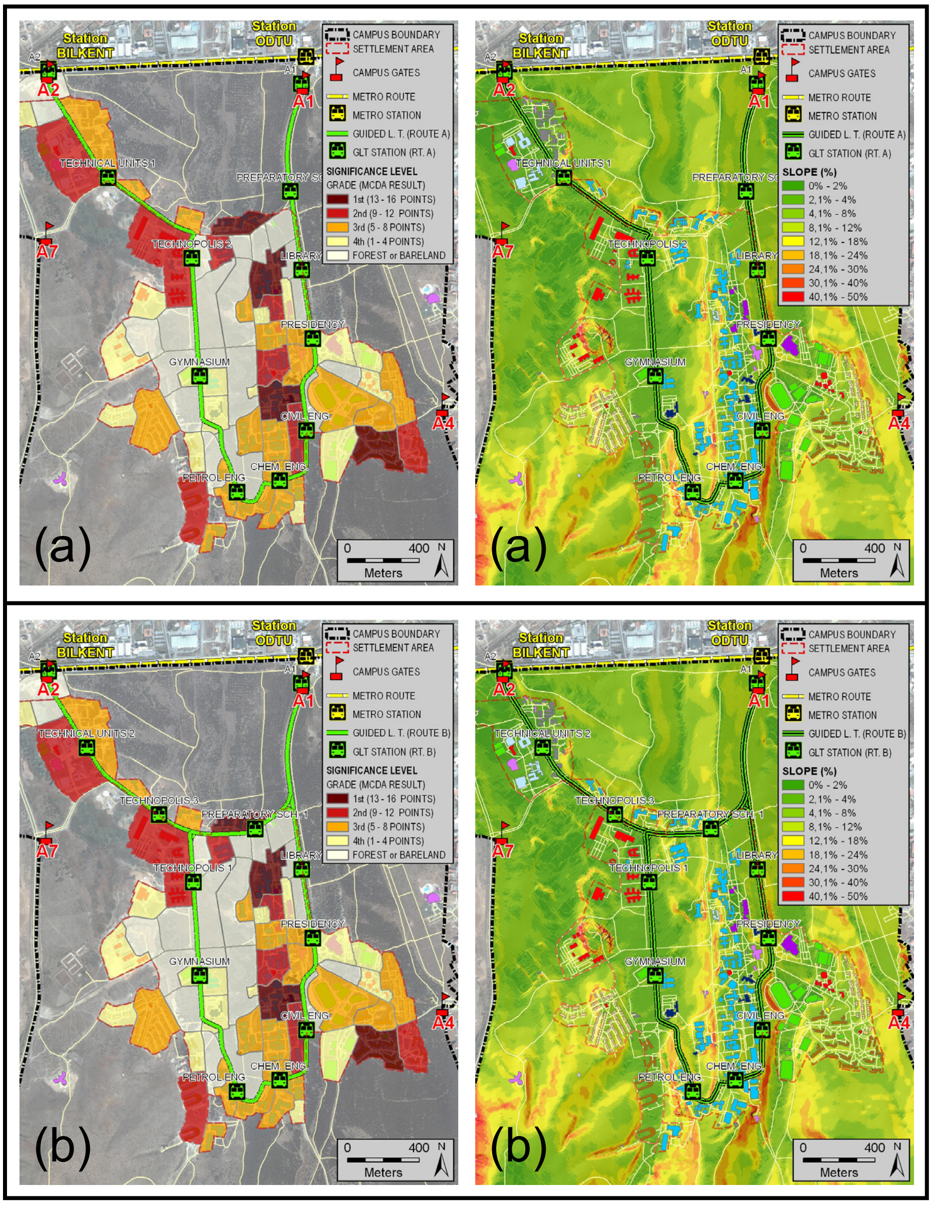


Figure O.1 Proposed route and station alternatives for guided light transit, overlaid with significant zones and slope map: (a) GLT route alternative A and (b) GLT route alternative B

