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MODELING OF FREIGHT TRANSPORTATION ON TURKISH HIGHWAYS

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ABSTRACT

MODELING OF FREIGHT TRANSPORTATION ON TURKISH HIGHWAYS

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Transportation planners are often faced with the problem of estimating passenger and freight flows between regions. In the literature there are many models for passenger flows. However, models about freight flows are more limited. Modeling freight flow is also more complex than modeling passenger flow and there are many agents related with freight flows. In addition, data availability is a critical factor. In this research, freight flows between provinces in Türkiye are forecasted by demand analysis.

Transportation is one of the important activities of human beings and plays an important role for spatial interactions in economic growth. In other words, there is a very strong linkage between economic growth and the freight flow, thus transportation demand. Regional trade as spatial flow appears on transportation systems as freight flows.

In this study, using the existing limited data and surveys in Türkiye, nationwide origin-destination (O-D) matrix of freight flows between provinces is obtained. Using this empirical matrix, the generation of freight flows of provinces is formulated depending on the socioeconomic and demographic variables by means of multiple linear regression analysis. In addition, interactions of freight flows between provinces and economic growth of regions are investigated.

The generations and attractions of provinces as freight flow are distributed between provinces with traditional gravity model. By comparing observed O-D matrix and simulated O-D matrix, gravity model is calibrated. Calibration is also performed by freight trip length distribution.

In this research, two steps of traditional “four-step analysis”, “trip generation” and “trip distribution”, are applied to develop nationwide freight demand model between the provinces in Türkiye. The developed model is single-mode, single commodity and nationwide.

Keywords: Freight Demand Modeling, Gravity Model, Trip Generation, Trip Distribution, Economic Growth, Spatial Interaction

ÖZ

TÜRKİYE KARAYOLLARI ÜZERİNDE YÜK TAŞIMACILIĞININ MODELLENMESİ

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Ulaşım plancılarının çoğunlukla karşılaştıkları problem yük ve yolcu talebini tahmin etmektir. Literatürde yolcu taşımacılığına ilişkin pek çok model mevcut iken yük taşımacılığına yüke ilişkin modeller daha sınırlıdır. Yük akımını tahmin etmek yolcu akımının tahminine kıyasla daha karmaşık ve ilgili paydaşlar daha fazladır. Buna ilaveten veri mevcudiyeti en kritik hususlardan birisidir. Bu araştırma ile Türkiye için iller arası yük hareketi tahmin edilmeye çalışılmıştır.

Ulaşım insanlığın en önemli aktivitelerinden birisidir ve mekansal ilişkilerde ekonomik gelişme açısından önemli bir rol oynamaktadır. Diğer bir deyişle ekonomik gelişme ve yük akımları ve dolayısı ile ulaştırma arzları arasında kuvvetli bir ilişki mevcuttur. Bölgelerarası ticaretin mekansal anlamda akışı ulaştırma sistemleri üzerinde kendini göstermektedir.

Bu çalışma ile mevcut kısıtlı veriler ve etütler kullanılarak, Türkiye için iller arası yük akımını veren ulusal başlangıç-son matrisi elde edilmiştir. Bu ampirik matris kullanılarak bölgelerin oluşturduğu yük miktarları sosyoekonomik ve demografik değişkenlere bağlı olarak çoklu lineer regresyon analizleri yardımıyla formülüze edilmiştir. Ayrıca iller arası yük akımları ile bölgesel gelişmeler arasındaki etkileşimin analizi yapılmıştır.

Bunlara ilaveten illerin ürettiđi ve çektiđi yük miktarları geleneksel çekim modeli kullanılarak iller arası hareket olarak dağıtılmıştır. Ampirik elde edilen başlangıř-son matrisi ile modelden elde edilen başlangıç-son matrisi kıyaslanarak çekim modelinin kalibrasyonu yapılmıştır. Modelin kalibrasyonu ayrıca seyahat mesafesi dağılımı ile de yapılmıştır.

Bu arařtırmada geleneksel “dört aşamalı ulaşım talep modeli”nin iki aşaması olan “seyahat yaratılması” ve “seyahatin dağıtılması” Türkiye için iller arası ulusal yük talep modellemesi geliřtirmek amaçlı uygulanmıştır. Geliřtirilen model tek modlu, ulusal ve tek yük grubuna bađlı bir modeldir.

Anahtar kelimeler: Yük Talep Modellemesi, Çekim Modeli, Seyahat Yaratılması, Seyahatin Dağıtılması, Ekonomik Büyüme, Mekansal Etkileřim

To my mother and father

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CHAPTER 1

INTRODUCTION

Transportation is a physical system that connects two distant geographical locations. Demand for its services is derived demand which means that its necessity arise from the needs of other sectors. It can not exist alone and its outputs can not be stored. Because of these properties it should be planned very carefully.

The outputs of transportation services are passenger flows and freight flows which can be defined as the movement of population and goods, respectively, on transportation network.

Transportation of passenger and freight has always been an essential and inseparable component of human societies in economic, social, political and cultural activities by playing a major role in time between spaces. Space is a constraint for the movements of passenger and freight which should be overcome and shaped by human and physical and spatial constraints such as distance, time, cost and topography. This constraint is also defined as the friction of movement and commonly known as friction of distance. Therefore, investments on transportation aim to overcome these spatial constraints. The objective of this research is to help planners and policy developers to decide on transportation investments and to plan highway network.

Public organizations need to forecast future transportation needs in terms of passenger and freight flows in order to provide necessary infrastructure and capital to supply efficient and effective movement and to take policy measures at the national level. Transportation planners need forecasted passenger and freight demand for facility planning, corridor planning and strategic planning, as well as for master and development plans. Facility planning is the planning of the appropriate capacity of new facilities that may be built and of existing facilities that are being considered for expansion. Corridor planning is the planning to determine the sufficiency of the existing

facilities and services in the corridor and the potential need for expanding these facilities and services. Strategic planning is the planning to evaluate the overall viability of alternative strategies. Thus freight demand forecasting becomes an essential need to plan existing and future facilities and also to operate and manage the existing system most efficiently.

A typical problem encountered by transportation planners is the estimation of passenger and freight flows between regions. A key aspect of transportation planning is modeling the flow of goods and passengers regarding the simple fact that a movement occurs between origin and destination by assigning to a network. Hence the objective of this research is the modeling and forecasting of freight demand on Türkiye's transportation system between chosen zones which are provinces. Transport Demand Modeling is developed for planning purposes, especially for the planning of transportation infrastructure, and also for operation and management purposes.

There is a strong relationship between regional economy (regional growth) and freight transportation not only from the point of supply side but also from the point of demand. Analysis of transportation from the supply point of view is generally based on the specification of cost structure of transportation service provider without a well structured and functioning transportation system.

Data availability is a critical consideration in any kind of modeling research. However, studies on demand modeling are data starving and are developed empirically. Commodity Flow Data are not available in Türkiye, therefore freight transportation planning studies are faced with data restrictions. However, there are limited truck trip data collected by General Directorate of Highways (KGM) by roadside surveys. In Lau (1995), roadside truck surveys give the best results. Also it is easy to get all the desired information. All data collected after 1988 by KGM are in electronic format. Under the context of this study, this limited data is used to develop a freight demand model between provinces in Türkiye. These data are very suitable to develop a nationwide Origin-Destination (O-D) matrix of intercity freight flow and enable to reveal the national freight flow characteristics.

In the literature, most of the previous research on transportation demand models has been concentrated on passenger demand models. There are many models developed for passenger movement especially in urban areas, however freight demand modeling is limited compared to passenger demand modeling. It is more complex to model freight demand than passenger demand since there are many actors and factors, involved either directly or indirectly, in freight transportation. Some of these actors, including but not limited to, are the government, shippers, carriers, producers and consumers. The factors are value of the commodity, volume of the commodity, shippers' behavior, network conditions, the traveling distance, performance of alternative modes and routes. The model developed in this research is not on personnel behavior which is disaggregated but based on zone to zone behavior which is aggregated. These behaviors are revealed, but they are not stated.

Studies on freight demand modeling have increased especially after The Second World War since highways started to be competitive with other modes. In many developed and developing countries highways are becoming the predominant transportation system. Even for the countries, like the United States of America, France, Canada, and Germany which have achieved industrial development earlier while structuring railway systems, highways are becoming the dominating transportation system. In the USA, 69.4 percent of total tonnage and 71.7 percent of total value shipped were carried by trucks according to 1997 U.S. Bureau of the Census Commodity Flow Survey (1999) (Fisher and Myong, 2001). In Türkiye, according to 2004 freight mobility values, 156,853,000,000 tonxkm were moved on highways which is 93% of total freight mobility (KGM, 2005). Therefore the model intended to be developed in this research regards one mode, which is highways, and it considers the highway system of Türkiye.

In addition, the reason why freight demand modeling is preferred in this thesis is the importance of freight movement in transportation planning, policy measures and regional social and economic development, regarding the fact that reduced mobility prevents development while increased mobility is a catalyst for development. Present-day trends have underlined that economic development has become more dependent on relations across space.

Under the context of this study, regional development, freight movement, origin and attraction capacities of regions are also analyzed. This research is an empirical study for Turkish highway system focusing on “trip generation” and “trip distribution” stages of the traditional “four-step model” using roadside surveys. The developed freight demand model is nationwide and base year is 2004. Although another approach to obtain nationwide trip distribution is to use input-output tables, the existing input-output tables in Türkiye are national and do not explain regional economic relations. In addition the flows are defined in monetary terms, which need to be converted. Therefore, this approach is not used in this research.

The first step in this study is to check whether it is possible to use axle load surveys performed by KGM as origin-destination surveys to obtain the base O-D matrix. The availability, utility and reliability of these surveys are all checked. The most important limitation of this research is the quantity of roadside surveys in representing each link of the Turkish Highway System. In order to develop the model, most of the time has been spent on surveys to obtain the base year matrix.

Second step is to define simplified network regarding 93% of freight flow occurred on highways in Türkiye. Therefore highway system is chosen as the transportation network. Within road network only state roads and motorways are regarded since they are the arterial network of the highway system that connects provinces. Provincial roads connecting provinces with its neighboring towns, which carry only 6% of freight traffic, are not considered (KGM, 2005).

Third step is to delineate zonal structure. 81 provinces which are administrative regions are chosen as traffic analysis zones and O-D matrix is obtained as freight flows between these 81 provinces, 23 border gates and 7 ports. These freight flows between provinces also give trading between provinces. Provinces are the smallest administrative units for which all socioeconomic variables are found in Türkiye however many variables are not available at province level for all years. Thus the needed variables are forecasted for the chosen base year.

At the fourth step, sample O-D matrices (observed) are obtained both as number of truck trips and as tonnage of goods. These O-D matrices are enlarged by considering 2004 freight movement figures to obtain the empirical base O-D matrix.

At the fifth step, rows and columns of enlarged matrix are summed. The summations of rows represent freight generation (production) of provinces and the summations of columns represent freight attraction (consumptions) of provinces.

At the sixth step, to model freight flow, some variables are selected as origin and destination variables. These variables are population, density, employment, vehicle ownership, truck ownership, Gross Domestic Product, GDP per capita and similar ones. The flow is regarded as a function of chosen origin and destination variables. Stepwise regression analysis is followed. By doing so, effects of the variables on trip generation and trip attractions are obtained, assuming trips are not chained and spatial freight flows are closed system which means whatever produced is consumed. Consequently, multiple linear regression analyses are performed to find the trip generation (trip production and trip attraction) equations explained with most descriptive socioeconomic variables.

At the seventh step, gravity model as trip distribution model is applied. It is calibrated for nationwide freight flow distribution between provinces in Türkiye. In this step, one of the conventional travel demand modeling package TRANPLAN is applied to distribute freight trip productions and attractions of TAZs between provinces in order to calibrate observed O-D matrices in truck trips. In addition exponential deterrence function is applied and parameters of the explanatory variables are estimated. By this way gravity model is calibrated comparing both observed and simulated matrices and also comparing observed and simulated trip length frequency distributions. Results on average trip length are also used to calibrate the gravity model. Gravity model as spatial interaction model explains the freight trip between provinces in Türkiye.

Freight flows between provinces that are obtained from the empirical O-D matrix are analyzed in this research by showing spatial interaction and checking how and why trade between provinces occurs. By this way related factors for spatial interaction between provinces are analyzed. However, not only spatial interaction but also the relation between regional development and freight flow are analyzed and shown in this research.

In addition usefulness of axle load surveys performed by KGM as roadside surveys to obtain O-D matrix is also checked and demonstrated.

As a summary, in this research freight demand between provinces in Türkiye is developed in two dimensions both as number of truck trips and tonnage of goods and the relation between freight flow and socioeconomic development of provinces is explained. The developed model is uni-model, uni-commodity and nationwide.

CHAPTER 2

BACKGROUND

This chapter reviews the studies in the field of freight transportation such as freight demand models, data requirements for modeling and practical studies. First, information about modeling, types of modeling, why modeling is needed and the importance of modeling are provided. Later, evolution of freight models, basic steps of modeling and the four-step model are given. Then spatial interaction models which are common demand models, Linear Programming Model, Gravity Model and Input-Output Model are reviewed. After a brief discussion on freight models, data requirements, data availability for modeling and data collection process, finally, similar practical studies from the literature are reviewed.

2.1 The Scope of Modeling

A model can be defined as a simplified representation of a part of the real world of any system to explore the consequences of particular policies or strategies (Bonsall, 1997; Ortuzar and Willumsen, 2001; Boile et al., 2004). The system of interest in this research is transportation, specifically the freight movement on road network. The aim of freight transport models is to forecast freight travel demand (Maurer, 2007).

According to Kim (1998) a model may be classified as a physical model or a mathematical model. All models, however, provides one common characteristics which is the transformation of a part of real world into a model (Black, 1981).

“This transformation is usually performed on a basis of the following process (Kim, 1998, 74):

- Perception of the real world,
- Interpretation of the real world,
- Generalization of specific conditions or environment,
- Simplification of the system,
- Abstraction of the given objectives, and
- Translation of the system into a type of model”.

The state of art in modeling for particular type of interventions can be subdivided into behavioral richness, mathematical and computer tractability, and availability of good solution algorithms (Ortuzar and Willumsen, 2001, 13). Models in the literature range from simple equations based on empirical data to more complex theory based equations (Bonsall, 1997, 110). These models are, but not limited to, growth models, time series models, averaging and smoothing, regression analysis, matrix estimation models, elasticity models, demand allocation and simulation models (Bonsall, 1997, 110-128).

Shvetsov (2003) reviewed the models in three basic groups: prediction models, simulation models and optimization models. Prediction models employ the results of changes in transportation network; simulation models aim to give answers to questions such as “how many” and “where to”; and optimization models optimize the routes of passenger and freight traffic establishing the optimal network.

Models are classified also as “supply models”, “demand models” and “assignment models” by Cascetta (2001). **Supply Models** simulate the performance of transportation infrastructures and services among different zones with flow network models for the users. **Demand Models**, however, simulate the relevant aspects of travel demand as a function of the performance of the activity system and supply. The travel demand model predicts the travel needs between origin and destination pairs, mainly regarding spatial activities and transportation modes (Xie and Levinson, 2007). The characteristics of travel demand include the number of trips in the reference period and their distribution among different zones, different transport modes and different paths (Cascetta 2001). **Assignment Models**, on the other hand, simulate how Origin-Destination demand and path flow loaded to various elements of the supply system (Cascetta, 2001).

Fundamental understanding of Freight Transportation is generally considered necessary by policy makers, planners and regulators as well as carriers and shippers (Terziev, Ben-Akiva and Roberts, 1975). “Planners need better planning models” in order to cope with problems related with increasing traffic as a result of increasing passenger and freight movement and to solve these problems via efficient and effective ways (Mao and Demetsky, 2002). Demand models are the major components of transportation planning and should be performed at three levels: strategic (long term), tactical (medium term) and operational (short term) (Crainic and Laporte, 1997; Regan and Garrido, 2002).

Transportation Demand Models have been used for many purposes such as planning, policy development, management and staffing (Wigan et al., 2005). Principal components of TDM are Passenger Demand Modeling (PDM) and Freight Demand Modeling (FDM). Transportation Demand Modeling (TDM) is an essential tool which is used to do better transportation planning for passenger and freight movement, to identify spatial spreading of freight and passenger flows, to make more reliable traffic forecast to test alternative transportation policies and traffic management studies, to provide transportation needs (such as infrastructure needs) for increasing the existing capacity, to reduce negative effects of freight and passenger activity on environment and to evaluate productivity and efficiency of transportation systems, and also to efficiently use all kinds of energy resources (Vanek, 2001; Russo and Comi, 2002; Wigan et al., 2005; Zorlu, 2006).

Transportation Demand Modeling is built by using a process based on a set of mathematical equations which helps to predict the effects of changes in the system with reliable data (Paquette, Ashford and Wright, 1972; Ortuzar and Willumsen, 1994; Kim, 1998; Chang and Meyers, 1999; Cascetta, 2001; Ferdman, Shefer and Bekhor, 2008). “The theory of transport demand is derived largely from the economic theory of consumer choice” (Morlok, 1978, 413).

“A **Transportation Demand Model** can be defined as a mathematical relationship associating the average values of demand flows with their relevant characteristics to given activity and transportation supply systems. In formal terms, it can be expressed as follows:

$$d_{od} [K_1, K_2, \dots] = d(\mathbf{SE}, \mathbf{T}; \boldsymbol{\beta})$$

where the average travel demand flow between zones o and d with characteristics $K_1, K_2, \dots$, is expressed as a function of a vector, $\mathbf{SE}$, of socioeconomic variables related to the activity system and/or to the decision makers and of a vector $\mathbf{T}$ of level-of-service attributes of the transportation supply system. Demand functions also depend on a vector $\boldsymbol{\beta}$ of the coefficients or parameters” (Cascetta, 2001, 175).

“Early travel forecasting models, originally developed in the mid 1950’s and taking a standard form by the late 1960’s” (Ben-Akiva et al., 2007, 116) Freight demand modeling, however, has been a major interest for researchers and planners since 1960’s (Baumol and Vinod, 1970; Allen, 1977). In addition there has been a growing interest of

freight movement in transportation planning because of its role in regional economic growth and development (Pendyala et al., 2002; Mao and Demetsky, 2002).

“Freight Transportation Demand (FDM) is closely connected to the production and distribution of goods, i.e. to economic system under study and to its interactions with external economic system” (Cascetta, 2001, 230).

Majority of demand modeling studies are on urban transportation for passenger movement (Cambridge Systematics, Inc. et al., 1998). Unlike passenger transportation, freight transportation models have been developed mostly on interregional flows compared to urban context (Regan and Garrido, 2002). In addition, freight modeling studies are limited due to data availability (Çelik, 2004). According to Meyer and Straszheim (1971, 165) “freight demand models are relatively crude, single-equation and fit to empirical data.”

Modeling methods are diverse and include statistical, econometric, mathematical and synthetic procedures (Zorlu, 2006). Literature survey shows that early demand modelers were transportation planners, engineers, economists, operational researchers and geographers (Çelik, 2004; Fisher, 2006). In general, researchers build models on the subject related to their professional background. Economists concentrate on econometric models and consider cost parameters and cost minimization; planners concentrate on spatial models and consider geography and land use patterns with time parameters and spatial interactions; operational researchers concentrate on statistical models and regression analysis. However, modeling should not be completely generalized or limited according to researchers’ disciplines since many researchers accept that transportation modeling studies are multidisciplinary studies (Sen and Smith, 1995; Curlee, 2005; Henser and Button, 2008).

Some of the factors affecting freight transportation demand are changes in demography, economy, energy availability and prices, industrial location patterns, packaging materials, trade and trade agreements, land use, globalization of business, logistic sources and practices, publicly-provided infrastructures, user charges and other taxes and the role of country in the global economy (Cambridge Systematics, Inc. et al., 1995; University of Wisconsin-Milwaukee et al., 2006). Such changes influence type of freight movement, its volume, origin-destination patterns and required transport systems.

2.2 Evolution of Freight Models

Travel demand modeling and developments in this area have long been a subject for researchers (Ben-Akiva et al., 2007). During 1920s and 1930s, initial studies about analyzing existing travel demand were performed to determine the capacity of highways to carry traffic (Weiner, 1997). In 1950s, however, great contributions in this field were employed considering the relationship between socio-spatial structures of cities and travel demand (Mitchell and Rapkin, 1954). 1950s were the years when the basic of transport modeling were developed in USA by Detroit and Chicago Studies (Bates, 2008). Travel forecasting and demand analysis, in a formal process and in a scientific manner, has begun in 1950s (Barners and Davis, 1999; Zorlu, 2006). The invention of more advanced demand modeling of transportation however has begun since the year 1970 (Barners and Davis, 1999; Ortuzar and Willumsen, 2001; Boile et al., 2004). 1980s were the years during which freight models focused on network modeling and during 1990s models were extended using multi-commodity context (Tavasszy, 2006). Demand models have been developed from static to dynamic, from aggregate to disaggregate, from analytical to simulation based, from trip-based to tour-based (or activity-based), and from deterministic to stochastic (Ben-Akiva et al., 2007).

Major improvements in freight modeling techniques were realized between 1970s and 1980s (Ortuzar and Willumsen, 1994; USDOT-FHWA, 1999). Until 1980s, the majority of transport planning studies depended on information about trip patterns revealed by a cross-section of individuals at a single point in time (cross-sectional) (Ortuzar and Willumsen, 1994).