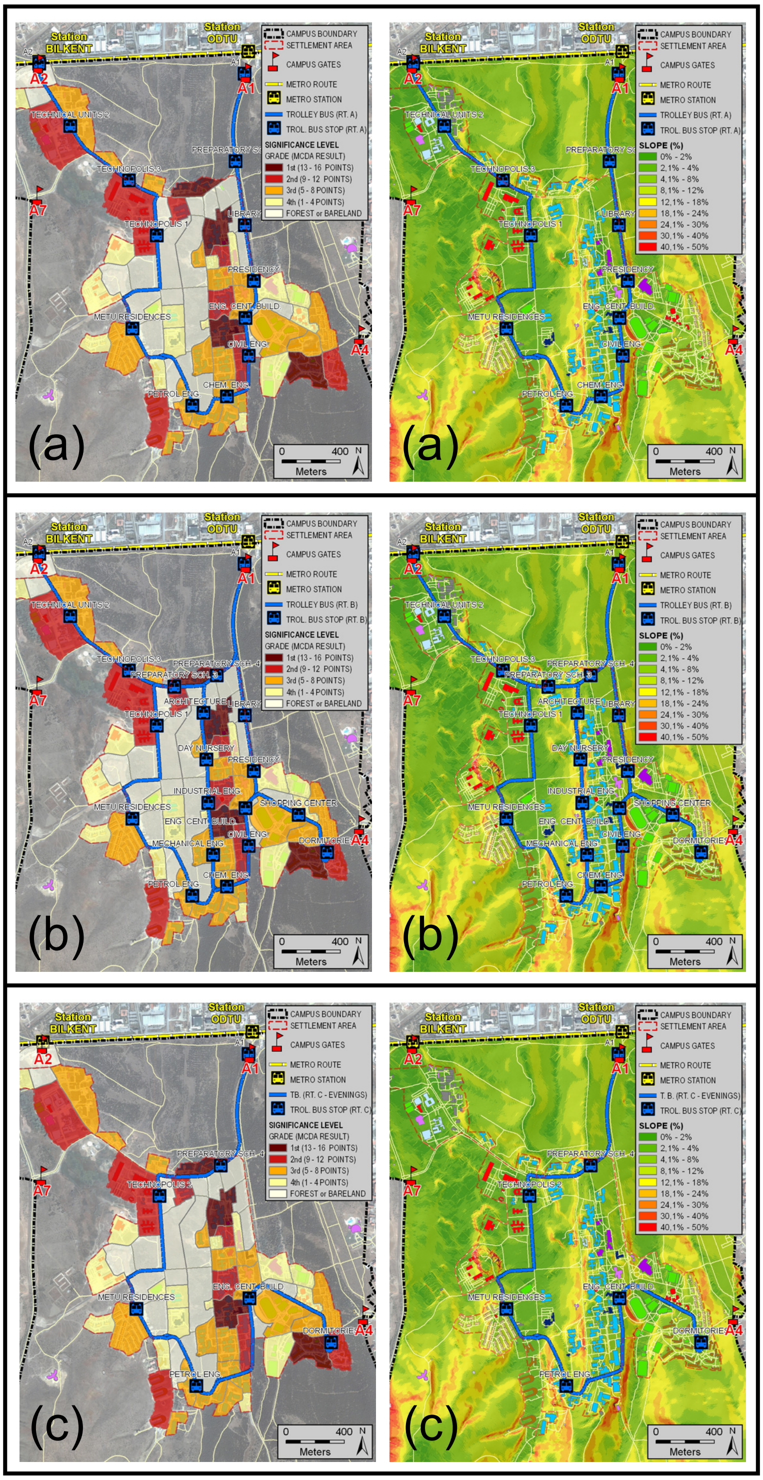


Figure O.2 Proposed route and stop alternatives for trolleybus services, overlaid with significant zones and slope map: (a) Alternative A, (b) Alternative B and (c) Alternative C

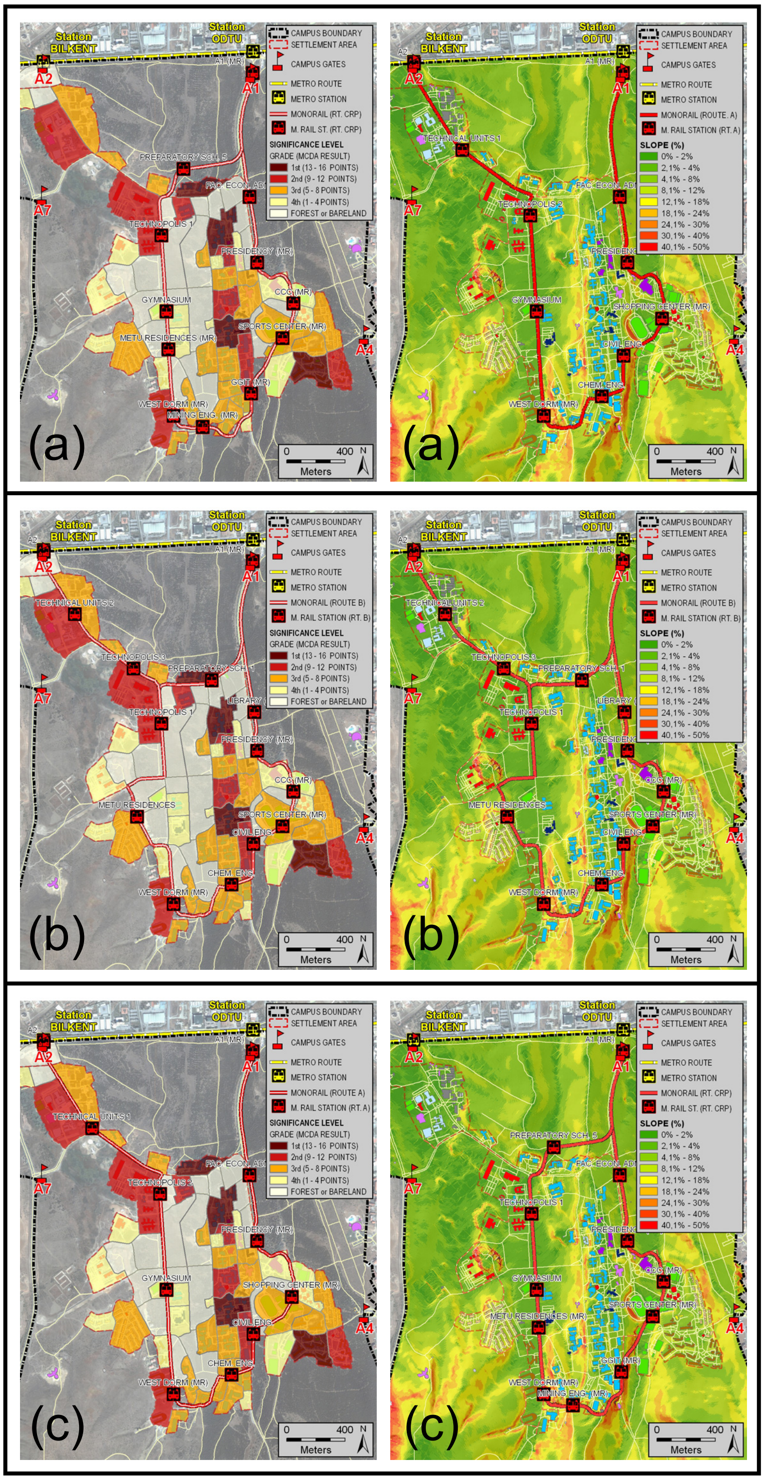


Figure O.3 Proposed route and station alternatives for monorail services, overlaid with significant zones and slope map: (a) Alternative A, (b) Alternative B and (c) Alternative C