Many researchers agree on that freight modeling is still less advanced than passenger modeling and lags behind it in spite of recent efforts (USDOT-FHWA, 1999; Ortuzar and Willumsen, 2001; Regan and Garrido, 2002; Pendyala et al., 2002; Tavasszy, 2006). One of the reasons for this is there are numerous agents involved in freight transportation and therefore freight modeling is more complex and needs more data than passenger modeling (USDOT-FHWA, 1999; Ortuzar and Willumsen, 2001; Victoria and Walton, 2004). The mentioned agents are producers (economic agents whose role in the system is production of goods), consumers (agents whose role is consumption of goods), shippers (agents whose role is purchasing transportation services from the carriers by organizing

the consignment), carriers (agents whose role is undertaking the movement and running transshipment, storage and custom facilities) and government bodies (defined as the set of national, provincial and local agencies involved in any way with freight transportation) (Harker, 1987; Ortuzar and Willumsen, 1994; Çelik, 2004; Victoria and Walton, 2004; Horowitz and Farmer, 2009). Different behaviors of involved agents increase the computational complexity of freight modeling (Friesz, Tobin and Harker, 1983; Stammer et al., 2002). Until mid 1980s, transportation demand modeling was based on information about observed choices, decisions and revealed preferences (empirical); however after mid 1980s preferences have been stated (hypothetical) (Ortuzar and Willumsen, 1994). Freight demand models are classified according to type of approach as behavioral or descriptive (Cascetta, 2001; Marzano and Papola, 2004).

“Different freight demand models can result depending on how one characterizes the decision making process. In addition, the variety of uses of freight demand models have contributed to the diversity of model development. For example, while one model may be useful for forecasting the demand for a new freight mode, it may have serious deficiencies when it comes to simulating different equilibria that could potentially result from changes in the economic development” (Winston, 1983, 419)

Models are based on the assumptions that some observable pattern (actual behavior) in the past or current behavior of systems or individuals can be used to predict future development or to predict unobserved behavior (Bonsall, 1997; Chang and Meyers, 1999). They can be grouped as qualitative and quantitative as given in Table 2.1.

After many years of neglect, freight models have been recently attracting substantial attention and there is wide perception among transportation analysts in order to overhaul the range of applications and issues with different forms (Wigan et al., 2005). Freight modeling techniques in the literature are in wide range and include: linear and non-linear regression model estimations of traffic volumes; spatial interaction (gravity, logit, entropy), neural network, Box-Cox models zone to zone freight movements; commodity-based, inter-regional input-output models; micro-simulation and agent-based models of individual freight vehicle movements; engineering cost-based, statistical based, statistical-engineering cost based, and hedonic freight pricing models network-based spatial price equilibrium models, etc. (Wigan et al., 2005).

Table 2.1 Types of Demand Models

QUANTITATIVE METHODS	QUALITATIVE METHODS
Statistical Methods <i>Time Series Analysis</i> Simple Regression Correlation Analysis Growth Models, etc. <i>Growth Factors Based on Historical Traffic Trends</i> <i>Growth Factors Based on Economic Projections</i>	Expert Opinion
Causal Methods <i>Input-Output Model</i> <i>Gravity Model</i> <i>Linear Programming Model, etc.</i>	

Source: (Adapted from USDOT-FHWA, 1999; Cambridge Systematics, Inc., Comsis Corporation, and University of Wisconsin-Milwaukee, 1996).

Freight demand modeling is classified as aggregate (more than one individual) or disaggregate (individual) according to data following Winston (Harker, 1987; Ortuzar and Willumsen, 1994; USDOT-FHWA 1999). Winston (1983) and later Zlatoper and Austrian (1989) classified freight models according to the nature of the data used for estimation purposes as aggregate where the basic unit of observation is an aggregate share of a particular freight mode at the regional or national level and disaggregate where the basic unit of observation is an individual decision maker's distinct choice of a particular freight mode for a given shipment.

“From aggregate to disaggregate representation of travel: models are focused on representing individual travelers and vehicles to capture heterogeneity of their decisions and movements” (Ben-Akiva et al., 2007).

Both aggregate and disaggregate models should eventually be derivable from individual firm behavior (Winston, 1983). However aggregate models use data which describe behaviors of large groups (Clark et al., 2005; Henser and Puckett, 2005).

“In general, the aggregate models have tended to be either ad-hoc or based on cost minimizing behavior by firms while the disaggregate models have attempted to be more finely-adjusted to the behavioral realities of freight transportation

decision making. While it could be argued that the disaggregate models are therefore more attractive than the aggregate models from a theoretical point of view, there are some practical drawbacks to these models, such as extensive data requirements, that suggest that aggregate models can be more useful than disaggregate models in particular contexts” (Winston, 1983, 419-420)

Winston (1983) observes that models based on aggregate data might be better for regional freight flows and recognizes the difficulties in collecting the huge amount of data required to calibrate disaggregate models. Therefore, conventional demand models based on aggregate characteristics of zones to predict the steady state level of demand in the presence of steady state network conditions are widely used (Harker, 1987; Ben-Akiva et al., 2007).

According to Ortuzar and Willumsen (1994) aggregate models as given in Table 2.2 are first generation models which represent behavior of entire population of interest and are criticized for their inflexibility, inaccuracy and cost; however disaggregate models are second generation models which have become popular after 1980s and they focus on behavioral aspects of decision maker. Many freight models in the literature are aggregate (Ortuzar and Willumsen, 1994). “Disaggregate behavioral models are very uncommon in freight transport” (de Jong et al., 2002).

In the following table a brief summary about freight models before and after 1980s is given (Ortuzar and Willumsen, 1994).

Table 2.2 Summary of Freight Model Developments Around 1980’s

FREIGHT MODELS		
<i>Before</i>		<i>After</i>
Aggregate First Generation Models Behavior of Entire Population Cross-section (Single point in time) Revealed Preferences Empirical (observed)	1980	Disaggregate Second Generation Models Individual Behavior Time-series Stated Preferences Hypothetical

Source: (Adapted from Ortuzar and Willumsen, 1994).

Harker and Friesz (1986) and Souleyrette, Hans and Pathak (1996) divide the prediction of intercity and interregional freight flow into two classes of models as spatial price equilibrium models and freight network equilibrium models.

“These models determine the flow between production and consumption regions by using demand and supply functions and, in addition, estimate commodity selling and buying prices” (Souleyrette, Hans and Pathak, 1996, 4).

Harker and Friesz (1986) conceptualize the agents (producers, consumers, shippers, carriers and government) and interactions between them using these two models. The “spatial price equilibrium model” includes the generation of trips, but fails to model the shipper-carrier interaction due to simple representation of transportation network (Harker and Friesz, 1986; Souleyrette, Hans and Pathak, 1996). They primarily use econometric methods to estimate supply and demand functions of the produced (generated) and consumed (attracted) commodities (Souleyrette, Hans and Pathak, 1996). On the other hand, the freight network equilibrium models attempt to model this interaction explicitly, but do not include trip generation (Harker and Friesz, 1986). Harker and Friesz (1986) stated that spatial price equilibrium models focus on the producer-consumer-shipper interactions. Transportation costs are not obtained from the model of carrier behavior but are stated as fixed values or as functions of the flows on the network. The freight network equilibrium model, however, focuses mainly on actions of shippers, carriers, potential carriers and interactions between them (Harker and Friesz, 1986; Harker, 1987). In this model the generation of trips from each region is assumed to be known, however spatial price equilibrium model finds the generation of trips by applying supply demand functions (Harker and Friesz, 1986). From these statements Harker and Friesz concluded that spatial price equilibrium model includes the generation of trips but fails to model shipper-carrier interaction, however, the freight network equilibrium model attempts to model shipper-carrier interaction without including trip generation (1986).

Early freight network models were developed in the late 1960s (Souleyrette, Hans and Pathak, 1996). Network models describe the transportation system as a set of nodes and arcs which represent the system infrastructure (Harker, 1987). Network models are developed considering shippers’ behavior therefore they are behavioral models. Shippers prefer to choose routes regarding cost, distance, time and energy use. Friesz, Tobin and

Harker (1983) cited some freight network models. One of them is Harvard-Brookings Model which is considered as the first freight network model (Friesz, Tobin and Harker, 1983; Souleyrette, Hans and Pathak, 1996). This model was developed for Colombia, a developing country, by Roberts in 1966 and modified by Roberts and Kresge in 1971 (Friesz, Tobin and Harker, 1983; Souleyrette, Hans and Pathak, 1996). In that model transport routes are defined as links and cities or regions are described as nodes (Friesz, Tobin and Harker, 1983). It is a multi-commodity and a multi-modal model including highway, rail, air and water modes. This model suggests using gravity model to distribute freight flows of highly aggregated heterogeneous commodity groups to obtain the flows between origin and destination (Friesz, Tobin and Harker, 1983). In this model shippers choose the shortest path that is also the cheapest route within the multi-modal network. Once the trip distribution process is completed, flows are assigned to the inter-modal network by using the shortest path (Friesz, Tobin and Harker, 1983).

Jones and Sharp (1980) published research on demand modeling for undeveloped rural regions of the USA in 1977. According to them planning problem of undeveloped rural regions is very different since the present traffic levels are low due to limited economic activity in these regions. Their model did not explicitly have any predictive function, and they did recognize that in underdeveloped regions the patterns of economic development could not be predicted by past trends because past trends lead nowhere.

Freight models are also classified at different levels concerning the geographical dimension (spatial considerations) as global (international), intercity and urban (Regan and Garrido, 2002; Marzano and Papola, 2004). Commodity flows may be either international or national (inter-city) or local (urban). Therefore freight models have been based on this spatial leveling. Different types of models are also suitable for different spatial levels. International flows occur as a result of international trade between different countries. This flow has been increasing due to operation of multinational firms (Regan and Garrido, 2002). Input-output analysis, gravity model and industrial organization model are also applied as the international freight models (Regan and Garrido, 2002). Input-output analysis and gravity model are used for intercity and urban freight models as well (Regan and Garrido, 2002). Intercity freight models are the most widely mentioned models in the literature as aggregate or disaggregate models (Winston,

1983; Regan and Garrido, 2002). The purpose of intercity freight model is to model freight traffic between spatially distant locations (USDOT-FHWA, 1999).

“The history of interregional input-output analysis, which is closely related to some models of freight transportation, dates back to the 1930s but serious attempts to forecast freight movements at a national or regional level were generally begun only after the first intercity passenger models were developed in the middle 1960s” (USDOT-FHWA, 1999).

According to de Jong et al. freight models at the national and international levels are much better developed than at the urban and regional level.

Smith (1974) categorizes freight transportation models based on their structure as given below:

- 1- Market Share or Trade Models
- 2- Input-Output Models
- 3- Inventory Theoretic Models
- 4- Gravity Models
- 5- Abstract Mode Models
- 6- Linear Programming Models

Smith (1974) cites that K. Mera found gravity model gave better predictions of international flows for more aggregated commodity flows, and the linear programming models gave superior results for homogeneous (disaggregated) commodity flows. It is concluded that either gravity or an abstract-mode model might be the best where available data is poor or commodity groups are quite aggregated.

Morton is the pioneer researcher who used statistical techniques to model intercity freight demand. He conducted one of the earliest studies about intercity freight demand in 1969 (USDOT-FHWA, 1999) where he applied linear regression analysis using the time series data for the years 1947 and 1969, for different commodity groups to develop equations for national rail freight volume and truck freight volume based on Gross National Product, rail shipping rates and truck flowing rates (Morton, 1969). Morton mentions that the models with two or three variables give better equations than the single variable and in order to make successful statistical forecasts even for a short period, at least 20 years time-series data are needed. According to Morton, regression analysis is

applied to obtain estimates of the income elasticity of demand, price elasticity of demand and the cross-price elasticity of demand for each transportation mode.

The simplest and widely used method to forecast future traffic is Simple Growth Factor Method (Cambridge Systematics, Inc., Comsis Corporation and University of Wisconsin-Milwaukee, 1996). This method is classified as follows: 1- based on historical traffic trends, 2- based on forecasts of economic activity. These methods assume that the growth rate is constant over time. These type of analyses are most commonly used to forecast demand on rural highway network. It is generally preferred because of its limited data requirement (USDOT-FHWA, 1999).

Most of the demand modeling and freight model studies are from North America. In USA many states have prepared their own statewide freight modeling. Two types of modeling techniques are used: 1- calculating growth factors by commodity to be applied to existing traffic patterns, 2- using forecasts of future freight flows by commodity distributed via a gravity model (USDOT-FHWA, 1999). Latest statewide freight models are the Wisconsin Freight Model and the Indiana Freight Model (USDOT-FHWA, 1999).

A traditional but still widely adopted model by practitioners is the four-step model (Chang and Meyers, 1999; Shvetsov, 2003; Yang and Chen, 2008). It is presented as the sequence of four sub-models: trip generation, trip distribution, modal split and traffic assignment which had been widely used for urban transportation modeling and preferred by planners to put into practice. In recent decades this model has also been used to model freight transportation with some modifications to freight (Ortuzar and Willumsen, 1994; Cambridge Systematics, Inc., et al., 1998). In the following sections first basic steps of freight modeling are given then four-step modeling is discussed in detail.

2.2.1 Basic Steps of Modeling

In order to build a freight transportation model the following steps are followed. These steps are given in USDOT-FHWA Guidebook on Statewide Travel Forecasting (1999) as basic steps for transportation modeling and adapted in this study. The following steps

are detailed itemized processes of the stages of the four-step model which is widely mentioned in literature.

First, Freight Data Issues. The first step for any kind of modeling is related with data since all models are inherently data demanding and are developed empirically (USDOT-FHWA, 1999; Ortuzar and Willumsen, 2001). Early models are empirical, preceding models are but hypothetical (Ortuzar and Willumsen, 1994). Still all models need data to be developed and/or to be calibrated and/or to be checked in terms of validity. However, there are other issues related with data as described in more detail in the following titles.

Collect Available Data

Review and Summarize Data

If Needed, Realize Needed Surveys to Obtain Additional Data.

Evaluate Reliability and Usefulness of Data

{ MODELING }

Calibrate the Model Using the Related Data

Check the Validity of the Model

Second, Develop Freight Modal Network. A network describes the transportation system as a set of nodes and links representing the system of infrastructures (Harker, 1987). Regions or cities are explained as nodes and the routes connecting these nodes are called as links. There are flows on these links going to or back from the nodes and they are called traffic flows (USDOT-FHWA, 1999). These flows may be centrifugal to the region or centripetal to out of the region. Since the network is transportation network, all alternative networks for each mode (road, rail, air, sea) should be developed.

Third, Define Traffic Analysis Zone (TAZ) Level. As a third step, level of spatial units which is called as TAZ is defined. These spatial units may be region, province, city or smaller as town. TAZ may also consist of group of provinces. All socioeconomic variables should be available at TAZ level and zoning level should be determined regarding this issue.

Fourth, Define and Develop Commodity Groups. Freight vehicle traffic is obtained from the movement of commodities. There are a large number of commodity groups such as agricultural products, mining, chemicals, metal products, textiles, machinery and equipment, lumber wood products, petroleum, transportation equipment, etc. In addition it is possible to subdivide these groups even further. Since growth forecast is done according to each sector, it is preferable to define commodity groups clearly in detail.

Fifth, Relate Commodity Groups to Industrial Sectors or Economic Indicators. “Separate economic indicators should be adopted for production and consumption of each commodity” (USDOT-FHWA, 1999). Input-Output (IO) tables can bridge the relationship between production and consumption of commodities (USDOT-FHWA, 1999).

Sixth, Find Base Year Origin-Destination (O-D) Matrix. In order to build a realistic model, origin and destination data for commodities must be used in this stage to obtain the observed O-D matrix (McCord et al., 1998). This data may be collected regularly or irregularly by commodity flow surveys or O-D surveys.

Seventh, Find Trip Generation Equation. In this step trip production and attraction are computed from the base O-D matrix. In this matrix, summation of rows give trip production and summation of columns give trip attraction. Later the relation between freight trip production and attraction and socioeconomic factors of TAZ’s should be determined to find trip generation equation preferably by commodity groups via regression analysis (Ferdman, Shefer, and Bekhor, 2008).

Eight, Forecast Growth Rates in Industrial Sectors. Growth rates change according to each sector, therefore their forecast should be done regarding industry and commodity groups (USDOT-FHWA, 1999). It is best to use sectorial growth rates by TAZ level.

Ninth, Forecast Commodity Flows. Industrial forecasts can be used to forecast future commodities (USDOT-FHWA, 1999). These forecasts can be applied to production or to consumption or to a whole commodity flow table (USDOT-FHWA, 1999).

Tenth, Distribute freight trip production and attraction between TAZs level. In this step forecasted trip production and attraction is distributed between TAZs level by means of

spatial interaction models. Most often applied trip distribution model in practice is the gravity model (Shvetsov, 2003).

Eleventh, Develop Modal Cost for Commodities. Cost minimization is the most widely used parameter for modal distribution (Ortuzar and Willumsen, 2001; Hensher and Button, 2007). Time is also a very important parameter for modal distribution. Briefly, mode split is determined to a large extent by cost considerations and/or time parameters (Ortuzar and Willumsen, 2001; Rodrigue, Comtois and Slack, 2006). According to Harker (1987) “modes are defined by a vector of attributes, such as reliability, price, etc.”

Twelfth, Split Commodities to Modes. Mode Split Models estimate mode sharing by comparing the relative cost of shipment between alternatives. Logit model is the one widely used for that purpose (USDOT-FHWA, 1999). Since freight flow time is also important, time parameters which generally mean the shortest path are also used for mode split (Ortuzar and Willumsen, 2001; Hensher and Button, 2008). As it is known and widely used fact that for some type of commodities best choice is to be “just in time” (Rodrigue, Comtois and Slack, 2006).

Thirteenth, Find Daily Vehicles from Load Weights and Days of Operation. Commodity flow survey gives data in terms of tons per year; however planning studies require data in the form of vehicles (USDOT-FHWA). Therefore converting goods flows to vehicle flows is necessary. So the amount of goods carried in a vehicle and number of daily vehicles in a year is determined (USDOT-FHWA, 1999).

Fourteenth, Assign Vehicles to Modal Networks. In a transportation system there are more than one alternative in the same mode. Between alternative routes cost effective, time effective and the most comfortable and capable route is chosen by carriers (Bates, 2008). Shipper and carrier behavior is not only important for mode selection but it is also important for route selection. Therefore these parameters should be considered to assign traffic to alternative links. A traffic assignment algorithm provides this information (USDOT-FHWA, 1999).

Fifteenth, Check the Vehicles Assigned to Routes with Counted Vehicles on the Network. The calibration of the model is performed by means of comparing the counted traffic values or observed behavior with the values obtained from the model (Bonsall, 1997).

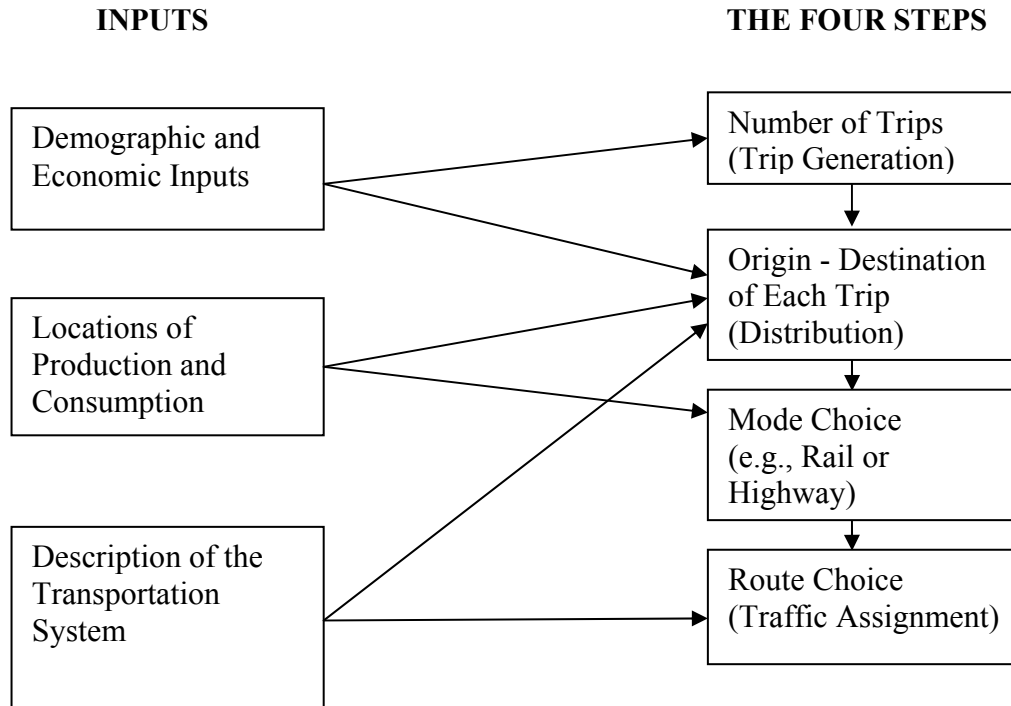
2.2.2 Four-Step Model

“**Four-step model**” or called as “**four staged model**” has been widely used for any kind of regional transportation forecasting (Chang and Meyers, 1999; Zhou, Chen and Wong, 2009). It is composed of four sub models which are trip generation, trip distribution, modal split and traffic assignment and all these stages are interrelated (Shvetsov, 2003). It has a sequential process and each step depends upon the others (Hasan and Safwat, 2000; Zhou, Chen and Wong, 2009). The output of one step is the input to the following step (Zhou, Chen and Wong, 2009). Some past research on the other hand employ modal choice stage before trip distribution and immediately after trip generation stage (Ortuzar and Willumsen, 2001). The criticism on this model is generally on its sequential process (Bates, 2008).

Four-step model is the outcome of model development attempts (Boyce, 2002). It was originally developed for passenger transport especially to forecast urban transportation during 1950s and 1960s, however, during the last quarter century it has been fruitfully adopted to forecast rural freight as well (Cambridge Systematics, Inc., et al., 1998; Ashtakala and Murthy, 1993; de Jong et al., 2002; Boile et al., 2004; Wang and Hofe, 2007). One of the differences between freight and passenger transportation is the diversity of decision makers and items being transported in freight (de Jong et al., 2002).

Four-step model is widely mentioned in the literature as traditional transportation model which is still being used (Holguin-Veras et al., 2001). It has been applied for more than 50 years (Hasan and Safwat, 2000). In addition, planners prefer to use four-step approach (Mao and Demetsky, 2002).

The four steps and related inputs are given in Figure 2.1. Formation of the origin-destination matrix is a key element of classic four-step model (Bierlaire, 1995). In the following paragraphs each step of four-step modeling is briefly described and given in Figure 2.2.



Source: (Adapted from Barnes and Davis 1999, page 33).

Figure 2.1 Four Steps for Regional Freight Movements

Trip Generation (How many Trips are Generated?): Trip generation models provide the estimates of the number of trips produced by or attracted to geographic areas named as Traffic Analysis Zones (TAZ) as a function of the demographic, socioeconomic, location and land use characteristics of the zones (Morlok, 1978; Wright, Ashford and Stammer, 1998; Boile et al., 2004). It depends on the relationship between trip frequencies and socioeconomic and land use characteristics to provide number of trips leaving from and reaching to each centroid of traffic analysis zones (Ferdman, Shefer and Bekhor, 2008).

Socioeconomic factors are the best explanatory variables for transportation demand modeling (Ferdman, Shefer and Bekhor, 2008). Most commonly used socioeconomic variables for freight transportation included in trip generation models are population, employment, income and passenger ownership (Mao and Demetsky, 2002; Çelik, 2004; Ferdman, Shefer and Bekhor, 2008; Yao, Guan and Yan, 2008). Employment density, population density, job-population balance, service employment density and dependency

ratio (the ratio between the employed population to the total population) are also regarded as land use variables in order to find trip generation equation (Fischer and Han, 2001; Ferdman, Shefer and Bekhor, 2008). The intensity, character, and location of land use activities are the important three characteristics of land use which have been related closely to trip generation (Wright, Ashford and Stammer, 1998, 266). Employment is, however, the best socioeconomic variable employed in freight trip production models (Black, 2003).

“The quantities and types of commodities generated in a region or zone are related to characteristics of the industries located there and to the population in the case of attractions of goods for final consumption” (Morlok, 1978, 449).

The flows produced from a set of origins (TAZ) are called trip production or traffic production and the flows attracted to a set of destinations (TAZ) are called trip attraction or traffic attraction. Both flows, however, are referred in literature as trip generation or traffic generation (Black, 2003). Trip generation models are three types (CALTRANS, 1992);

- 1- Trip production models,
- 2- Trip attraction models,
- 3- The normalizing or scaling process that converts the total trips generated into trip production and attraction.

“Trip production models estimate trip produced in a zone, trip attraction models estimate trips attracted to a zone and the scaling process ensures that for each trip purpose, the number of trips attracted within the total modeling domain equals the number of trips produced” (CALTRANS, 1992, 33).

According to Ferdman, Shefer and Bekhor (2008), land use variables have a greater effect on trip attraction models than on trip production models. Developing commodity attraction models are however not easy since commodities are attracted for the purpose of consumption either by industries or by consumers (Black, 2003). Therefore, most models in the literature on commodity attraction employ variables representing both the manufacturing system and the consumers' behavior (Black, 2003). Attraction models in the literature are generally behavioral models (Russo and Comi, 2002).

The simplest technique to estimate trip generation is the Simple Growth Factor Method however more sophisticated approach is using regression analysis (Fisher and Han, 2001; Stammer et al., 2002). Thus, to estimate generated and attracted trips regression analysis, specifically multiple regression analysis, is a common approach and is traditionally used (Paquette, Ashford and Wright, 1972; Fisher and Han, 2001; Huang et al., 2007; Wang and Hofe, 2007; Yao, Guan and Yan, 2008). Since 1950s, regression analyses have been widely used to estimate trip generation and the results of this statistical approach satisfy the researchers (Black, 1997). Multiple regression is the most frequently used model to form trip generation equation (Papacostas and Prevedouros, 2005, 355). In multiple regression analysis the dependent variables are either total trips produced by a zone or total trips attracted by a zone (Papacostas and Prevedouros, 2005). Independent variables employed in regression analysis are suggested to be obtained through a primary measurement, not derived from secondary data (Hooper, 2001). According to CALTRANS (1992) “trip generation models should be calibrated from survey data and re-calibrated every 10 years”. The deficiency of this method is that it does not allow for the possibility of induced traffic by the quality of the transport network (Daly, 1997).

Trip Distribution (Where do Trips Goes?): Trip distribution is one of the important stages of four-step modeling which is used to distribute all trips generated in a zone to all possible attraction zones (CALTRANS, 1992; Leung, 2007). The distribution step completes the demand estimation by forming O-D matrix using the outputs of trip generation which are base-year production and attraction (Bierlaire, 1995; McCord et al., 1998; Wright, Ashford and Stammer 1998). In order to employ this stage the planner should have the knowledge on the number of trips attracted or produced of each TAZ (Paquette, Ashford and Wright, 1972). In this stage the correspondence matrix defining the volume of traffic between each pair of TAZ is obtained (Shvetsov, 2003).

“Most of the techniques used in the distribution process depend greatly upon the origin-destination study for calibration purposes, just as future trip generation was predicted from behavior patterns observed in the base-year” (Wright, Ashford and Stammer 1998, 272).

O-D matrix estimation is the basis and also the best representation of transportation demand (Ashtakala and Murthy, 1988; Bierlaire, 1995). O-D matrix estimation in

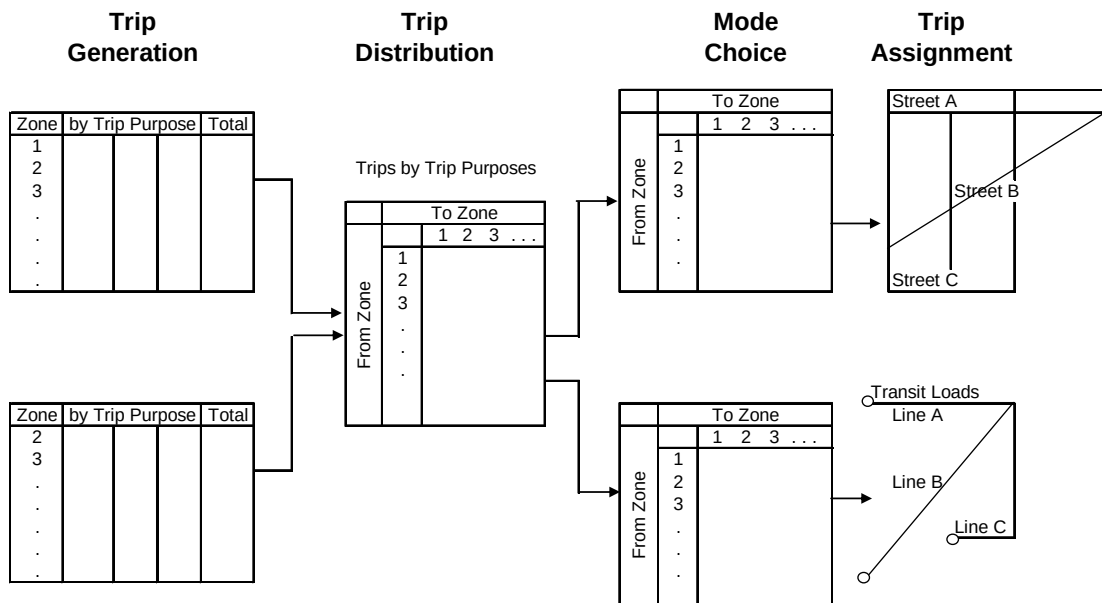
literature can be grouped in three classes as direct estimation, modeled (simulated) estimation and estimation from traffic counts (Ianno et al., 2002). Each cell of the matrix is the representation of freight or passenger movement between each origin and destination pair (Ashtakala and Murthy, 1988). The rows and columns of O-D matrix represent the zones of study area (Ashtakala and Murthy, 1988; Bierlaire, 1995). The rows of the matrix represent centroids of origin and the columns of the matrix represent the centroids of destination and therefore this matrix is called as demand matrix or spatial interaction matrix (Bierlaire, 1995; Rodrigue, Comtois and Slack; 2006). The initial or base O-D matrix is generally produced empirically using surveys. However the simulated matrix is obtained using models or theories such as gravity model. It is also possible to estimate O-D matrix from traffic counts (Bell, 1983; Ortuzar and Willumsen, 2001; Zijpp, 1997). Freight distribution models found in literature are mostly based on aggregate data (de Jong et al., 2002).

The most popular trip distribution models are Fratar Model, Gravity Model, Input-Output Model and Linear Programming Model (Meyer and Straszheim, 1971; Ortuzar and Willumsen, 2001; Papacostas and Prevedouros, 2005). Within these models, Gravity model has been the most widely used in transportation planning since 1950s (Leung, 2007; Wright, Ashford and Stammer 1998; Black, 1997). It is one of the first mathematical models which predict the interregional traffic flow (Shvetsov, 2003). The only new approach for trip distribution in the last three decades is the use of artificial neural network (Black, 1997).

Mode Choice (Which Travel Mode is Preferred for Each Trip?): It is the allocation of freight and vehicle movement to a particular mode considering level of service, cost, time, comfort, shippers' behavior, truckers' choice and other variables and performance characteristics of the modes (Meyer and Straszheim, 1971). Mode choice is based on cost saving, profit maximization, technological advantages and physical aspects of the transportation system since freight traffic is very sensitive to the cost of transport modes (Meyer and Straszheim, 1971; Regan and Garrido, 2002). Modal split models found in literature are both aggregate and disaggregate models (de Jong et al., 2002).

Trip Assignment (What is the Route of Each Trip?): "Assignment in general simulates the route choice of travelers or vehicles within a transport network thus

allocating the demand to the network” (Friedrich, Haupt and Noekel, 2003). In this step traffic flow for each mode is assigned to the related network routes (Bierlaire, 1995). The used parameters to assign trips to transportation network are capacity, cost, travel time, travel distance, level of service, speed limit, etc. (Cambridge Systematics, Inc., Comsis Corporation, and University of Wisconsin-Milwaukee, 1996). In the literature “a number of freight models do not include assignment step” (de Jong et al., 2002).



Source: (CALTRANS, 1992, page 32).

Figure 2.2 Four Steps of Regional Transportation Model

2.3 Spatial Interaction Models

“Freight transportation demand is a highly variable process over space and time” therefore freight transportation is highly related with time and space concept (Garrido and Mahmassani, 2000). In freight flow, it is very important to be just in time where it is transported. In this statement “**just-in-time**” (right before time is up) is the concept related with time and **where** is the concept related with space (Rodrigue, Comtois and Slack, 2006). Spatial interaction is explained as the realization of movement of freight or people or information (Rodrigue, Comtois and Slack, 2006).

“Spatial separation is the essence of travel demand, and the majority of models aim to recognize the spatial distribution of travel explicitly, by means of an appropriate system of zones” (Hensher and Button, 2008, 14).

From the point of transportation, spatial interactions are realized by the movement of people and/or the movement of freight between origin and destination pairs over geographic space (Fisher, 2006).

“Freight by its nature is spatial. The pattern of freight movement refers to the distribution of an aggregate freight volume between different origin-to-destination pairs of places” (Southworth, 2003, 4-8).

“Economic activities are generating (supply) and attracting (demand) flows” (Rodrigue, Comtois and Slack, 2006, 164). These flows (passenger or freight flows) on a network, as a result of spatial and economic activities between origin and destination pairs, enable to evaluate the demand for transportation services (Rodrigue, Comtois and Slack, 2006).

The freight flows on the network are the movements of goods from generation (production) location to attraction (consumption) location in terms of truck trips or volume (tonnage) (Pendyala et al., 2002). It is driven by economic trade among sectors between origin and destination regions (University of Wisconsin-Milwaukee et al., 2006). The more production and consumption takes place the more freight is moved. Therefore, it is inferred that trading concerns the movement between production and consumption regions and freight flow concerns the freight movement between origin and destination.

Spatial interaction models refer to the trip distribution process as a function of interactions in space (Holguin-Veras, et al, 2001). Freight distribution models can be modeled with statistical-descriptive models, network-based spatial price equilibrium models and multi-sectorial multi-regional macro-economic models based on Input-Output theory (Cascetta and Di Gangi, 1996).

In the following sections the widely known and used spatial interaction models known as trip distribution models are described in detail. Spatial movements of freight interaction between production and attraction regions are empirically investigated using O-D matrix and economic characteristics of TAZ. In other words spatial interactions are explained as

the function of the attributes of origin, the attributes of destination and the accessibility between origin and destination (Rodrigue, Comtois and Slack, 2006).

The spatial interaction models refer to the trip distribution process as a function of interaction in space (Holgin-Veras, 2001). Spatial interaction models are traditionally calibrated by regression, maximum likelihood and by numerical heuristics (Mozolin, Thill and Usery, 2000). Neural networks have also been used in recent years for calibration of trip distribution (Mozolin, Thill and Usery, 2000). Researches on transportation planning and regional economy have been often focused on the spatial distribution and connection of commodities (Zhao, Jin and Hong-sheng, 2007).

2.3.1 The Transportation Model of Linear Programming

Linear Programming Model is one of the distribution models and it optimizes the assignment of origin quantities to destinations (Ortuzar and Willumsen, 1994; Victoria and Walton, 2004). This methodology was introduced by Garrison to geographic literature in 1950s and early description was presented by Cox in 1960s (Black, 2003, 131). It is the simplest and most widely used method of mathematical programming (Rodrigue, Comtois and Slack, 2006, 93). According to Rodrigue, Comtois and Slack (2006, 90), “the term linear implies proportionality; programming is used in the mathematical sense of selecting an optimum allocation of resources”

There is a very close relationship between the family of gravity model and the transportation model of linear programming (Batten and Boyce, 1986). Model is formulated as the following equation to solve the transportation problem (Ortuzar and Willumsen, 1994; Çelik, 2001; Black, 2003). The transportation problem may be distribution of goods between m origins to n destinations (Black, 2003).

$$\text{Minimize } Z = \sum_{ij} T_{ij} C_{ij} \quad (2.1)$$

Subject to;

$$\sum_i T_{ij} = D_j \quad i = 1, 2, \dots, m \quad (2.2)$$

“total flow from any i to each of the j destinations cannot exceed the supply at the i origin” (Black, 2003, 131).

$$\sum_j T_{ij} = O_i \quad j=1,2 \dots n \quad (2.3)$$

“total flow to any j destination from all i origins cannot exceed the demand at that j destination” (Black, 2003, 131).

Where;

- Z = Total cost of transporting freight flow
- T_{ij} = Total freight flow from origin i to destination $j \geq 0$ for all i, j
- C_{ij} = Transport cost of the flow between origin i to destination j
- O_i = Total trips originating at zone i
- D_i = Total trips destined at zone j

“The cost of distributing a unit of the product from each of the origins to each of the destinations is known. The problem is to distribute the good in such a way that the demand at all destinations is met. The supply at each of the origins is not exceeded, and the overall cost of distributing the good is a minimum. This is obviously minimization problem” (Black, 2003, 131).

The objective of this model is minimizing the summation of transport costs of each origin-destination pair while maximizing the profit (Ortuzar and Willumsen, 1994; Rodrigue, 2007). Employing linear programming to transportation problems, the shortest path is chosen in order to distribute commodities to numerous destinations by minimizing total transportation cost (Rodrigue, Comtois and Slack, 2006).

“Standard linear programming assumes simple transportation problems in which supplies and demands and the costs of flows between pairs of location are known” (Rodrigue, Comtois and Slack, 2006, 93).

By this model Transportation problem is solved very efficiently and in a very simple way (Ortuzar and Willumsen, 2001).

Berkman (1976) employed linear programming to analyze net movements of sectoral service flows in terms of number of employees between provinces of Türkiye by minimizing transportation cost. Her research briefly mentioned in the following subtitles.

2.3.2 Gravity Models

Gravity Model, as it is understood from the name, is developed using Newton's Law of Gravity which describes gravitational force between two bodies (CALTRANS, 1992). It is one of the earliest interaction models (Fisher, 2006; Rodrigue, Comtois and Slack, 2006). The socioeconomic interactions in space can also be explained by Newton's Theory known as Gravity Hypothesis. According to Newton's Law of Gravity, the attractive force (F_{ij}) between any two bodies (i and j) is directly related to their respective masses (m_i and m_j) and inversely related to the square of the distance between two masses (d_{ij}) (equation 2.4) (Batten and Boyce, 1986; Wang and Hofe, 2007).

$$F_{ij} = k m_i m_j / (d_{ij})^2 \quad (2.4)$$

The earlier researchers, such as Carey, Ravenstain and Reilly, tried to explain the socioeconomic interactions in the form of flows during 19th century (Black, 2003). During 1950s Stewart also observed gravitational aspects of flows between zones (Black, 2003). Again in 1950s first Gravity Model was employed in areawide transportation planning in Chicago, Detroit and others (Meyer and Miller, 1984; Weiner, 1997). Intervening opportunities models, such as trip distribution models, filled the journals during 1960s and 1970s but they are not accepted as strong followers (Black, 1997).

In the literature gravity models are referred as spatial interaction and synthetic models which produce spatial interaction matrices in transport geography and are used to estimate freight flows between set of production and consumption regions (Hamburg, Kaiser and Lathrop, 1983; Ortuzar and Willumsen, 1994; Ho et al., 2005). It is also known as one of the most important spatial interaction models (Rodrigue, 2007)

The family of gravity models is the most appropriate and widely used for trip distribution analyses and it is employed to estimate the interactions between two regions (Holgin-Veras et al., 2001; Mao and Demetsky, 2002; University of Wisconsin-Milwaukee et al., 2006). It is the most popular spatial interaction model because of its phenomenon and multi-faceted character in regional economy (Mikkonen and Luoma, 1999). It is particularly useful when there are sizable distances and cost differences

between each pair of production and consumption regions (Ho et al., 2005). The result varies directly with a certain function of the distance separating the two points (Batten and Boyce, 1986). Therefore the attractiveness between pairs of zones is referred as impedance or deterrence and it is explained via a function of travel time or cost or distance (CALTRANS, 1992).

“Consequently, the general formulation of spatial interactions can be adapted to reflect this basic assumption to form the elementary formulation of the gravity model” (Rodrigue, Comtois and Slack, 2006, 167).

$$T_{ij} = k P_i P_j / d_{ij} \quad (2.5)$$

Where;

- T_{ij} are trips between the location of origin and the location of destination.
- P_i and P_j are the importance of the location of origin and the location of destination, respectively.
- d_{ij} is the distance between the location of origin and the location of destination.
- k is proportionality constant related to the rate of the event and is obtained empirically.

Gravity model was introduced into transportation modeling in the 1950s and traffic engineers initially began to employ this theory in transportation field following Voorhees who offered his *general theory of traffic movement* (Paquette, Ashford and Wright, 1972, 302; Black, 2003; Ho et al., 2005, 5;).

$$T_{ij} = P_i (A_j / d_{ij}^b) / \left[\sum_j^m A_j / d_{ij}^b \right] \quad (\text{Black, 2003, 169}).$$

Where;

- T_{ij} = flow of traffic from zone i to zone j
- P_i = total traffic produced in zone i
- A_j = total traffic attracted to zone j
- d_{ij}^b = distance between i and j raised to the b power

The simplest formulation of gravity model was introduced by Wilson in the following manner during 1960's based on Newton's Gravity and used by the following researchers (Nijkamp, 1975; Batten and Boyce, 1986; Bierlaire, 1995; Black, 2003).

$$T_{ij} = k O_i D_j f(d_{ij}) \quad (2.6)$$

Where;

$$\begin{aligned} T_{ij} &= \text{flow between origin } i \text{ and destination } j \\ k &= \text{constant of proportionality} \\ O_i &= \text{flow originating from place } i \\ D_j &= \text{flow terminating at place } j \\ f(d_{ij}) &= \text{deterrence function between places } i \text{ and } j \end{aligned}$$

T_{ij} is assumed to be a decreasing function of deterrence $f(d_{ij})$. This kind of gravity model is frequently used in analyzing trip origin-destination flows, commodity flows, and other forms of spatial interactions. The deterrence function $f(d_{ij})$ is generally represented by travel distance, travel time, travel cost or some weighted combination of these factors (Wilson, 1970; USDOT-FHWA, 1999; Victoria and Walton, 2004; Fisher, 2006; Wang and Hofe, 2007). Moreover, it is usually defined in terms of distance (Mao and Demetsky, 2002; Shvetsov, 2003).

Three different impedance functions are most widely mentioned in literature. These are power function ($f(d_{ij}) = d_{ij}^{-n}$), exponential function ($f(d_{ij}) = \exp(-\beta d_{ij})$), Tanner or gamma function (combined) ($f(d_{ij}) = d_{ij}^n * \exp(-\beta d_{ij})$) (Ortuzar and Willumsen, 2001; Fisher, 2006). A fourth one is also mentioned in a limited number of literature: Generalized Tanner Function which is formulated as ($f(d_{ij}) = d_{ij}^n * \exp(\beta^2 d_{ij})$) (Sen and Smith, 1995; Fisher, 2006). Calibration of the impedance function is a key issue in Gravity Models in the literature.

More general specification of gravity model is given by Batten and Boyce, 1986:

$$T_{ij} = k O_i^a D_j^g f(d_{ij}) \quad (2.7)$$

Relationship between these two functions (2.6) and (2.7) can be considered as functions that determine T_{ij} as an unweighted arithmetic and a weighted geometric average of O_i and D_j , respectively (Batten and Boyce, 1986). Gravity model is a closed system (Ho et al., 2005).

“Since gravity model is a closed system, where all flows are consumed within the system, the summation of consumption capacities should equal to production capacities. Therefore an iterative process is employed to adjust T_{ij} to achieve equality between production and consumption” (Ho et al., 2005, 6).

$$\sum_{j=1}^n T_{ij} = O_i \quad i = 1, \dots, n \quad n = \text{number of zones} \quad (2.8)$$

$$\sum_{i=1}^n T_{ij} = D_j \quad j = 1, \dots, n \quad n = \text{number of zones} \quad (2.9)$$

In other words the summation of trips from zone i (O_i) is assumed to be equal to the summation of trips from zone j (D_j) (Leung, 2007; Wang and Hofe, 2007). It is also regarded as condition of balance of the general arrival and departure (Shvetsov, 2003). When these conditions are satisfied, the gravity model is referred as doubly constrained gravity model and the model is formulated as follows (Batten and Boyce, 1986; Leung, 2007).

$$T_{ij} = A_i B_j O_i D_j f(d_{ij}) \quad (2.10)$$

Where the parameters A_i and B_j are defined respectively as (Batten and Boyce, 1986; Leung, 2007);

$$A_i = \left\{ \sum_{j=1}^n B_j D_j f(d_{ij}) \right\}^{-1} \quad (2.11)$$

and

$$B_j = \left\{ \sum_{i=1}^n A_i O_i f(d_{ij}) \right\}^{-1} \quad (2.12)$$

Parameters A_i and B_j are balancing factors that ensure equations (2.8) and (2.9) are satisfied (Batten and Boyce, 1986; Ortuzar and Willumsen, 2001; Leung, 2007). In

empirical work, these unknown parameters can be obtained by means of iterations (Batten and Boyce, 1986; Leung, 2007).