APPENDIX P

RESULTS OF SERVICE AREA AND ACCESSIBILITY ANALYSES FOR PROPOSED STOPS/STATIONS

Table P.1 Results of service area and accessibility analyses according to the proposed stops/stations in campus

Stops / Stations		Estimated Service Area and Accessibility Indicators (*)					
ID	Annotation	# of Facilities	Floor Area of Facilities	Total Pop. of Students	Total Pop. of Staff	Total Pop. of Dorms & Resid.	Total Pop. of All Groups
0	A-1 Gate	0	0	0	0	0	0
1	Fac. Econ. & Adm. Sci.	5	20.423	2.380	372	0	2.752
2	Presidency	20	86.049	2.945	1.497	0	4.442
3	Civil Engineering (K-1)	31	107.036	4.481	886	443	5.810
4	Chemical Engineering	25	85.992	3.809	724	0	4.533
5	Petrol. & Nat. Gas Eng.	19	58.540	2.365	459	634	3.458
6	Gymnasium (West)	14	30.783	0	101	177	278
7	Technopolis (TEKMER)	14	53.857	2.356	1.628	0	3.984
8	Technical Units	20	25.392	1.532	455	0	1.987
9	Library	9	36.802	2.912	960	0	3.872
10	Technopolis (Silicon Bl.)	13	39.334	2.667	1.514	0	4.181
11	Technopolis (Halıcı Co.)	11	45.938	1.774	1.123	0	2.897
12	Tech Units & Found. Sch.	41	45.219	2.078	661	0	2.739
13	Preparatory School (A)	12	38.347	5.034	649	0	5.683
14	A-2 Gate	11	10.844	197	147	0	344
15	Prep. School (Junction)	4	9.980	1.976	207	0	2.183
16	Engineering Cent. Build.	30	116.736	4.509	1.479	0	5.988
17	METU Resid. (West)	40	49.084	0	81	686	767
18	Preparatory School (B)	13	46.063	3.934	1.214	0	5.148
19	Preparatory School (C)	10	32.583	4.529	585	0	5.114
20	Fac. of Architecture	14	62.210	6.122	1.078	0	7.200
21	Day Nursery	17	67.069	3.577	1.403	0	4.980
22	Industrial Engineering	24	83.933	4.278	1.008	0	5.286
23	Mechanical Engineering	28	92.437	5.005	837	0	5.842
24	Shopping Center	40	72.482	0	180	1.810	1.990
25	Dormitories (East)	34	73.488	0	210	4.601	4.811
26	A-1 Gate	0	0	0	0	0	0
27	Fac. of Econ. Adm. Sci.	4	13.623	2.092	292	0	2.384

Table P.1 (continued)

Stops / Stations		Estimated Service Area and Accessibility Indicators (*)					
ID	Annotation	# of Facilities	Floor Area of Facilities	Total Pop. of Students	Total Pop. of Staff	Total Pop. of Dorms & Resid.	Total Pop. of All Groups
28	Shopping Center	37	82.597	728	687	1.079	2.494
29	Presidency	15	68.873	2.211	1.440	0	3.651
30	Dormitories (West)	12	56.271	976	246	1.919	3.141
31	Library	7	33.155	2.436	891	0	3.327
32	Cultural & Conv. Center	28	59.551	527	565	388	1.480
33	Sports & Gymnasium	35	98.214	813	510	2.391	3.714
34	Civil Eng. (K-4) & GGIT	21	71.093	3.142	599	0	3.741
35	Mining Engineering	19	58.442	2.164	447	634	3.245
36	METU Resid. (West)	25	55.746	530	202	890	1.622
37	Preparatory School (D)	7	22.539	2.665	560	0	3.225

(*) Column "# of facilities" stands for the total number of facilities and/or buildings that can be reached from that stop/station according to its service area calculated via isochrone approach. Similarly, "floor area of facilities", "total population of students", "total population of staff", "total population of dormitories and residences" and "total population of all groups" columns stand for their respective indicators which can be reached from any stop/station.