A more general specification of equation (2.10) has also been proposed (Batten and Boyce, 1986):

$$T_{ij} = A_i^{a-1} O_i B_j^{g-1} D_j f(d_{ij}) \quad (2.13)$$

The generality of equation (2.13) is evident from the number of gravity models subsumed in its structure with predetermined values of a and g (Batten and Boyce, 1986, 366).

1. $a = 1, g = 1$ entails traditional gravity models (*unconstrained*)
2. $a = 0, g = 0$ entails two-way distribution models (*doubly constrained*)
3. $a = 1, g = 0$ or $a = 0, g = 1$ entails one-way distribution models (*singly constrained*)

Batten and Boyce (1986) argue that a and g should be empirically estimated rather than predetermined.

Unconstrained gravity model means there is not any constraint on the total number of trips produced and attracted by the traffic analysis zones, singly constrained gravity model means, either origin or destination constraints either total production or total consumption by the TAZs (Holguin-Veras et al., 2001). And doubly constrained gravity model means both number of trips produced and attracted by the TAZs are constrained (Holguin-Veras et al., 2001). According to Mozolin, Thill and Uesry (2000) doubly constrained gravity model yields the most accurate results.

The mathematical equations of four variants of the gravity model are given below (Holguin-Veras et al., 2001):

$$\begin{aligned} T_{ij} &= O_i D_j f(d_{ij}) && (\text{unconstrained gravity model}) \\ T_{ij} &= O_i (D_j f(d_{ij}) / \sum_j D_j f(d_{ij})) && (\text{origin constrained gravity model}) \\ T_{ij} &= D_j (O_i f(d_{ij}) / \sum_i O_i f(d_{ij})) && (\text{destination constrained gravity model}) \\ T_{ij} &= A_i O_i B_j D_j f(d_{ij}) && (\text{doubly constrained gravity model}) \end{aligned}$$

Briefly, “in the gravity model, the number of trips between two zones in the Region is a function of the number of trip ends in each zone and their spatial separation measured in terms of travel time, distance and/or cost” (University of Wiskonsin-Milwaukee et al, 2006, 83).

In addition, gravity model is calibrated by comparing trip length frequency distribution and average computed trip length to the observed values (Victoria and Walton, 2004; Papacostas and Prevedouros, 2005). Many studies in the literature have been conducted to calibrate gravity model by Trip Length Distribution (TLD) and also to find the impedance function (Ashtakala and Murthy, 1988; Mao and Demetsky, 2002; Leung, 2007). “The frequency of trips eventually decreases with increasing impedance” (Papacostas and Prevedouros, 2005, 370).

Gravity Model as one of the trip distribution models based on the analogy to the law of gravity has some limitations (Papacostas and Prevedouros, 2005). The major limitation is the absence of behavioral basis of the model to explain the choice of destination (Ashtakala and Murthy, 1988; Papacostas and Prevedouros, 2005).

Urban truck travel model for the Phoneix Metropolitan area in the USA is one of the good examples of using the gravity model on freight transportation (Cambridge Systematics, Inc., Comsis Corporation, and University of Wiskonsin-Milwaukee, 1996). Friction factors are developed based on truck type and are as follows (Cambridge Systematics, Inc., Comsis Corporation, and University of Wiskonsin-Milwaukee, 1996):

Four-tire Trucks	$F(d_{ij}) = e^{-0.08 t_{ij}}$
------------------	--------------------------------

Single Unit Trucks (6+tires)	$F(d_{ij}) = e^{-0.1 t_{ij}}$
------------------------------	-------------------------------

Combinations	$F(d_{ij}) = e^{-0.03 t_{ij}}$
--------------	--------------------------------

Where t_{ij} is travel time between i and j

This model is also referred and used in FHWA Quick Response Freight Manual II in the USA (Cambridge Systematics, Inc. et al., 2007). Used gravity model is destination constrained (Cambridge Systematics, Inc. et al., 2007). Many states in the USA followed this manual. Indiana Freight Model is another good example on using gravity manual in the USA and used friction factor is $F(d_{ij}) = \exp(\beta d_{ij})$ (USDOT-FHWA, 1999). In this equation (d_{ij}) is the distance in miles and (β) is the constant varied by commodity type

USDOT-FHWA, 1999). Brief information about this model is given in the following titles.

As an example of applying gravity model for a developing country, Kaysi, El Hussein and Ramadi (2000) used gravity model for modeling national goods movement of Lebanon with limited data. The friction factor used in their model is the inverse of the square of the distance between zones of all commodity groups. The obtained matrix is 20x20 matrix representing O-D flows between twenty zones.

Artificial Neural Network on the other hand has become a new approach during the recent years for distribution modeling to calibrate gravity-types of models involving productions, attractions and spatial separation or generalized cost (Black, 1997).

2.3.3 Input-Output Models

Input-Output (IO) Model which is known as inter-industry model was first developed by Professor Wassily Leontief in the late 1930s but serious attempts to predict freight flows at national or regional level began after the first intercity passenger models, and were developed in the middle 1960's (USDOT-FHWA, 1999; Çelik, 2001). Input-Output models are macroeconomic models and employ econometric techniques in order to estimate freight transport demand (Zlatoper and Austrian, 1989; de Jong et al., 2002). It is one of the important spatial models to forecast domestic and international patterns of manufactured goods, since manufactured goods give rise to the basic pattern of freight traffic and are essential for long term freight demand forecasting (Jin et al., 2000).

“The input-output method is an adoption of the neo-classical theory of general equilibrium to the empirical study of the quantitative interdependence between interrelated economic activities. It was originally developed to analyze and to measure the connections between the various producing and consuming sectors within a national economy” (Leontief, 1966, 134).

Input-Output Model starts with spatial Input-Output Table which is generally described at national level. The difficult part of Input-Output Analysis is the formation of Input-Output Table (USDOT-FHWA, 1999; Jin et al., 2000). This table describes how much goods and services are produced in a year through domestic products and imports and

how much goods are consumed by households, government, stocks and exports (USDOT-FHWA, 1999; Jin et al., 2000).

Input-Output table is prepared using software packages (US FHWA, 1999). Once the table is ready, remaining mathematical calculation is simple and done on a spreadsheet (USDOT-FHWA, 1999). The input-output matrix requires a disaggregation of the economy into sectors and disaggregation into two dozen sectors is often sufficient (Meyer and Straszheim, 1971). This model employs observed economic data for a specific geographic region such as country, region, province, etc. (Miller and Blair, 1985).

Holguin-Veras et al. (2001) cited basic Input-Output Model based on some assumptions, i.e., in a given sector, the products are homogeneous, production technologies within a sector can be represented by the average technology, the technology of production can be assumed to be constant, and there is equilibrium between total supply and total demand.

“By contrast, estimating the regional or spatial dimension of input-output relationship, something that is usually essential to transport planning, is almost always a serious practical problem. Regional data are often unavailable. The determination of regional activity must usually be based on individual regional surveys with frequent reliance on proxy measures for regional output derived from employment or tax records and application of common (national) input-output relationship to the estimates of output for each region. The objective is to provide necessary disaggregation in intersectoral flows, indexed by their origin and destination” (Meyer and Straszheim, 1971, 167).

“A regional input-output model traces the interactions of local industries with each other, with industries outside the region, and with final demand sectors” (Schaffer, 1999, 14). The central element in this model is a regional transaction table and divided into four quadrants as Table 2.3.

“Input-output table traces the paths by which incomes flow through the economy. Quadrant I is where the spending cycle begins and is where finished goods go to satisfy the needs of final consumers. Quadrant III is where the production cycle starts, with households and other resource owners, including governments, receiving payments for their contributions to the production process. Quadrant II traces production relationships, describing the technology of production in the economy. It outlines the market sector of the economy. Quadrant IV identifies nonmarket flows of money, showing purchases of labor

inputs by governments, taxes paid by households, surpluses and deficits of governments, and transfers between governments and other governments and people” (Schaffer, 1976, 8-9).

Table 2.3 Transactions Table as a Picture of the Economy

		Production	Final Demands	
Final Payment	Distribution	II Interindustry Structure	I Consumption	Total Outputs
		III Incomes	IV Nonmarket Transfers	
		Total Inputs		

Source: (Schaffer, 1999, page 15).

An input-output table provides a detailed statistical account of the flows of goods and services among the producing and purchasing sectors of a national economy over a stated period of time (Leontief, 1966; Polenske and Fournier, 1993). All entries in that table are amount or monetary values of goods or services. The preferred numbers of sectors tabulated in that table are several aggregated from hundred even thousand divisible producing sectors (Miller and Blair, 1985). From input-output table; final demand, the purchase by private consumers, government purchasers, capital goods buyers, and foreign trades, is found (Polenske and Fournier, 1993).

“Central to the concept of **Input-Output Analysis** is the idea of *total output* (**X**), *intermediate demand* (**W**) and *final demand* (**Y**)” (Holguin-Veras et al., 2001, 19). These concepts are outlined in Table 2.4.

“If the economy is divided into n sectors, and if we denote the total output of sector i by X_i and the total final demand for sector i ’s product by Y_i , then we may write;

$$X_i = Z_{i1} + Z_{i2} + \dots + Z_{ii} + \dots + Z_{in} + Y_i \quad (2.18)$$

The Z terms on the right hand side show the inter industry sales by sector i , thus the entire right hand side is the sum of all sector i 's interindustry sales and its sales to final demand. The equation given above represents the distribution of sector i 's output. The following equation shows these reflecting sales of the output of each of n sectors (Miller and Blair, 1985)".

$$X_i = \sum Z_{ij} + Y_i \quad i = 1, \dots, n \quad j = 1, \dots, n \quad (2.19)$$

$$W_i = \sum Z_{ij} \quad (2.20)$$

$$X_i = W_i + Y_i \quad (2.21)$$

Table 2.4 Single Region Input-Output Matrix

				Purchasing Sectors																	
				Intermediate Demand					Final Demand				Total Production X								
									Inv I	Cons C	Exp E	Gov G		Total Y							
				Sectors																	
1	2	3	4		j		n	w													
Producing Sectors	Produced Inputs	Sectors	n		i		4	3	2	1	Z_{ij}					W_i	Y_i				X_i
			u																		
			Primary Inputs																		
Total Consumption				X_j																	

Source: (Holguin-Veras et al., 2001, page 20).

The magnitudes of flows between different industries can be shown in input-output table, with sectors of sellers listed on the left and the same sectors purchasers listed across the top (USDOT-FHWA, 1999).

"In input-output work, a fundamental assumption is that the interindustry flows from i to j , recall that these are for a given period such as a year, depend entirely and exclusively on the total output of sector j for that same time period. Clearly, no one would argue against the idea that the more cars produced in a year, the more steel will be needed during that year by automobile producers. Where argument does arise is over the exact nature of this relationship. In input-output

analysis it is as follows: After observing Z_{ij} , the flow of inputs from i to j , and X_j , the total output of j , from the ratio of input to output, Z_{ij}/X_j , denoted a_{ij} .” (Miller and Blair, 1985).

$$a_{ij} = Z_{ij}/X_j \quad (2.22)$$

This ratio is named as technical coefficient, input-output coefficient or (direct) input coefficient (Leontief, 1966; Polenske and Fournier, 1993). It gives the amount of input required by an industry per unit of output (Polenske, 1967). According to Jin et al. (2000) the more aggregate the Input-Output table (the fewer the number of sectors), the more stable the Input-Output coefficients will be over time. In other words, limitation of sectors keeps the validity of Input-Output Table through time (Jin et al., 2000).

From equation (2.22) the following equation is produced (Polenske and Fournier, 1993);

$$Z_{ij} = a_{ij}X_j \quad (2.23)$$

$$X_i = \sum a_{ij}X_j + Y_i \quad i \text{ and } j = 1, \dots, n \quad (2.24)$$

$$\mathbf{X}_{(n \times 1)} = \mathbf{A}_{(n \times n)} \mathbf{X}_{(n \times 1)} + \mathbf{Y}_{(n \times 1)} \quad (\text{in matrix form})$$

Let's assume that a_{ij} are known and X_n are to be found. Then, bring all X terms to the left and obtain the following equation (Polenske and Fournier, 1993).

$$\mathbf{X}_{(n \times 1)} - \mathbf{A}_{(n \times n)} \mathbf{X}_{(n \times 1)} = \mathbf{Y}_{(n \times 1)} \quad (\text{in matrix form}) \quad (2.25)$$

Then grouping X_1 's together in the first equation, X_2 's in the second, and so on the following equation is obtained (Polenske and Fournier, 1993).

$$(\mathbf{I}_{(n \times n)} - \mathbf{A}_{(n \times n)}) \mathbf{X}_{(n \times 1)} = \mathbf{Y}_{(n \times 1)} \quad (\text{in matrix form}) \quad (2.26)$$

Then by inverting $(\mathbf{I}-\mathbf{A})$ matrix (Polenske and Fournier, 1993),

$$\mathbf{X}_{(n \times 1)} = (\mathbf{I}_{(n \times n)} - \mathbf{A}_{(n \times n)})^{-1} \mathbf{Y}_{(n \times 1)} \quad (\text{in matrix form}) \quad (2.27)$$

The inverse coefficient a_m , “which are derived from the set of technical coefficients give the direct and indirect production requirement per unit of final demand” (Polenske, 1967,

23). The matrix $(I-A)$ is sometimes called the “Leontief Matrix” in recognition of Wassily Leontief. In addition $(I-A)^{-1}$ is therefore called the “Leontief Inverse”.

National input-output tables are generally developed for many countries especially by central statistical office (de Jong et al., 2002). In general national Input-Output Model is the aggregation of large number of diverse regions (Park et al., 2008). The last national input-output table of Turkish economy is for the year 2002 (T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2008). Before that nine tables had been prepared for the years 1959, 1963, 1968, 1973, 1979, 1985, 1990, 1996 and 1998; the first two by State Planning Organization and the rest by Turkish Statistical Institute (T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2001; T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2008).

Input-output tables are generally produced at national level. However, during the last 20-30 years, interest in economic analysis has been intensified at regional level (Schaffer, 1999). Regional input-output analysis can be done at the levels of single-region, two-region as well as multi-region. Interregional Input-Output Table shows both commodities from one industry to another industry and also from one region to another region (Inamura and Srisurapanon, 1997). Multi-Regional or spatial Input-Output tables for many countries however do not exist (de Jong et al., 2002). It does not exist for Turkish economy either.

The most important task in constructing regional input-output table is the estimation of interregional trade flows since input-output tables are linked via interregional flows (Kauppila, 1999; Çelik and Guldman, 2007).

“Trade flows have, however, been mainly estimated using either non-survey methods or surveys based on smaller samples and more aggregated regions. Trade flows studied have normally been born as a by-product of regional IO-tables” (Kauppila, 1999).

“The core of national input-output model is the table of intermediary shipments” (Nijkamp, Rietveld and Snickars, 1986, 263). However multi-regional input-output (MRIO) models concern the adoption of the interregional flows to market signals of different kind as price of transport as well as transport network properties (Nijkamp, Rietveld and Snickars, 1986). If a multi-regional input-output scheme is used, a basis is provided for consistent estimates of transportation requirements by industry and region.

“MRIO models allow to simulate the quantity of goods produced and traded among regions, through an explicit representation of different economic sectors” (Marzano and Papola, 2004).

There are three major MRIO formulations; row coefficient model, the column coefficient model, and the gravity model (Holguin-Veras et al., 2001, 22). These are given in the following Table 2.5.

Table 2.5 Summary of MRIO Models

	Row Coefficient	Column Coefficient	Gravity Model
<u>Trade Coefficients</u>	$x_i^{gh} = r_i^{gh} x_i^{go}$	$x_i^{gh} = c_i^{gh} x_i^{oh}$	$x_i^{gh} = \frac{x_i^{go} x_i^{oh}}{x_i^{oo}} q_i^{gh}$
	$\mathbf{R}' \Delta \mathbf{X} = \hat{\mathbf{A}} \Delta \mathbf{X} + \Delta \mathbf{Y}$	$\Delta \mathbf{X} = \hat{\mathbf{C}} (\mathbf{A} \Delta \mathbf{X} + \Delta \mathbf{Y})$	$\mathbf{T}' \Delta \mathbf{X} = \hat{\mathbf{S}} (\mathbf{A} \Delta \mathbf{X} + \Delta \mathbf{Y})$
<u>System Equations</u>	$(\mathbf{R}' - \hat{\mathbf{A}}) \Delta \mathbf{X} = \Delta \mathbf{Y}$	$(\mathbf{I} - \hat{\mathbf{C}} \mathbf{A}) \Delta \mathbf{X} = \mathbf{C} \Delta \mathbf{Y}$	$(\mathbf{T}' - \hat{\mathbf{S}} \mathbf{A}) \Delta \mathbf{X} = \mathbf{S} \Delta \mathbf{Y}$
	$\Delta \mathbf{X} = (\mathbf{R}' - \hat{\mathbf{A}})^{-1} \Delta \mathbf{Y}$	$\Delta \mathbf{X} = (\mathbf{I} - \hat{\mathbf{C}} \mathbf{A})^{-1} \mathbf{C} \Delta \mathbf{Y}$	$\Delta \mathbf{X} = (\mathbf{T}' - \hat{\mathbf{S}} \mathbf{A})^{-1} \mathbf{S} \Delta \mathbf{Y}$

Source: (Holguin-Veras et al, 2001, 22)

“Where:

$\Delta \mathbf{X}$ = Change in production (output) of commodity i produced in region g,

$\Delta \mathbf{Y}$ = Change in consumption of commodity i by final users in region g,

$\hat{\mathbf{A}}$ = Block diagonal matrix (nm x nm) with n square matrices (m x m) containing the technical coefficients,

$\mathbf{S}, \mathbf{T}$ = Square matrix (nm x nm) filled with diagonal matrices (m x m). The elements t_i^{gh} relate outflows from region g to the production in the region, while the s_i^{gh} elements relate inflows into region g to the consumption in the region,

$\mathbf{R}$ = Square matrix (nm x nm) with elements r_i^{gh} that represent the total production of commodity i in region g that is exported to region h,

$\mathbf{C}$ = Square matrix (nm x nm) with elements c_i^{gh} that describe the fraction of total consumption of commodity i in region h that is imported from region g.

The elements x_i^{go} and x_i^{oh} represent the total amount of commodity i produced in region i, and the total amount of commodity i demanded in region i, respectively” (Holguin-Veras et al., 2001, 22-23).

Multi Regional Input-Output modeling is data hungry, in addition building multi-regional and multi-industry input-output modeling is prohibitively expensive (Nijkamp, Rietveld and Snickars, 1986; Çelik and Guldman, 2007). In a framework, there are N sectors and R regions (Nijkamp, Rietveld and Snickars, 1986). In order to have statistical data needed by the model these regions are relatively large zones and the sectors are economic activities of production and consumption (Cascetta, 2001). These models are not reliable for long-term forecasting because of ever-changing production technologies (Çelik and Guldman, 2007). In general applications of input-output models were carried out at the national level. “The role of input-output models is not as strong in applied context at a regional level as it is in national economic analysis” (Nijkamp, Rietveld and Snickars, 1986, 263).

The MRIO model produces region-to-region trade flows matrices for each economic sector using final demand vectors, technical coefficient matrices for regional economies and inter-regional trade coefficients elastic with respect to generalized transport costs. These matrices expressed in monetary terms are transformed into Origin-Destination matrices of freight quantities” (Cascetta and Di Gangi, 1996).

There is a close relation between Inter Regional Freight Flow (IRFF) and Inter Regional Trade Flow (Inamura and Srisurapanon, 1997). Because of that relation it is easy to convert freight flow to trade flow or trade flow to freight flow. Inamura and Srisurapanon (1997) carried out a study using Inter Regional Input Output (IRRIO) Table and converted it to IRFF. “IRRIO model requires the Chenery-Moses type interregional square input-output (IRSIO) table or regional input-output tables, and national output (V) table as the input data” (Inamura and Srisurapanon, 1997). Inamura and Srisurapanon’s study comprises three sections (1997). First section describes the analysis of IRFF model using hybrid method. He uses IRSIO and National Output tables. The data is from the survey done by the Management and Coordination Agency of Government of Japan. In the second section the methodology of an analysis of IRFF by using a survey method is illustrated. This method requires two kinds of input data; the interregional 3-day data and one-year regional output vectors obtained from the survey done by the Ministry of Transportation of Japan (Inamura and Srisurapanon, 1997). Last section shows the comparison between technical coefficients of freight flows estimated by hybrid method and the ones complied by the survey (Inamura and Srisurapanon,

1997). As a result Inamura and Srisurapanon (1997) show the consistency of the estimated and surveyed IRFF.

According to some researchers (Nijkamp, Rietveld and Snickars, 1986; Inamura and Srisurapanon, 1997) input-output analysis has played a dominant role in regional modeling and it has been a powerful tool in the empirical description of the space economy.

2.4 Selected Studies

Similar cases to this research found in literature are given in the following paragraphs as selected studies.

These are;

- The models developed for some states in USA for their own purposes: Wisconsin Freight Model, Indiana Freight Model,
- Çelik's PhD research titled "Spatial Interaction Modeling of Interregional Commodity Flows", The Ohio State University, USA, 2001,
- Berkman's research titled "Analysis of Interprovincial Service Flows for the Determination of Hierarchy in Turkey" Middle East Technical University, Ankara, Türkiye, 1976.

In USA many states developed statewide freight model however only two of them are reviewed and given as a summary in the following paragraphs.

One of these freight models is the Wisconsin Freight Model which estimates 39 commodity groups between 140 traffic analysis zones (TAZ) by four transportation modes: air, water, truck and rail (USDOT-FHWA, 1999). The data used in the model is from Reebie's TRANSEARCH which is one of the richest databases about freight transportation in the USA (USDOT-FHWA, 1999). The TRANSEARCH flows are simply distributed at the county level by following the given four steps instead of developing generation equations (USDOT-FHWA, 1999). "First, the total flows are determined from the base year TRANSEARCH data for each commodity group. Second, freight origins are identified and assigned to the county level TAZs based on county

employment data” (USDOT-FHWA, 1999). Third, proportion of each commodity group’s flow destined for industrial consumption and destined for household consumption is determined based on a national input-output table (USDOT-FHWA, 1999). Finally, county-level destinations are allocated on employment and population information. That model forecasting of future freight flows depends on econometric models that include employment forecasts and productivity forecasts (USDOT-FHWA, 1999). Current modal share is projected into the future.

The other freight model is Indiana Freight Model which predicts both truck and rail traffic volumes for a network that includes TAZ for each of Indiana’s 92 counties and 53 other TAZs which include other states and District of Columbia (Horowitz and Farmer, 2009; USDOT-FHWA, 1999). The production and attraction information are based on county-level employment and population projections (Horowitz and Farmer, 2009; USDOT-FHWA, 1999). For areas outside Indiana, forecasts are based on national growth factors. Consequently trip generation freight shipments are distributed by gravity model. Finally traffic is assigned to the network after dividing the freight tonnages into an equivalent number of vehicles (USDOT-FHWA, 1999).

Çelik (2001) investigates interregional commodity flow in USA. The purpose of his study is to expand empirical research on interregional commodity flows. He finds the determinants of the flows of 16 commodity groups between origin and destination. Çelik uses commodity flow surveys in 1993 and 1997 in order to compare results. By using gravity model, he expresses the flow between any two points as a function of three vectors of variables. These vectors are origin variables, destination variables and friction between origin and destination variables. In his model origins serve as supply points and destinations serve as demand points. Origin variables are employments by sectors, value added by sectors, wholesale employment, personnel income per capita, total population and average plant size. Destination variables are manufacturing employment, wholesale employment, personnel income per capita and total population. Celik’s research is a spatial interaction model explained by variables of origin, variables of destination and a function between origin-destination. In addition, the function between origin and destination is expressed as geographical variables regarding distance between O-D pairs.

Çelik's research is developed for USA Continent regarding 48 states and 16 commodity groups. Çelik (2001) applied Box-Cox transformation $(X^{(\lambda)} = (X^\lambda - 1) / \lambda)$ to normalize the used data since many statistical tests and intervals are based on the assumptions of normality. In addition he compared the results of logarithmic transformation and Box-Cox transformation and summarized his conclusion as;

(1) “although past spatial interaction models of commodity flows have generally used gravity-type log-linear specifications, the optimized Box-Cox specifications proves to be superior to the log-linear one”, and (2) “while past empirical research has tried to best-fit simple functional forms with very few variables, that provide the highest fit, this research on the other hand selects a large number of explanatory variables” (Çelik, 2001, 109).

Çelik's (2001) empirical results are transportation costs explained in terms of distance and have a negative affect for all commodity groups and the adjacency significantly affects the trade.

Berkman's research which was performed in 1976 is on inter-provincial service flows in Türkiye. Berkman criticizes inter-provincial service flows (in terms of people) and spatial hierarchical pattern for provinces in Türkiye. She uses the method developed by Boudeville to compute service flows regarding the general definition of service as a commodity that is consumed where it is produced. Berkman proposes her hypothesis based on following assumptions;

- The flows analyzed will be net movements of services in terms of number of employees,
- There are no net flows between the exporting regions, or between the importing regions,
- For each service sector, production is assumed proportional to employment,
- The consumption of (or demand for) national services by a region is proportional to its income (Berkman, 1976).

Berkman uses employment figures of 1965 for 67 provinces according to 21 service sectors defined by State Institute of Statistics (now called Turkish Statistics Institute), 1965 population census results including income per capita values and 1965 Highway

Map to obtain distance matrices. She classifies service sectors in accordance with the classification made by State Institute of Statistics.

The following formula developed by J. R. Boudeville (1966) for France was resorted to calculate net exports (supply) and imports (demand) for each sector and for each province in her research.

$$X_{IJ} = E_{IJ} \frac{P_I Y_I}{P_N Y_N} E_{NJ} \quad (2.28)$$

Where;

$I = 1, \dots, m$

$J = 1, \dots, n$

$m = \text{number of provinces}$

$n = \text{number of sectors}$

$X_{IJ} = \text{amount of export } I \text{ region and import of the } J^{\text{th}} \text{ sector}$

$E_{IJ} = \text{region } I\text{'s employment in sector } J$

$P_I = \text{population in region } I$

$P_N = \text{national population}$

$Y_I = \text{income per capita in region } I$

$Y_N = \text{national income per capita}$

$E_{NJ} = \text{national employment in } J^{\text{th}} \text{ sector}$

At the first stage Berkman employs equation (2.28) for 21 service sectors and for 67 provinces to separate importing and exporting provinces. Berkman delivers the exporting and importing values for each province and for each sector in her research. In addition she presents these values as maps for 21 sectors to show spatial pattern of provinces as exporters and importers.

After calculation of net exports and imports for each region (province) these flows are distributed on the system. In order to find inter-provincial distribution system she uses the following formula adapting the minimization of transportation principle. She uses an optimization program.

$$\text{Minimize } T = \sum_I \sum_J d_{IJ} X_{IJ} \quad (2.29)$$

I = exporters

J = importers

d_{IJ} = Distance between the regions I and J

with regarding the following constraints:

$\sum_J X_{IJ} = X_I$ (a region can not export more than its capacity)

$\sum_I X_{IJ} = M_J$ (the total supplied to a region is equal to its needs)

$X_{IJ} \geq 0$ (all deliveries are positive)

According to Berkman (1976), service flows show the attraction of people to the service exporting centers, rather than sending to the places of demand. She concludes that there is no flow between cities where there is excess (more than local needs) export (supply) and between cities where there is excess import (demand) for each sector. However there are flows between cities where there are excess supply in one city and lack of demand in another city in accordance with the distance between them. Her second conclusion is that service activities are generally dense in big centers where there is diversification of functions and are performed at higher levels than local needs. Berkman explains the attraction of major centers by means of this result. The third conclusion is that at high levels of hierarchy there are a few predominant centers that influence the nationwide flows which are İstanbul, İzmir and Ankara (Berkman, 1976).

Berkman also aggregates 21 sectors into four groups: **Group 1:** Banking, Insurance and Cooperative Services, Air Transport, Shipping and Traveling Agencies and Storage, Recreational Services. **Group 2:** Electricity, Water and Gas Supply, Wholesale Trade, Sales of Furnitures and Fixtures, Sales of Pharmacies, Sales of Machinery and Equipment, Sales of Wood and Construction Materials, Sea Transportation. **Group 3:** Sales of Textiles and Footwear, Railway Transportation, Highway Transportation, Communication Services, Administrative Services, Personal Services. **Group 4:** Construction Industry, Sales of Food Products, General Services.

Berkman (1976) shows that the important exporters for Group 1 are İstanbul (48.8%), Ankara (40.5%), İzmir (5.5%) and Adana (2.2%) and main importers are Zonguldak, Kayseri, Kocaeli, Manisa, Urfa, Sivas, Kars and Adana. However the biggest exporters for Group 2 are İstanbul (50.5%), Ankara (14.5%), İzmir (4.6%), Hatay (3.9%), Samsun (2.8%), and İçel (Mersin) (2.6%) and important importers are Zonguldak, Ankara, Konya, and Adana. Also the main exporters for Group 3 are Ankara (18.7%), İstanbul (10.5%), Gaziantep (5.8%), Hatay (4.8%), İzmir (4.6%) and Bursa (4.2%) and main importers for this group are İstanbul, Zonguldak, Konya, Kocaeli and Kayseri. For the last group the important exporters are Ankara (20.7%), Trabzon (5.6%), Diyarbakır (4.4%), Aydın (3.8%), Gaziantep (3.4%) and Erzurum (3%) and main importers are İstanbul, Zonguldak, Konya and Adana.

2.5 Freight Data Requirements

Availability of data is one of the important issues of modeling studies and it differs by objective and type of the model (CALTRANS, 1992). Reliable, consistent, comprehensive and timely data about freight movement is needed to develop better models (TRB, 2003). In addition data is also important to validate and calibrate the model.

Transportation modeling efforts have traditionally suffered from lack of reliable data which generally occurs because of the cost and complexity to obtain the data (Victoria and Walton, 2004). Socioeconomic data at desired level for analyzing trip generation and commodity origin-destination data to both assign inter-zones freight movements by truck and to determine trip-generation factors are the major data gap areas (Victoria and Walton, 2004).

Travel Demand Models require a large variety of data compared to supply models (Garrido, 2003). The reason for this is that the demand models are essentially based on econometric models (Garrido, 2003). In addition there is a direct relationship between the quality of the data and the quality of the model, i.e., the nature of data restricts the choice of the model to a single option (Ortuzar and Willumsen, 1994). Moreover freight planning covers computationally data-intensive process (Southworth, 2003).

Travel Forecasting Guidelines (CALTRANS, 1992) recommends dividing the needed data into six groups as socioeconomic data, special trip generators data, external stations and trip network data, travel cost data and calibration and validation data.

Socioeconomic and demographic data involves direct observation of social and/or economic characteristics of regions (CALTRANS, 1992), such as population, number of households, number of employment, national accounts, vehicle ownership and land use. Data about transportation network characteristics are number of zones, centers of zones, number of links, each link lengths, capacity of links, speed and number of lanes in each link (USDOT-FHWA, 1999). Transportation system users' behavior data are however related with cost. These costs are vehicle operating cost, tolls, parking cost etc. and also taxes related with the selected mode (CALTRANS, 1992).

Researchers noted that extensive data is needed to develop better models since numerous parties are involved in freight issue (Horowitz and Farmer, 2009). In addition there are many transportation alternatives (modes, corridors, systems) that make the collection process more difficult.

“Sometimes data are unavailable at the desired level of aggregation. At this point, the modeler has two options; data disaggregation and data collection. Data collection involves surveys and other means of acquiring new data. This process of data collection however can be time consuming and expensive” (Stammer et al., 2002, 47).

The major freight flow data are; origin-destination of freight, type and characteristics of commodity, type of firm, value of goods, weight of goods, average shipment size, transportation time, mode of transport, market share, private or hire shippers, etc. (Murthy and Ashtakala, 1987; TRB, 2003). A good freight data consists of large-scale freight database with inter-modal flows. The steps to obtain freight data are adapted and given below (Roger Creighton Associates, Inc., Delmar New York and R. L. Banks & Associates, Inc., 1977):

1. Determine the purpose why freight data is needed (Identify the problem and objective),
2. Determine the needed data to solve potential problem (Identify data requirement),

3. Classify and prioritize data needs,
4. Search for available data (If all needed data is available go to step 8),
5. If needed data is not available decide data survey and type of survey,
6. Realize survey and collect data,
7. Record and archive data,
8. Solve potential problem.

The freight data is also categorized in two types as primary and secondary data (Roger Creighton Associates, Inc., Delmar New York and R. L. Banks & Associates, Inc., 1977; Cambridge Systematics, Inc., Comsis Corporation, and University of Wisconsin-Milwaukee, 1996; Victoria and Walton, 2004). Primary data is the data obtained using survey techniques like tube counts, classification counts, roadside surveys, mail back surveys, surveys with freight terminal operators and port authorities, and interviews with shippers and carriers (Cambridge Systematics, Inc., Comsis Corporation, and University of Wisconsin-Milwaukee, 1996). Primary data collection activities are both expensive and time consuming. In addition, primary data collection is usually considered when there is a lack of data or there is a deficiency in the existing secondary data (Roger Creighton Associates, Inc., Delmar New York and R. L. Banks & Associates, Inc., 1977). Secondary data sources include existing reports, abstracts, or statistics from various public and private agencies at the local, provincial and national levels, which can be adopted in the freight analysis (Cambridge Systematics, Inc., Comsis Corporation, and University of Wisconsin-Milwaukee, 1996; Victoria and Walton, 2004). However, these data may become outdated or usage restricted.

“Principal data source descriptions have more information, including (1) the collecting agency, (2) the form of the data, (3) time period covered, (4) coverage, (5) relevant context of the source file, (6) available summaries, (7) a description of the data collection process, (8) significant exclusion of data, (9) future update of extension plans, (10) data availability and constraints on dissemination, and (11) an evaluation of the data source as to its usefulness in nationwide freight transportation systems planning” (Roger Creighton Associates, Inc., Delmar New York and R. L. Banks & Associates, Inc., 1977, 15).

The initiative to improve freight data must come from central government in cooperation with local governments (TRB, 2003). The followings are adapted from Roger Creighton Associates, Inc., Delmar New York and R. L. Banks & Associates, Inc., (1977) and presented as the basic strategies to improve quality and quantity of available data.

1. Assembling of similar data sets,
2. Archiving of available data,
3. Publishing and disseminating data,
4. Establishing close working relationship with carriers,
5. Expanding the sample rates of national data sets,
6. Realization of more surveys to collect more data,
7. Forming data banks in the related government organization and sharing data,
8. Convincing private agencies involved in freight issues to keep and share their data,
9. Expanding the census of transportation.

In transportation planning, most of the data are collected through surveys or questionnaires (Ortuzar and Willumsen, 2001). However the cost of surveying is very high and needs a substantial amount of personnel. Therefore, sampling is also used as an important data collection method for freight data gathering. Collection method to obtain data is sampling so survey procedure and survey responsibility have direct impact on the reliability of data. Sample size is also important; however there is not a definite way of selecting sample size (Ortuzar and Willumsen, 1994). The larger the sample size the more reliable the sample estimates. Surveys are classified as Origin-Destination (O-D) surveys, single station O-D surveys, truck travel surveys, truck intercept surveys, cordon surveys, license plate surveys and on-board surveys by the techniques mail out/mail back surveys, internet surveys, telephone interviews, personal interviews, roadside interviews etc. (Lau, 1995; Boile et al., 2004; Victoria and Walton, 2004). These surveys may be one-time or periodical.

In addition data to validate and to calibrate the model is also important. “Calibration data is used to determine the parameters and constants of the model travel demand equations. Validation data is used to determine the accuracy of the model” (CALTRANS, 1992). Hence “calibration applies to each step in modeling process, while validation applies to the model as a whole” (USDOT-FHWA, 1999).

Freight transportation is commonly measured and described by two terms; commodity flow (CF) and vehicle flow (VF) (Regan and Garrido, 2002; Mao and Demetsky, 2002; Boile et al., 2004). CF are represented by an OD matrix focusing on type and quantity of moved goods however VF are represented by traffic flows in different modes (Reagan and Garrido, 2002). Therefore the modeling approach are conducted employing two-sub approaches such as the vehicle based approach (focus on commercial vehicle trips) and the commodity based approach (focus on commodity flows) (Victoria and Walton, 2004; Boile et al, 2004). Freight movements are classified in various units such as weight, volume and value of goods and also number of trucks which explains their analytical complexity (Victoria and Walton, 2004; Holguin-Veras and Thorson, 2002). These features represent the ways to define and measure freight transportation demand in the above mentioned approaches (Holguin-Veras and Thorson, 2002). Vehicle based modeling considers both loaded and empty trips, however, commodity based modeling has limitation on this issue (Holguin-Veras and Thorson, 2002).

The survey which is generally structured according to sampling of shippers or recipients from numerous businesses is called Commodity Flow Survey (USDOT-FHWA, 1999). Commodity Flow Survey can give good estimates of external-to-internal flows and internal-to-external flows (USDOT-FHWA, 1999). Commodity Flow Survey is also defined as providing data on the flow of goods by mode of transport (Garrido, 2003). Commodity flow surveys are performed to capture the data on origin and destination of the flows, type of commodity, average shipment size, annual tonnage, mode of transport, shipment value among and within cities and traveled distance (km) by the modes of inter-modal combinations (Ashtakala and Murthy, 1993).

Commodities have been classified according to mobility, dispensability, geographic occurrence, and weight loss (Isard, 1956). In addition there are other characters for commodities. These are perishability, fragility, volatility, and seasonality (Roger Creighton Associates, Inc., Delmar New York and R. L. Banks & Associates, Inc., 1977; Meyer and Straszheim, 1971).

Freight demand is derived from the socioeconomic system in which raw materials, semi-finished products and manufactured goods are needed at specific locations at specific times (Russo and Comi, 2002). Therefore dividing commodities into groups as raw

materials, semi-finished goods, and manufactured (finished) goods is also important for flow modeling (Garrido, 2003; Rodrigue, Comtois and Slack, 2006). Semi-finished (also known as intermediate goods) are sold to local industries for use in producing other products; however, finished goods are sold to final consumers (Schaffer, 1976). The explanation on this classification is given in the following paragraphs:

Raw Materials: “The origin of these goods is linked with environment (agricultural products) or geological (ores and fossil fuels) conditions” (Rodrigue, Comtois and Slack, 2006, 152).

Semi-finished Products: “These goods already had some transformation that confers them an added value. They involve metals, textiles, construction materials and parts that will be used to make other goods” (Rodrigue, Comtois and Slack, 2006, 152).

Manufactured Goods: These are the goods that are shipped towards larger consumption markets (Rodrigue, Comtois and Slack, 2006).

The shape of exporting and importing commodity flows of a region is kaleidoscopic (Figure 2.3, Figure 2.4) (Isard, 1960). The economy of a region is influenced very much by these inflows (import) and outflows (export). Regional analysis therefore must be outward as well as inward.

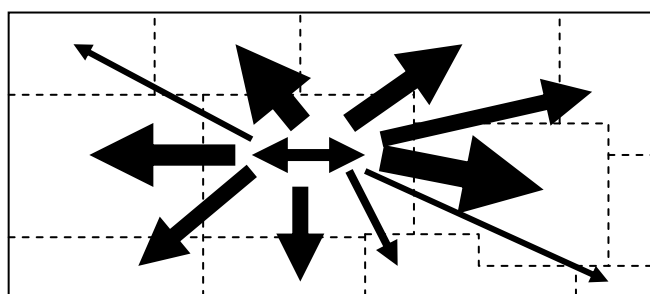


Figure 2.3 Schematic View of Origin of X Region Y Products

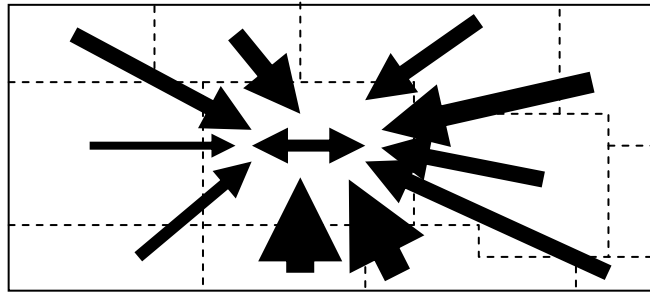


Figure 2.4 Schematic View of Destination of X Region Y Products

Data requirements have been subdivided into five major groups according to Roger Creighton Associates, Inc., Delmar New York and R. L. Banks & Associates, Inc. (1977) as follows;

1. Traffic flow data,
2. Carrier data,
3. Shipper/Consignee attribute data,
4. Physical and operational data,
5. Direct and indirect impacts data.

Data in this study however is reviewed and analyzed in three groups as follows;

1. Network and Zoning Data,
2. Traffic Flow Data,
3. Land use, Socioeconomic and Demographic Structures Data.

2.5.1 Network and Zoning Data

Katz and Shapiro (1994) defined network as a system of compatible devices and as a system that can be any combination of a durable goods, associated goods and services that perform some desired function. In terms of transportation the desired function is the movement of people and goods; a durable good is transportation fixed facilities; associated goods are transportation vehicles; and associated services are services of vehicle operators, maintenance fixed facilities, traffic operations and some others (Yevdokimov, 2009).

In brief, a transportation network is represented by spatial structures that permit either vehicular movement or flow of some commodity. It “consists of entirely nodes and links and the values of their attributes” (USDOT-FHWA, 1992). The network representation of the highway system is also composed of links, centroids, centroid connectors and nodes to serve and to facilitate travel between Traffic Analysis Zones (Ortuzar and Willumsen, 2001). Transportation network is perceived and grouped in three types which are infrastructure, network as transportation cost function and network as spatial objects (Yevdokimov, 2009).

One of the most important decisions to represent a network is defining the level of spatial units (Ortuzar and Willumsen, 2001). These spatial units, called zones, may represent a region, or province, or city, or town or a smaller unit. However, analysts are significantly constrained by resource availability in deciding how many zones to create in a region and what the boundaries should be for these zones. Generally, more zones increase the accuracy of the model; however, they increase the computational complexity as well (Ortuzar and Willumsen, 2001). Additionally land use data and socioeconomic data are difficult to obtain for finer geographic levels.

Traffic Analysis Zones (TAZ) may consist of entire cities or groups of cities in regional or national projects (Cascetta, 2001) and based on census divisions. According to Ortuzar and Willumsen (2001), there are six criteria about zoning. These are: 1- Zoning size must be such that the aggregation error caused by the assumption that all activities are concentrated at the centroid is not too large, 2- The zoning system must be compatible with other administrative divisions, particularly with census zones, 3- Zones should be as homogeneous as possible in their land use and/or population composition, 4- Zone boundaries must be compatible with cordons and screen lines and with those of previous zoning system, 5- The shape of the zones should allow an easy determination of their centroid connectors, 6- Zones do not have to be equal size (Ortuzar and Willumsen, 2001, 115).

Trips which are being produced in one TAZ and being attracted to another TAZ are called inter-zonal trips while trips starting and ending in the same TAZ are called intra-zonal trips (Cascetta, 2001).

Centroids are the center of activity of the zones which do not represent the geographic center of the zone, unless development is uniform within the zone (CALTRANS, 1992). According to Cascetta (2001) centroids are fictitious nodes and are approximation of the actual starting and ending points of trips.

“A **link** is a straight line segment representing a portion of a travel path”, “**nodes** are primarily used to represent interactions or bends in a road” and “**path** is a sequence of nodes and links, starting at an origin centroid and ending at a destination centroid” (USDOT-FHWA, 1999, 43).

“Nodes in a transportation network are usually by the cities that are connected to each other by a particular set of linkages” (Taaffe, Gauthier, and O’Kelly, 1996, 12). A model network typically contains information about existing traffic data, lengths, speeds, capacity values, functional class and other data items of road network such as type of road, road width, number of lanes, etc. (Ortuzar and Willumsen, 2001).

2.5.2 Traffic Flow Data

Traffic flow data are gathered from surveys. These surveys include, but not limited to, traffic counting and classification surveys, O-D surveys and truck travel surveys (Boile et al., 2004; Cambridge Systematics, Inc. et. al., 2005). Other than traffic data, highway data, such as geometric and operation data is critical for building an accurate model. This data is generally available from the Highway Information System (HIS) database. Travel time or travel distance data are also required for network representation.

Traffic Counts and Classification Surveys

Traffic counts are conducted manually or by automatic devices. There are basically three types of counts performed generally by government authorities to obtain traffic values. These counts are continuous counts, seasonal counts and coverage counts (USDOT-FHWA, 1999; Cambridge Systematics, Inc. et. al., 2005). Continuous counts are realized throughout the whole year to keep all data related with traffic to get hourly, daily, weekly, monthly and seasonal variation (Boile et al., 2004). Seasonal counts are realized to get seasonal variation, however coverage counts are short term counts and done to obtain traffic values for each road segments (USDOT-FHWA, 1999).

Counts are also classified in two types as traffic counts and classification counts. From traffic counts total traffic volume of each road segments are obtained. However from classification counts traffic volume by vehicle types of each road segments are obtained. Classification counts on highways are realized in point of separation of freight traffic from passenger traffic and especially from passenger car traffic (USDOT-FHWA, 1999).

Number of vehicle category differs from nation to nation but generally considered as autos, buses and trucks. Number of vehicle category may be defined according to vehicle length and number of axles and distances between axles and also according to purpose of transportation as freight or passenger. Sometimes the classification is considered as small, medium and heavy vehicles. Automatic classification surveys are realized by pneumatic tube counters, loop detectors, piezoelectric sensors, ultrasonic sensors, radars, microwaves and videos (Boile et al., 2004; Victoria and Walton, 2004; Cambridge Systematics, Inc. et al., 2005).

From these counts a.m. peak period, p.m. peak period, midday time period and nighttime period are also obtained (Cambridge Systematics, Inc. et al., 2005). In addition Annual Average Daily Traffic (AADT) values are estimated for each road segment regarding daily counts.

“Correction factors such as seasonal adjustment factors, day of week factors and axle correction factors are applied in the calculation of the AADT estimates” (USDOT-FHWA, 1999, 62).

By using the correction factors AADT values for all road segments are obtained and traffic volume maps are produced. These data are generally used in order to validate the model, to obtain origin destination matrix and also to find truck trip generation rates (Mao and Demetsky, 2002).

In addition, time of day distribution, percent of each vehicle type by hour of day, day of week distribution, month of year distribution and similar data are obtained by these surveys.

Truck Travel Surveys

Truck travel surveys are conducted in order to obtain data about freight transportation on highways. The past experience on truck travel surveys is not so different than the current ones. The difference is only the methodology. The most common surveys in the past were the roadside interviews; however this method is discarded in many developed countries since it is very expensive and frequently impossible to find locations to stop and interview trucks at road side (Fisher and Han, 2001). But that system is still used in Türkiye. Other surveys are mail out-mail back surveys, telephone interviews, combined telephone-mail out-mail back surveys, toll gate surveys, and similar surveys (Cambridge Systematics, Inc., Comsis Corporation, and University of Wisconsin-Milwaukee, 1996).

From these surveys origin and destination information of freight flow is easily obtained and therefore these surveys are used to generate nationwide or regional origin-destination matrix. This data is most commonly used in developing a model, finding trip generation by TAZs and in distribution of freight flows between TAZs. It is also used for pavement management system, travel time analysis, truck route assignments, impact of toll facilities and to get information on travel behavior (Boile et al., 2004).

Conducting these surveys is very expensive. Especially telephone interviews are very expensive and require a lot of qualified staff (Lau, 1995; Fisher and Han, 2001). Roadside surveys are also difficult to conduct since drivers do not easily accept to stop but they are “very good at high response rate with complete information” (Lau, 1995; Victoria and Walton, 2004).

Survey outputs are average vehicle weight, average axle weight, truck size, average trip length, average travel duration, route choice, internal-internal, internal-external, external-external trips, international freight traffic, freight type distribution, average vehicle weight by freight type, average vehicle weight by commodity types, etc. (Lau, 1995).

2.5.3 Land Use, Socioeconomic Structure and Demographic Data

Land use, socioeconomic and demographic structure are all important inputs for freight modeling. Models cover a basic socioeconomic and demographic theory since travel

patterns depend not only on modal attributes but also on environment (Quandt, 1970). However socioeconomic and land use data are sometimes confused. “Land use data involves data in areal units which are as km² forest, km² agricultural area etc.” but socioeconomic data involves direct observations of social and/or economic characteristics such as vehicle ownership, employment, employment by economic sectors, Gross National Product (GNP), Gross Domestic Product (GDP), etc. (CALTRANS, 1992). Additional land use data includes density data such as employment density, population density, service employment density, employment-population balance. (Parsons Brinckerhoff Quate & Douglas, Inc., 1994; Ferdman, Shefer and Beckhor, 2008) Demographic data is population, household size and number of households, population distribution by rural and urban areas, population distribution by gender, etc. The most obvious demographic factor explaining the travel demand between zones is population (Quandt, 1970).

Socioeconomic and demographic data is generally required for freight traffic generation. Truck trips and freight volume (tonnage) generation requires travel or commodity flow data and demographic data. Increasing vehicle ownership is accepted as the main factor to model urban passenger transportation however increasing consumption and production as a result of increased population, increased GDP, increased employment, increased trade, etc. are the main factors to model freight transportation.

2.6 Summary

In this chapter, background information on freight modeling, modeling process, types of modeling and modeling needs are given. Since a model is regarded as a simplified representation of the real world, modeling is generally defined as empirical research thus it needs qualified and quantified data. The greatest challenge of modeling studies is therefore data availability.

In the literature there are many studies on passenger modeling but freight modeling has been in the process of development during the last decades. Even though there are many actors, and direct and indirect effects of factors on freight modeling, theories are very similar in terms of major steps.

In the literature there are more studies on the traditional four-step model. The four-step model is in a way the key component of travel modeling in a series of stages which are generation, distribution, model split and assignment. Planners usually prefer to apply four-step approach. Many other developed and detailed models are itemized processes of the stages of four-step models. Some of them concentrate on one of the steps and others on more steps. For example spatial interaction models constitute the distribution stage of the four-step model.

Spatial interaction models are very reliable at regional transportation modeling to show not only spatial interaction but also economic interaction. Economic interaction or named as trade between regions is very influential for freight movement forecasting to make better transportation planning and to develop transportation policies.

Data requirement is discussed in detail in this chapter emphasizing that data requirement is critical not only to develop a model but also to calibrate and to validate the model. Collecting and dissemination of data are generally performed by public authorities, not only at national but also at local level. However some of the data are outdated or their usage is restricted. In addition collection of good data is a time-consuming and a very expensive process.

CHAPTER 3

METHOD OF RESEARCH

When a new transportation facility is to be built, a transport model is usually employed to determine how much traffic the facility will carry. Traffic forecast is one of the key factors to determine policies and to make decisions about economic growth, land use, transportation congestion, environmental effects, traffic safety, etc. Therefore traffic forecasts are essential to make decisions and to develop strategies on national transportation investment.

Transportation models are regularly applied in many countries around the world to predict the international, national, regional, or local traffic flows (de Jong et al., 2006). A transport model consists of equations combining inputs and parameters that express how the output, such as travel demand or link flows, depends on inputs (de Jong, et al., 2006). Briefly transportation demand models are the tools to forecast the traffic and to better understand the travel behavior between units of analysis. These tools are based upon the relationship between socioeconomic characteristics and travel patterns.

Freight models in the literature generally depend on the methods and models developed for passenger transportation (de Jong et al., 2002). Most of the models are derived from the traditional “four-step model”. The steps are “trip generation”, “trip distribution”, “mode split” and “traffic assignment” (Ortuzar and Willumsen, 2001)..

Transportation demand models are data hungry, complex and time consuming models. In recent years, computer technologies are extensively serving to solve the computational difficulties of the models and to save time. Geographic Information System (GIS) based maps are also produced using the advantage of the developments of computer technology and transportation models use these maps as inputs on network. Most of the transportation modeling software are GIS based and provide graphical environment for both storage and representation of modeling data bases (Chang and Meyers, 1999). Thus researchers are recently developing models on the more complex computational

processes. Transportation demand models cover both passenger demand model and freight demand model.

Freight demand models need data such as “transportation networks”, “socioeconomic and demographic structures data” and “truck travel data” to determine the expected demand for transportation facilities. Within the models, mathematical equations are used to explain truck trips.

The model applied in this research covers only highways regarding that more than 90% of freight and passenger flows are on highways in Türkiye (KGM, 2007). The whole process in this research is based on both commodity flows and truck trips since data on both truck trips and volume of commodity are available. Modal split stage is not included in this research due to having high percentage of modal share of highways and the availability of truck trip data. In addition truck traffic is not assigned to highway network and traffic assignment step is also not covered in the model. The model is empirically developed covering two steps of the traditional “four-step model” which are “trip generation” and “trip distribution” to determine freight demand between origin and destination pairs and to explain them in terms of mathematical equations.

The main objectives of this research are twofold. The general objective is to display the relationship between regional economic development and regional freight demand. The specific objective is however to describe a simplified and empirical freight demand model for Türkiye by applying truck trip generation and truck trip distribution stages of the traditional four-step model to forecast freight demand on Türkiye’s highway system. The developed model is nationwide which is a big scale and therefore is expected to give better results on long distance and on inter-zonal (inter-provincial) freight movements. It is a single modal (uni-modal) - single commodity (uni-commodity) model which explains the total freight movement between provinces in Türkiye.

3.1 Database

This research is an empirical study and therefore a considerable amount of effort was spent on data issues. Data collection needs budget, staff and time; however these were not available for this research. Yet, the readily available data on truck travel surveys

named as axle load surveys by General Directorate of Highways (KGM) is used for modeling of freight demand. Three data sets are used in this research. These are “transportation and network data”, “freight traffic flow data”, “socioeconomic and demographic structures data”.

“Transportation and network data” is about the highway system, such as traffic analysis zones, links, nodes, etc., “freight flow data” is truck travel origin-destination data, and “socioeconomic and demographic structures data” is about population, household, employment, income, vehicle ownership, and similar. Changes in population, employment, economic conditions, etc. play an important role in the quantity of transportation demand.

The following steps are used in data mining and analysis to develop a model.

- 1- Identification of variables,
- 2- Checking data availability and reliability,
- 3- Collecting and archiving the available data,
- 4- Deciding on the related surveys and sampling for unavailable data,
- 5- Permission of related authorities to conduct the surveys for unavailable data and execution of the surveys by related authorities,
- 6- Gathering all related data,
- 7- Regarding all data limitations,
- 8- Running the model,
- 9- Model calibration.

The sources of data for modeling studies are mostly public authorities. Even some data required for modeling are open to public use, some of them are restricted. In addition to that some of the required data are up-to-date but some of them are outdated or not released for some years. In this study the data source about freight flow, highway system network and characteristics, truck trip characteristics and the like is General Directorate of Turkish Highways (KGM), and the data source about demographic and socioeconomic characteristics of zones is Turkish Statistics Institute (TÜİK).

3.2 Method of the Research

This research uses freight flow survey data and statistical approaches in order to estimate freight flows at national level between provinces. The main steps of the research are developing Origin-Destination (O-D) matrix, developing freight trip generation equations by means of regression analysis and applying gravity model for freight trip distribution to estimate freight demands between O-D pairs which are provinces and calibration of the Gravity Model comparing simulated and observed O-D pairs and trip length frequency distribution. Studies done on each step are explained in more detail in the following sections, and the steps of the research are given in Figure 3.1 as flowchart.

3.2.1 Formation of Base Origin-Destination (O-D) Matrix

Origin-Destination matrix is a key element of the traditional four-step model and widely used in transportation models. This research starts with the formation of nationwide freight flow O-D matrix regarding that this matrix corresponds to the distribution stage of the traditional four-step model.

The developed matrix is an observed matrix and represents transportation demand by means of trip matrices between zones. Each cell of the matrix is the representation of the freight flow between origin and destination pairs which are provinces. It is generated from outcomes of roadside surveys. This matrix is also a representation of spatial interaction of freight movements between provinces as a result of trade and socioeconomic interactions. The rows of this matrix represent the center of the Traffic Analysis Zones (TAZ) as origins of the freight movements and the columns of this matrix represent the center of the TAZs as destinations of the freight movements. Three (number of truck trips, tonnage of moved goods, tonxkm freight mobility) three-dimensional (origin, destination, commodity type) matrices are obtained at this stage of the study.

Truck trips are classified as internal, external and international in this research. Internal trips (intra-provincial) are the trips whose origin and destination are within the same province. External trips (inter-provincial) are the trips between provinces and international trips are the trips with origin, and/or destination in different countries.

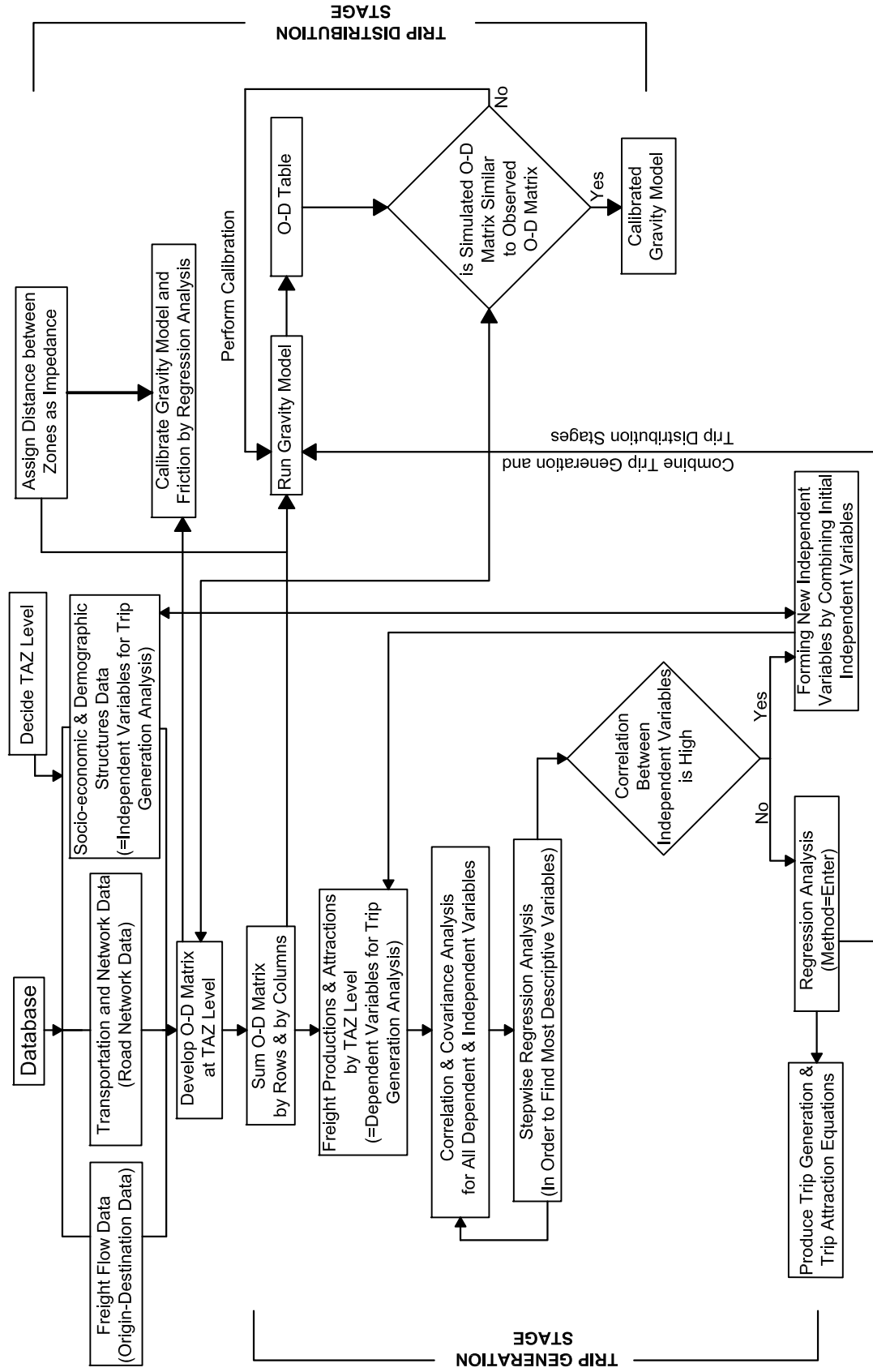


Figure 3.1 Stages of the Research

There may be failures to capture some trip pairs, especially intra-provincial truck trips because of the insufficiency of surveys to give intra-provincial truck trips. Therefore these matrices do not give good results for short distance movements. In the observed O-D matrices the geographic level is the province but it may be aggregated for a larger geographic level. They are also static O-D matrices where flows do not depend on the time of the day and day of the year. All demands in this research are determined both as number of truck trips and tonnage of moved goods in a year.

3.2.2 Freight Trip Generation by Provinces

Formation of the trip generation equation is one of the main steps of this research. Trip generation is the prediction of the total number of trips that will be generated in each zone by converting demographic and socioeconomic variables into truck trip productions and attractions. Trip generation models are truck trip based or commodity based. Regression analysis is traditionally applied in order to understand the relationship between socioeconomic development and freight flow. The trip production module is employed to estimate the number of truck trips produced from a zone and the trip attraction module is employed to estimate the number of trips attracted to a zone. The inputs are zonal demographic and socioeconomic variables and the model outputs are truck trip production and attraction values of the zones.

Freight Productions and Attractions by Traffic Analysis Zones (TAZ)

The first stage of the model application is the calculation of freight production and attraction of each province, as well as explaining them with independent variables via regression analysis. In addition trip generation equations are developed for trip productions and attractions, assuming trips are not chained.

Independent variables may be the indicators on either demographic and socioeconomic activities or land uses. However, while land use may be an important independent variable for passenger trip generation, employment may be an important independent variable for freight trip generation. Therefore selection of independent variables is one of the critical steps in this research and regression analysis is used to model the demand and to determine the significant variables.

The summation of rows in the O-D matrix gives the production of the provinces and summation of columns gives the attraction of the provinces as freight flows. All freight flows of each province are developed both as number of truck trips and tonnage of goods as originated from and directed to.

Outputs of the Model

Dependent variables are expected outputs of the model and are produced empirically from the observed O-D matrices, and explained by origin and destination socioeconomic variables as number of truck trips and tonnage of moved goods. In many studies, production and consumption of goods are measured in value (currency) and need to be converted to tonnage of shipments (using value-to-weight ratios). Then commodities are allocated to modes by freight mode and finally converted to truck trips. Many studies convert tonnage of freight flows into truck trips using average payload factors. However, in this research this step is not applied since truck trips are directly obtained from observed O-D matrix as both tonnage freight flows and number of truck trips. In this way empty truck trips are also covered indirectly.

The dependent variables are total number of trucks originating from provinces (NOTor), total tonnage of moved goods originating from provinces (TOMGor), total number of trucks ending at provinces (NOTdes) and total tonnage of moved goods ending at provinces (TOMGdes).

At the beginning of the research, O-D matrices where the commodity types are treated as a third dimension are developed to obtain all these variables for each commodity group, but the used surveys are not very good to obtain each TAZ's production and attraction by commodity types. Therefore these details are not considered in regression analysis and the developed model is a single commodity model i.e., all commodity groups are aggregated. However, for each province, the attraction and production quantities of freight flows as tonnage of moved goods and number of truck trips by commodity types are produced and given in Chapter 4.

Inputs of the Model

The main independent variables that are used in many studies to obtain freight trip generation equations are “employment” and “Gross Domestic Products”. In order to estimate accurate results, employment data should be disaggregated by economic sectors. According to Ortuzar and Willumsen (1994) most descriptive independent variables for freight trip productions and attractions include: number of employees, number of sales, roofed area of firms, and total area of firms.

The choice of significant independent variables is one of the most essential decisions in formulation of trip generation equation. However, there is not a single method to determine how many regressors to include. To make a decision in this case, the strong theoretical base is found and each variable is tested (t-test) to decide whether it is significant or not. An extensive number of regression analyses are employed to determine more significant variables. The limitation of data about independent variables is one of the greatest problems of regression analysis. Some of the indicators which may explain the relation with freight flow better are not available at province level therefore the ones available are preferred. In addition, new variables are obtained by combining preferred variables such as GDP per household, number of employees per household, dependency ratio, etc. to avoid multicollinearity.

The potential independent variables which are available at province level are population, the number of households, and the number of employees, gross domestic products, land squares and vehicle ownership by vehicle types. Since the base year is selected as 2004, the independent variables of provinces provided for 2004 are obtained. Land squares and vehicle ownership by vehicle types given by TUIK and population for 2004 forecasted by TUIK are used. However, GDP, number of employees, and number of households are not available for the year 2004, therefore by using trend extrapolation these variables are estimated for the year 2004 and for all provinces.

The acronyms of variables are Population (POP), Population Growth Rate (POPGR), Number of Households (NHH), Land Squares (LS), Density, Employment (EMP), Employment Excluding Agriculture (EEXCAGR), Percent of Employment Excluding Agriculture Sector (PERCENT), Gross Domestic Products (GDP), Number of Total

Vehicles (NTV), Number of Passenger Cars (PC) and Number of Trucks (TT). Production and attraction values of provinces as number of trucks and tonnage of freight volume are estimated by the equations that were obtained as a result of regression analysis.

Regression Analysis

Regression analysis is a statistical tool to investigate the relationship between two or more quantitative variables: a dependent variable (response variable), whose value is to be predicted, and an independent variable(s) (explanatory variable), which is available in terms of a mathematical model (Alpar, 2003).

In this research first simple regression analyses are performed to understand the relation between all independent variables (socioeconomic indicators) and their other mathematical forms (such as quadratic, cubic, inverse, logarithmic, etc.) to include the non-linear relationships between dependent variables (freight trips). Later, equations of stepwise multiple linear regression are applied that relate freight volume (and number of trucks) and variety of demographic and socioeconomic indicators and their other mathematical forms to find the significant indicators. Models with two or more variables give better equations than the ones with a single variable. Multiple regression analyses are performed and all GOF test checked with providing all regression assumptions.

The major conceptual limitation of regression techniques is that one can only ascertain relationship, but never be sure about underlying causal mechanism (StatSoft, Inc., 2009).

3.2.3 Freight Trip Distribution by Provinces

Trip distribution model provides a new origin-destination trip matrix to reflect new trips in the future made by population, employment, and other socioeconomic changes and the reflects of the changes in these variables also changes the freights choice of destination. Trip distribution models are regarded as spatial interaction models and spatial interaction models refer to the family of the models that describe the trip distribution process as a function of interactions in space (Holguin-Veras, 2001). These models are referred in the

literature as gravity, entropy, logit and neural network-based models (Ortuzar and Willumsen, 2001; Rodrigue, Comtois and Slack, 2006).

In this research Gravity Model is used as trip distribution model and the socioeconomic interactions in space are explained by Newton's Gravitational Law. The assumption of this model is that all trips starting from a zone are attracted by various traffic generators in other zones. This attraction is directly proportional to the relative attraction of the zone and inversely proportional to the separation between the origin and destination zones. The separation is generalized to allow inclusion of any travel index. This index is used as zone-to-zone travel distance more precisely travel time or travel cost. The general formulation of the spatial interactions is adapted to reflect this basic assumption to form the elementary formulation of the gravity model as (Rodrigue, Comtois and Slack, 2006);

$$T_{ij} = k P_i A_j F_{ij} \quad (3.2)$$

Where;

- T_{ij} are the trips between the origin i and destination j ,
- P_i is the size of the movement starting from origin i ,
- A_j is the size of the movement ended at destination j ,
- F_{ij} is the friction of movement between origin i and then destination j ,
- k is model constant and obtained empirically.

There are several model forms considering the Newton's theory of gravity and formulated as (Rodrigue, Comtois and Slack, 2006; Rodrigue, 2007);

$$T_{ij} = k T_i^\lambda T_j^\alpha / (d_{ij}^\beta) \quad (3.3)$$

Where;

k	proportionality constant
α	potential to attract movements
λ	potential to generate movements
β	a parameter of transport friction,
d_{ij}	is distance or cost or time function,
T_i	is inbound trips, destinations,
T_j	is outbound trips, origins.

“Variations of beta, alpha, and lambda exponents have different impacts on the level of spatial interactions” (Rodrigue, Comtois and Slack, 2006; Rodrigue, 2007).

This basic interaction is usually rewritten as the following formula in order to be used in transportation planning (Batten and Boyce, 1986):

$$T_{ij} = k O_i D_j f(d_{ij}) \quad (3.4)$$

Where;

T_{ij}	is flow from place i to place j ,
k	is constant of proportionality,
O_i	is flow originating from place i ,
D_j	is flow terminating at place j ,
$f(d_{ij})$	is distance impedance function between places i and j .

“Impedance” is the resistance in travel between two zones represented by travel time or distance or cost (Fisher, 2006; Wilson, 1970). The impedance variable is explained as, the longer it takes to travel between two zones, the less likely there will be an interaction between them, and the shorter travel time leads to the greater interaction between zones. Since inter-provincial movements are of interest in this study, travel distance is used as the impedance factor. The followings are cited in the literature as popular impedance functions and the first two of them are employed in this research (Fisher, 2006; Ortuzar and Willumsen, 2001):

The exponential form	$f(d_{ij}) = e^{-\beta d_{ij}}$
The polynomial function	$f(d_{ij}) = d_{ij}^{-n}$
The combined function	$f(d_{ij}) = d_{ij}^n e^{-\beta d_{ij}}$

Developing a gravity model is a trial and error process that requires considerable care (Batten and Boyce, 1986). This process is often called calibration and identifies the approximate impedance function (Ortuzar and Willumsen, 2001).

An important consideration in developing trip distribution models is balancing productions and attractions, i.e. sum of attractions (consumption) is equal to sum of productions in the study area. In other words, total number of produced trips (the origins O_i) at all zones will be equal to the number of attracted trips (the destinations D_j) to them as in the following equation (Leung, 2007; Ortuzar and Willumsen, 1994):

$$\sum_{j=1}^n O_{ij} = \sum_{i=1}^n D_{ij} \quad n = \text{number of TAZs} \quad (3.5)$$

There are four gravity models as “unconstrained”, “origin constrained”, “destination constrained”, and “doubly constrained” improved by Wilson (1970). These are mathematically formulated as (Holguin-Veras et al., 2001);

$$\begin{aligned} T_{ij} &= O_i D_j f(d_{ij}) && (\text{unconstrained gravity model}) \\ T_{ij} &= O_i (D_j f(d_{ij}) / \sum_j D_j f(d_{ij})) && (\text{origin constrained gravity model}) \\ T_{ij} &= D_j (O_i f(d_{ij}) / \sum_i O_i f(d_{ij})) && (\text{destination constrained gravity model}) \\ T_{ij} &= A_i O_i B_j D_j f(d_{ij}) && (\text{doubly constrained gravity model}) \end{aligned}$$

Where;

$$A_i = 1 / (\sum_j B_j D_j f(d_{ij}))$$

$$B_j = 1 / (\sum_i A_i O_i f(d_{ij}))$$

Unconstrained gravity model proposes that there is not any constraint on the total number of trips produced and attracted by the traffic analysis zones, origin constrained gravity model means origin limits the total production by the TAZs and destination constrained gravity model means destination limits the total consumption by the TAZs

(Holguin-Veras et al, 2001). In addition doubly constrained gravity model means both number of trips produced and attracted by the TAZs are constrained (Holguin-Veras et al, 2001).

In this research, T_{ij} (freight movement starting from i and ended at j), O_i (total freight movement originated from i), D_j (total freight movement ended at j) are all obtained from the observed O-D matrices as number of trucks and as tonnage of moved freight. In addition, $f(d_{ij})$ is the impedance between origin and destination zones and the impedance is represented as “distance” between zones. In this study, logarithmic transformation of equation (3.3.) is also employed to find the related parameters via regression analysis and gravity model is calibrated.

Additionally the travel modeling package TRANPLAN is used to obtain the simulated O-D matrix and also to calibrate the gravity model by comparing the observed and simulated O-D pairs and trip length distributions. The parameter, β , is calibrated to make sure that the Trip Length Distribution (TLD) is reproduced as closely as possible. TRANPLAN run as many times as possible until the observed TLD is closely fit to simulated TLD. As a result, the best fitting β value is obtained.

Gravity models are popular trip distribution procedures and rely on historical O-D information in order to calibrate. Gravity model is used for trip distribution and also to determine and to calibrate impedance function. Furthermore the observed (empirically produced) O-D matrix is calibrated by the predicted O-D matrix.

3.3 Summary

Trip generation and trip distribution stages of the four-step model are applied in this research to determine freight demand model for Türkiye. The developed model is nationwide and explains freight flow between provinces. It is a single modal and single commodity model and developed in two dimensions which are number of truck trips and tonnage of goods.

First freight trip production and attraction equations are identified by means of regression analysis and employing socioeconomic and demographic variables for the

year 2004. Then, gravity model is applied to estimate freight flow distribution between provinces. In this research gravity model is calibrated comparing simulated and observed trip length frequency distributions and O-D pairs. In addition impedance function is also obtained using travel demand modeling package, TRANPLAN. Furthermore gravity model is also calibrated via application of the regression analysis on the logarithmic transformation of gravity formula by finding the related parameters and interpreting them.

CHAPTER 4

EMPIRICAL STUDY AND APPLICATION OF THE MODEL

In this chapter data sources, data used in the model, study area and application of the model are explained. First of all, data sources to develop a model in the context of this research are given as three sets. Following data description and availability, usefulness of all available socioeconomic and freight flow data is checked in point of the possibility of developing a model regarding the linkages between freight flow and socioeconomic and demographic structures of regions. Freight flow data reliability is also reviewed in this section. Later, using these data, the nationwide Origin-Destination (O-D) matrices between selected Traffic Analysis Zones (TAZ), i.e. provinces, are obtained as freight movement in three dimensions by volume (tonnage), by truck trips (number of truck trips) and by truck mobility (tonxkm). The observed O-D matrices are sample matrices; therefore using national freight flow data, these matrices are enlarged to obtain empirical nationwide O-D matrices which are also described as target matrix or base matrix in the literature.

In addition, using these data, national freight flow characteristics, and top 50 intercity freight flows in terms of number of truck trips and moved tonnage per year as well as per day are obtained and given in this chapter. Later, the two steps of the traditional four-step analysis are employed. The first two steps are trip generation and trip distribution. In order to apply the trip generation step, first, freight flow productions and attractions by analysis zones are obtained using the base O-D matrices. Regarding freight flow productions and attractions as dependent variables and socioeconomic and demographic structures of TAZs as independent variables, multiple regression analyses have been performed. Results of the regression analyses are expected to give freight trip production and attraction equations as a function of social, economic and demographic structures of provinces. By means of regression analyses, demographic and socioeconomic variables are converted into freight trips both as produced freight trips and attracted freight trips.

All of the processes in this research are based on both commodity flow (tonnage of goods) and truck trips (number of trucks).

Gravity model is applied as the second step to distribute freight trip productions and attractions and to find freight trips between provinces. In this study, one of the traditional modeling Packages, TRANPLAN, is used to find the simulated O-D matrix using the gravity model module. Afterwards, observed and estimated (simulated) freight trips are compared to calibrate the gravity model. This calibrated gravity model can be used to estimate future (horizon year) freight distribution between provinces by applying the forecasted freight trip productions and attractions which can be predicted using projected socioeconomic variables and the regression equations obtained at the trip generation step.

Using the empirical nationwide O-D matrices between provinces and the regression analyses results, the linkages between inter-provincial freight flow and economic growth as well as the hierarchy of the provinces in Türkiye have been stated. Additionally, the effect of the distance between provinces on the trade and the hierarchy is explained.

4.1 Database

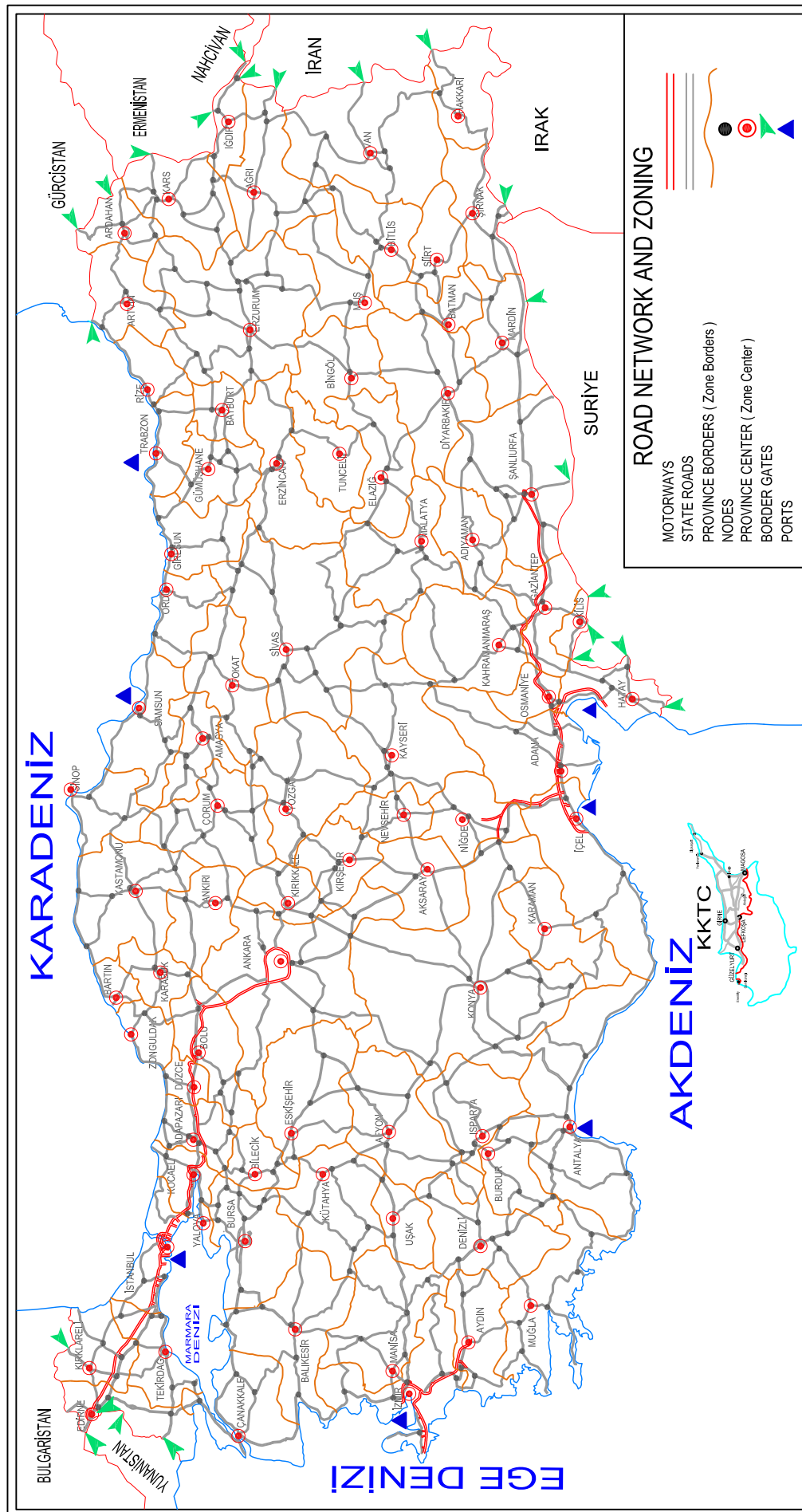
4.1.1 Transportation Network and Zoning Data

Transportation network consists of railways, highways, seaways and airways. In general, majority of freight flow occurs generally on highways and railways. In Türkiye, more than 90% of freight and passenger traffic (KGM, 2007) takes place on the road network and therefore road network in this study is taken as the transportation network. In this research, models are developed both as commodity flow based and vehicle flow based. It is mentioned in the literature that vehicle flow based models do not need model split step. Therefore, regarding this issue and the fact that the majority of freight flow is realized on the highway network, model split step is not included in this research. Thus, modeling to forecast freight flow is developed for a single mode, i.e., highways, and the developed model is a unimodal model. Thence it is not needed to collect data on the networks of other modes.

The arterial road network of Türkiye represents the transportation network in this research. This road network includes state roads which are about 30.000 km. in total and motorways which are about 2.000 km. in total in 2004. On the other hand, provincial roads that are nearly 30.000 km. in length are not considered in the context of this research because as much as 94% freight flows in 2004 occurred on intercity state roads and motorways in Türkiye (KGM, 2007).

The preferred level of analysis zone is the provinces. Cities are regarded as the centroids of the zones. The province level is very suitable for national level analysis and also it is small enough to include intra-zonal trips (called in this study as internal-internal trips) in the analyses. It is also possible to find related socioeconomic and demographic data such as population, employment, economic and demographic growth rates, vehicle ownership, national accounts, and similar data at provincial level. In addition, zoning at the provincial level provides researchers to aggregate related socioeconomic data at bigger zones developed by TÜİK. TÜİK zoning is based on the Nomenclature of Territorial Units for Statistics (NUTS) of EU zoning at three levels: Level 1 for geographic regions; Level 2 focused on geographic and economic conditions of cities and Level 3 for provinces (see Table A.1 in Appendix A). The principal factors considered in this zoning method are population, regional development plans, socioeconomic development of provinces, principal statistical indicators and the geography.

In this research 81 provinces of Türkiye represented by TAZs, state roads and motorways around 32,000 km. in total length are represented in the network and 81 province centers, 23 border gates and 7 ports are represented by centroids (see Figure 4.1). Not all border gates and ports are represented since only 23 border gates and 7 ports presented in Figure 4.1 were regarded during axle load surveys. Diverging and merging road sections are considered as terminal nodes. List of Provinces and their areas are given in Table A.2 in Appendix A.



4.1.2 Traffic Flow Data

Traffic flow data is obtained from General Directorate of Highways (KGM). KGM is the related authority which is responsible to collect traffic data of intercity roads. Nevertheless, there is not any regularly collected data for local (intra-city) roads which are under the responsibility of local authorities.

KGM performs “traffic counting and classification surveys”, “origin-destination surveys”, “axle load surveys” and “weigh in motion surveys” on the main state highway sections annually. By these surveys variations in traffic counts (time of day, day of week, season/month of year, directional variations and geographic variations), freight type, average truck load, axle type and axle loads and similar data are obtained.

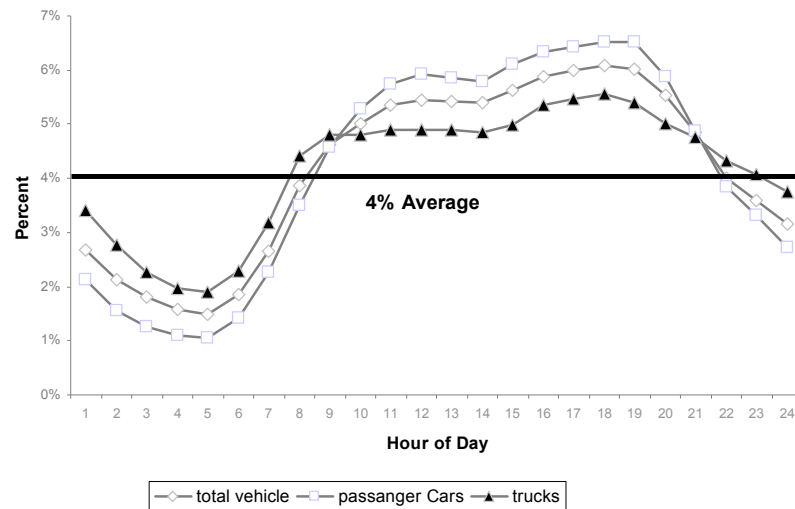
Traffic Counts and Classification Surveys

Traffic counts and classification data in this research are acquired from KGM. KGM collects traffic data manually and/or by automatic devices. Manual counts are performed especially on turning movements. Automatic device counts are realized as short duration counts and continuous counts. Continuous counts are used to collect variations in traffic based on 5 or 15-minute time intervals, 24 hours a day all around the year. Short duration counts are also performed by automatic devices. These devices are mobile and shifted after 7 day counts on each season. These counts provide geographic coverage and need to be factored to estimate annual average daily traffic data. On average 1,000 locations are covered annually. The majority of the counts are classification counts and vehicle classification for each system is given in Table A.3, A.4 and A.5 in Appendix A.

Hourly traffic and hourly truck traffic distributions and percent trucks by hour of day are obtained using the data from these surveys and the results are given in Figure 4.2 and 4.3. Figures show that majority of trucks move on day hours. On the average 35% of the traffic is trucks and 57% of the traffic is passenger cars in a day. Passenger car traffic distributions are more than truck traffic distributions during day hours.

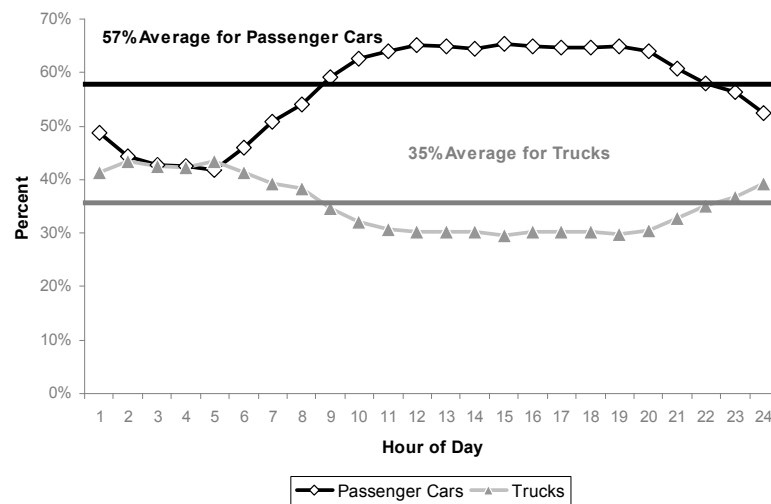
By means of continuous and short duration counts, KGM produces Annual Average Daily Traffic (AADT) values for each road segment and also the traffic volume map (see www.kgm.gov.tr). Traffic and transportation information is published annually by KGM.

Total Traffic Volume Map (2005) is given in Figure A.1 and Total Truck Volume Map (2005) is given in Figure A.2 in Appendix A.



Data Source: KGM, 2004

Figure 4.2 Typical Time of the Day Pattern for Vehicles



Data Source: KGM, 2004

Figure 4.3 Percent of Vehicles by Hour of Day

Weigh in Motion Surveys

The purpose of weigh in motion surveys is to collect truck weight data and axle load data. This data is essential for pavement design. There used to be 19 WIM stations on Turkish highways. However, this number decreased due to aging of pavement on these sections. Data about number of vehicles for each concerned class, vehicle speeds, weight of axles, number of axles, truck total weights and distances between axles by type of trucks are obtained from these surveys (see Table A.5 in Appendix A for vehicle classification of WIM system).

Using the outcomes of these surveys KGM produces overloading for all types of trucks annually. According to survey results performed by KGM in 2004, 29% of three-axle trucks, 32% of four-axle trucks, 29% of five-axle trucks and 35% of six-axle trucks were overloaded. The overloading is one of the enormous problems of highway transportation in Türkiye.

Freight Origin-Destination (O-D) Surveys

KGM has 17 regional divisions and all regional divisions (except 17th Regional Division) perform truck surveys at least at 2 or 3 stations annually. These surveys are performed and coded by regional divisions' staff. In total KGM conducts almost 45 to 50 freight surveys on Turkish State Highways annually. These are roadside truck intercept surveys called as "axle load surveys" by KGM. The main purpose of performing these surveys is to get average axle load weights of trucks to obtain freight mobility (tonxkm) of Turkish highways and also to get Equivalent Single Axle Load (ESAL) to be used in pavement design. However these surveys are also regarded as Single Station Origin-Destination surveys (SSOD) since origin and destination of the freight movement are also investigated. During these surveys trucks are stopped at the roadside according to predetermined sampling ratio, interviewed, and weighed. Survey time is 8 hours daily between hours 08:00 a.m. to 4:00 p.m. and all surveys are conducted in four days as two days on the east-west (north-south) direction and two days on west-east (south-north) direction. Surveys start on Tuesday and finish on Friday. Each KGM Regional Division carries on surveys on different seasons. Surveys are not conducted in the winter. Thus all

seasons are not represented since the winter conditions do not allow to perform these surveys. The following questions are asked to truck drivers during surveys.

- Freight Type
- Origin of the Trip
- Destination of the Trip

The following information is also recorded during surveys for each interviewed truck.

- License Plate Number
- Vehicle Type
- Gross Weight
- Axle Type
- Survey Date and Time
- Survey Location
- Others

During surveys automatic traffic counting and classification are also performed at the location where the survey is conducted to check sampling ratio.

Data on freight types are collected in nine groups as “empty”, “agricultural products”, “mining”, “construction materials”, “animal products”, “manufactured products”, “live animal”, “forestry” and “others”. The surveys conducted after 1995 are all in electronic format at KGM. However, there are some deficiencies on the data collection system. The collection method is time consuming and not economical. It needs a lot of paper work and therefore lots of data miscoding occur. Furthermore, collecting data about the volume of freight by stopping and weighing the trucks are not easily accepted by drivers. However, stopping truckers and weighing trucks give the more accurate and reliable data.

Moreover, it is not possible to stop trucks and weigh them on motorways. Therefore KGM performs toll gate-surveys on motorways. Trucks moving on motorways are being interviewed at toll gates, the same questions on state highways are asked and the volume of freight declared by drivers is accepted. However these surveys are for special purposes and KGM does not conduct them periodically.

Annual roadside surveys of KGM and interviewed truck drivers are limited in order to obtain a reliable origin-destination matrix. Truck intercept survey stations between 1996 and 2004 are given in Figure A.3 in Appendix A. The average number of total interviewed trucks in a year is around 10,000.

KGM uses the following equation in order to determine the sampling ratio for the roadside and toll gate-surveys. This equation (4.1) is suggested by Ortuzar and Willumsen (1996).

$$n > \frac{P(1-p)}{(e/z)^2 + p(1-p)/N} \quad (4.1)$$

n	number of trucks to survey
p	proportion of trucks with a given destination
e	acceptable error (generally taken as 0.1)
z	standard normal variate value for required confidence level taken as 1.96 for confidence level 95%
N	Population (observed truck at survey station)

Transportation and Highway Statistics

Transportation and highway statistics give information on modal share of passenger and freight transportation, total length of transportation systems by mode, number of passengers and volume of the goods carried by transportation mode, vehicle ownership, fuel consumption and similar data. These data are released by TUIK and KGM.

The latest data published on modal share of freight and passenger flow is for 2003. According to this information highway system was the predominant mode and 92% of goods and 95% of passenger flows occurred on highways (KGM, 2007). According to 2004 values 23,735,000,000 tonxkm (15%) of freight moved on motorways, 123,340,000,000 tonxkm (%79) of freight moved on state roads and 9,778,000,000 tonxkm (6%) of freight moved on provincial roads (KGM, 2007).

Annual values on vehicle-km, ton-km and passenger-km and growth rates are given in Table A.6 in Appendix A. This table shows that annual growth rates of freight mobility

(tonxkm) differ from -10.3% to 44.5% between the years 1975 to 2004. During the economic recessions (1979, 1980, 1991, 1994, 2001, etc.) mobility of freight decreased however during economic growth periods (1993, 1996, 1997, 1998, 2000, 2004, etc.) mobility of freight increased. It is inferred that during economic recessions production and consumption decreases. It also explains the relation between freight movement and economic growth.

4.1.3 Data on Land Use, Socioeconomic and Demographic Structures

Data on socioeconomic and demographic structures at regional and national levels are obtained from TÜİK. Although most of the socioeconomic data are open to public use, it is not always possible to find current and annual data at province level. In this research, national data are used to show the relation between freight flow and socioeconomic indicators. In addition regional (at province level) data are used to develop regional freight flow model.

The data used in this research at national level are annual population, employment, national accounts (GNP, GDP, growth rates) and vehicle ownership by vehicle types (see Table A.7 to A.10 in Appendix A). Regional socioeconomic data include population, number of total vehicles, number of trucks, GDP, GDP per capita, GDP and employment by economic sectors at province level. However some socioeconomic data for 2004 at province level are not found and projections are performed to obtain missing years data.

Demographic values include population, population growth rates, population density, number of households and average household size by provinces between 1980 and 2000 for every five years are given in Appendix C in tables C.1 through C.5. Among these values only population and population growth rates as of 2004 are obtained from TÜİK, others are predicted.

National accounts as Gross Domestic Product at 1987 prices (Million TL) for every five years from 1990 and also including the latest released data by TÜİK for the year 2001 are given in Table C.6 in Appendix C. Gross Domestic Product in current prices for 2000 by economic sectors and provinces is given in Table C.7 and also in Figure C.1. In addition Gross Domestic Products of provinces in current prices for 2000 by the values

of agricultural output, industry, construction, and trade are presented on Türkiye's map of provinces to see spatial distribution in figures C.2 through C.5 in Appendix C.

Employment statistics include unemployment rates, share of industrial employees in total employed population, the share of annual average manufacturing industry employees in Türkiye by provinces starting from 1980 to 2000 for every five years are given found but could not be used since data for 2004 is not accessed. Employed population of provinces for 1990 and 2000 are given in Table C.8. In this table employed population forecasted for 2004 is also provided. In addition, in Table C.9, number of employed population at NUTS2 level for 2004 is given. This table is used to predict employed population by provinces for 2004.

Vehicle ownership of provinces by vehicle types for 2004 is also given in Table C.10 in Appendix C.

4.2 Utility and Reliability of Available Data

The model is based on the relationship between economic development and freight movement in both demand and supply sides. Freight demand is assumed to be related to national, provincial and local economic conditions and patterns. Therefore national socioeconomic and demographic data are analyzed to understand the significance of the relationship between freight flow and socioeconomic structures. Then existing freight flow data are processed to check their reliability to develop a model. Additionally national characteristics of freight flow in Türkiye are given.

4.2.1 Checking the Reliability of Data to Develop a Model

In order to understand the relationship between demographic and socioeconomic variables with freight flow, i.e., population and tonxkm, employment and tonxkm, GNP and tonxkm, GDP and tonxkm, number of vehicles and tonxkm and number of trucks and tonxkm are plotted and simple regression analysis between these variables and Freight Mobility (FM) (tonxkm) are conducted (see Figure D.1 through Figure D.6 in Appendix D). In these analyses FM is regarded as the dependent variable. From these analyses the following coefficients of determinations (R-squared) are obtained.

Table 4.1 Results of Regression Analyses between National Freight Flow and Socioeconomic Variables

	National Socioeconomic Variables					
R^2	Population	Employment	GNP	GDP	Number of Vehicles	Number of Trucks
National Freight Mobility (tonxkm)	0.8617	0.9528	0.933	0.9262	0.9551	0.9254

The coefficients in Table 4.1 show the strong relationship between the national socioeconomic variations (population, employment, GNP, GDP, number of vehicles and number of trucks) and FM (tonxkm) in Türkiye. This table shows that transportation is a key function of socio-economic growth. Thus socioeconomic variables can be used to forecast generation and attraction of freight volume of TAZs.

In this part growth rates of population, employment, GDP, GNP and number of total vehicles are plotted versus to the growth rates of mobility (vehiclexkm and tonxkm) (see Figure D.7 through Figure D.11. in Appendix D). These figures also support the relation between national freight mobility and socioeconomic structures of Türkiye.

Focusing on the recession years (1978, 1979, 1994, 1999, and 2001) on these graphs, it is observed that the freight mobility decreases in recession or in the following year depending on the recession time within the year.

4.2.2 Checking the Reliability of Freight Flow Data

In this stage, first of all, existing freight flow surveys, characteristics of these surveys, location of surveys, data source, data availability and reliability, and their current and potential future use to obtain national freight movement characteristics and to generate reliable base nationwide origin-destination matrix were studied. Survey performed in 2004 was the latest survey when this research started. Since the surveys of 2003 and 2004 are not representative for all links and are particularly small, it is searched

whether it is possible to combine other surveys which would allow more geographical coverage with more detailed information.

As the next step, the aggregated roadside surveys between 1998 and 2004 are searched to see their employability to develop a nationwide model. Thus, before aggregating surveys between 1998 and 2004, it is analyzed whether surveys between these years give similar and homogeneous results in order to be aggregated. Because of economic recession in 1999 and 2001 in Türkiye, freight mobility between 1998 and 2004 were not increased (see Figure D.3 in Appendix D). Hence it is assumed that this condition makes it possible to combine surveys in these years.

The data between 1999 and 2004 are examined in homogeneity by means of four different analyses. These analysis are: 1) whether the truck license plate numbers belong to movement origin or destination or to none of them (Table 4.2), 2) possibility of re-meeting license plate numbers in annual surveys (Table 4.3), 3) freight type distribution of annual surveys (Table 4.4), 4) average trip lengths of trucks in annual surveys (Table 4.5).

The outcomes of the analyses show that 30% of trucks have their destination license plate numbers, 33% have their origin and the rest 37% have the license plate numbers of provinces which are not related with their routes. On the other hand for articulated trucks 25% have their destination, 27% have their origin and the rest 48% have the license plate numbers of provinces which are not related with their routes. In point of possibility of re-meeting license plate numbers, 7% of all surveyed trucks (trucks + articulated trucks) are met again during annual surveys but 93% are not. Results associated with freight type of trucks are; 24% empty, 15% agricultural products, 3% mining, 10% construction materials, 2% animal products, 21% manufactured, 2% live animal, 2% forestry and 20% other products. For articulated trucks the commodity types are; 33% are empty, 7% are agricultural products, 4% are mining, 11% are construction materials, 1% are animal products, 23% are manufactured, 0.5% are live animal, 1.5% are forestry and 19% are other products. The outcomes related with average trip lengths of trucks on state roads are 544 km for externally (inter-provinces) moving trucks and 60 km for internally (intra-provinces) moving trucks. Regarding all movements, average trip length for trucks is 400 km.

Regarding the results between 1999 and 2004 which are given in tables 4.2 through 4.5, it is decided that data between these years are homogeneous and may be aggregated to form base origin-destination (O-D) matrix and this empirically generated matrix can be used to employ a model.

Table 4.2 License Plate Numbers Belonging of in Motion Trucks by Years 1999-2004

Vehicle Type	Licence Plate Number Belongs to	1999		2000		2001		2002		2003		2004		AVERAGE	
		Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent
Truck	None	3444	38,90%	3033	35,75%	2549	36,30%	2846	37,39%	3313	37,37%	2893	35,04%	3013	36,82%
	origin	2821	31,86%	2713	31,97%	2235	31,82%	2471	32,46%	2942	33,19%	2913	35,28%	2683	32,78%
	destination	2588	29,23%	2739	32,28%	2239	31,88%	2295	30,15%	2610	29,44%	2451	29,68%	2487	30,39%
Total		8853	100%	8485	100%	7023	100%	7612	100%	8865	100%	8257	100%	8183	100%
Articulated Truck	None	398	51,09%	489	50,83%	375	46,18%	456	47,45%	543	46,37%	587	47,19%	475	48,04%
	origin	187	24,01%	244	25,36%	247	30,42%	269	27,99%	338	28,86%	340	27,33%	271	27,41%
	destination	194	24,90%	229	23,80%	190	23,40%	236	24,56%	290	24,77%	317	25,48%	243	24,56%
Total		779	100%	962	100%	812	100%	961	100%	1171	100%	1244	100%	988	100%
TOTAL	None	3842	39,89%	3522	37,28%	2924	37,32%	3302	38,52%	3856	38,42%	3480	36,63%	3488	38,03%
	origin	3008	31,23%	2957	31,30%	2482	31,68%	2740	31,96%	3280	32,68%	3253	34,24%	2953	32,21%
	destination	2782	28,88%	2968	31,42%	2429	31,00%	2531	29,52%	2900	28,90%	2768	29,13%	2730	29,77%
Total		9632		9447		7835		8573		10036		9501		9170	

Data Source: KGM (from 1999 to 2004)

Table 4.3 Possibility of Re-Meeting License Plate Numbers in the Course of Annual Surveys

Vehicle Type	Licence Plate Number	1999		2000		2001		2002		2003		2004		AVERAGE	
		Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent
Truck	same	538	6,08%	717	8,45%	358	5,10%	638	8,38%	630	7,11%	398	4,82%	547	6,68%
	different	8315	93,92%	7768	91,55%	6665	94,90%	6974	91,62%	8235	92,89%	7859	95,18%	7636	93,32%
Total		8853	100%	8485	100%	7023	100%	7612	100%	8865	100%	8257	100%	8183	100%
Articulated Truck	same	47	6,03%	66	6,86%	61	7,51%	104	10,82%	82	7,00%	60	4,82%	70	7,08%
	different	732	93,97%	896	93,14%	751	92,49%	857	89,18%	1089	93,00%	1184	95,18%	918	92,92%
Total		779	100%	962	100%	812	100%	961	100%	1171	100%	1244	100%	988	100%
TOTAL	same	585	6,07%	783	8,29%	419	5,35%	742	8,66%	712	7,09%	458	4,82%	617	6,72%
	different	9047	93,93%	8664	91,71%	7416	94,65%	7831	91,34%	9324	92,91%	9043	95,18%	8554	93,28%
Total		9632		9447		7835		8573		10036		9501		9171	

Data Source: KGM (from 1999 to 2004)

Table 4.4 Freight Type Distributions of Trucks and Articulated Trucks by Years
1999-2004

	TRUCK						
FREIGHT TYPE	1999	2000	2001	2002	2003	2004	AVERAGE
empty	25%	29%	25%	24%	22%	21%	24%
agricultural products	16%	13%	17%	15%	15%	16%	15%
mining	2%	2%	3%	2%	3%	3%	3%
construction materials	10%	11%	8%	11%	10%	10%	10%
animal products	1%	2%	2%	1%	2%	2%	2%
manufactured	21%	20%	24%	22%	18%	23%	21%
live animal	3%	3%	2%	2%	2%	3%	2%
forestry	2%	2%	3%	2%	3%	3%	2%
other	21%	19%	17%	20%	25%	18%	20%

	ARTICULATED TRUCK						
FREIGHT TYPE	1999	2000	2001	2002	2003	2004	AVERAGE
empty	33%	39%	30%	37%	31%	28%	33%
agricultural products	4%	9%	9%	8%	7%	7%	7%
mining	6%	2%	4%	5%	4%	3%	4%
construction materials	10%	10%	14%	10%	9%	14%	11%
animal products	1%	2%	1%	1%	2%	1%	1%
manufactured	21%	22%	27%	21%	22%	25%	23%
live animal	0%	0%	0%	0%	0%	0%	0%
forestry	1%	1%	1%	1%	2%	2%	1%
other	25%	15%	12%	16%	23%	21%	19%

Data Source: KGM (from 1999 to 2004)

Table 4.5 Average Trip Lengths According to Geographic Classification of Freight
Movement by Years 1999-2004 (for State Roads Only)

	Average Trip Length Km. (external-external) (inter-provincial)						
Vehicle Type	1999	2000	2001	2002	2003	2004	Average
Truck	537	510	537	530	553	498	528
Articulated Truck	564	610	555	552	592	567	573
Average	551	560	546	541	559	507	544

Average Trip Length Km. (internal-internal) (intra-provincial)

60 km

Average Trip Length Including All Trips
(inter-provincial, intra-provincial and international) Km.

400 km

Data Source: KGM (from 1999 to 2004)

4.3 Generation of Nationwide Base Origin-Destination (O-D) Matrices Using Roadside Surveys

The generated O-D base matrix in this study gives the freight movement between provinces. This matrix is obtained from roadside surveys. Each cell of the O-D matrix represents the freight flow between corresponding origin and destination pairs (provinces). This matrix is also a representation of spatial interaction of freight movements between provinces. Rows of this matrix represent the provinces originating the freight movement and columns represent the provinces destination of the freight movement.

In the following sub-sections, information on roadside surveys is given. This information is on how the surveys in this study are selected, detailed information about surveys as sampling, representation problems, data miscoding, etc. Following this, survey findings as average trip lengths, geographical classification of freight movements, average truck weights, and average freight weight per truck by commodity types, axle type distribution, and trucks movements by commodity types obtained from aggregated roadside surveys are given as the characteristics of national freight movement of Türkiye.

4.3.1 Roadside Surveys as Origin-Destination Data

The roadside surveys which are named as axle load surveys and performed on state roads by KGM are also origin-destination surveys on freight flow and are used in this research. Although these surveys are very useful about freight flow with very high response rate, they are very limited in terms of annual number of surveyed trucks (between 8,000 and 10,000) and they are not representative for each link of state roads and for motorways. Therefore aggregated surveys on state roads between 1998 and 2004 (including just one survey in 1996) are used. However not all annual surveys are aggregated. Starting from the latest survey one survey from each link was aggregated to obtain the O-D matrix. In spite of this aggregation all links were still not represented.

Total number of aggregated surveys on state roads are 111 and total number of surveyed trucks is 36,123 (Figure 4.4). The list, the locations and other related data about surveys

on state roads (road number, province, survey date, year and season, number of surveyed trucks, total AADT and AADT for each vehicle type, suggested sampling, actual sampling, etc.) are given in Table A.11 in Appendix A. All axle load surveys have been conducted on state roads by KGM; however 15% of tonxkm were transported by motorways as of 2004. This would be the biggest limitation in point of representation. Therefore it is asked to KGM to realize the O-D surveys on motorways at toll gates in such a way to overcome that problem and to develop a more reliable O-D matrix. The surveys at 20 toll gates on 6024 trucks in 2005 were performed considering this request. These surveys on 6024 trucks were also aggregated to obtain a reliable O-D matrix (Figure 4.5).

Since there are a lot of miscoding problems in annual surveys, some of the data are checked and corrected but the others which are difficult to be corrected are disregarded.

The limitations of these surveys are;

- Sampling.
- Time and duration of the surveys.
- Limited number of commodity types.
- Data miscoding.
- Insufficient representation of seasons, links and road types.

Sampling: There are some road sections where the sampling is still lower than necessary and some road sections where the sampling is higher than required. Four day-surveys are considered as one day survey. The average sampling ratio of the surveys on road sections in this research is 28.25%, the highest sampling is 94.97% and the lowest is 2.45% (see Table A.11 in Appendix A). Actual sampling is 3.67 times higher than suggested on average (see Tale A.11 in Appendix A) which offers that survey data is sufficiently reliable.

Time and Duration of the Surveys: Since the surveys are carried out between 8:00 a.m. and 4:00 p.m., all hours of a day are not represented. Truck trips mostly occur during the midday period between 9:00 a.m. to 9:00 p.m. (Figure 4.2) however transit truck traffic seems to avoid peak periods and tends to travel at night. Truck traffic between 8:00 a.m. and 4:00 p.m. corresponds to 30 to 60 percent of daily truck traffic and its average is

45% (Figure 4.2). Moreover, surveys start on Tuesday and finish on Friday, therefore all days of a week, especially weekends, are not represented either. However truck trips mostly occur on weekdays and decrease significantly at the weekends.

Hourly truck traffic varies from 5% to as high as 70% and on average 35% of total hourly volume occur during peak hours (Figure 4.3).

Commodity Types: The commodity types considered for freight surveys are grouped in nine categories: empty, agricultural products, mining, construction materials, animal products, manufactured products, live animal, forestry and others. Roadside survey results are categorized using these groups. These nine groups represent major commodity types but they are not sufficient and a detailed classification is necessary. Freight flow studies in USA are conducted regarding 39 groups and freight flow studies in European Union Countries are carried on regarding 20 groups (Appendix E).

Data Miscoding: Data miscoding occur in different ways. One of them is entering numeric data as character and character data as numeric. It is easy to correct this kind of miscoding, but miscoding on freight type is irrecoverable. It is also recognized that different KGM Regional Directorates categorize commodity types in different ways. For example lumber is entered as forestry by a lot of regional directorates, but as construction material by some other regional directorates.

Representation: Limitation for representation of data is generally about surveys. Surveys are conducted in spring, summer and fall seasons. Winter is not represented. In this research 30% of trucks were surveyed in spring, 40% of trucks were surveyed in summer and 30% of trucks were surveyed in fall (see Table A.11 in Appendix A).

Moreover some links between cities were never surveyed. These are; Edirne-Kırklareli, Tekirdağ-Çanakkale, Kütahya-Afyon, Uşak-Afyon, Denizli-Muğla, Isparta-Konya, Bartın-Karabük, Kastamonu-Sinop, Kastamonu-Amasya, Ordu-Giresun, Ordu-Tokat, Rize-Artvin, Artvin-Ardahan, Ardahan-Kars, Bingöl-Muş, Batman-Bitlis, Batman-Siirt, Bitlis-Siirt, Siirt-Şırnak, Şırnak-Hakkari, Hakkari-Van, Gaziantep-Kilis (Figure 4.6).

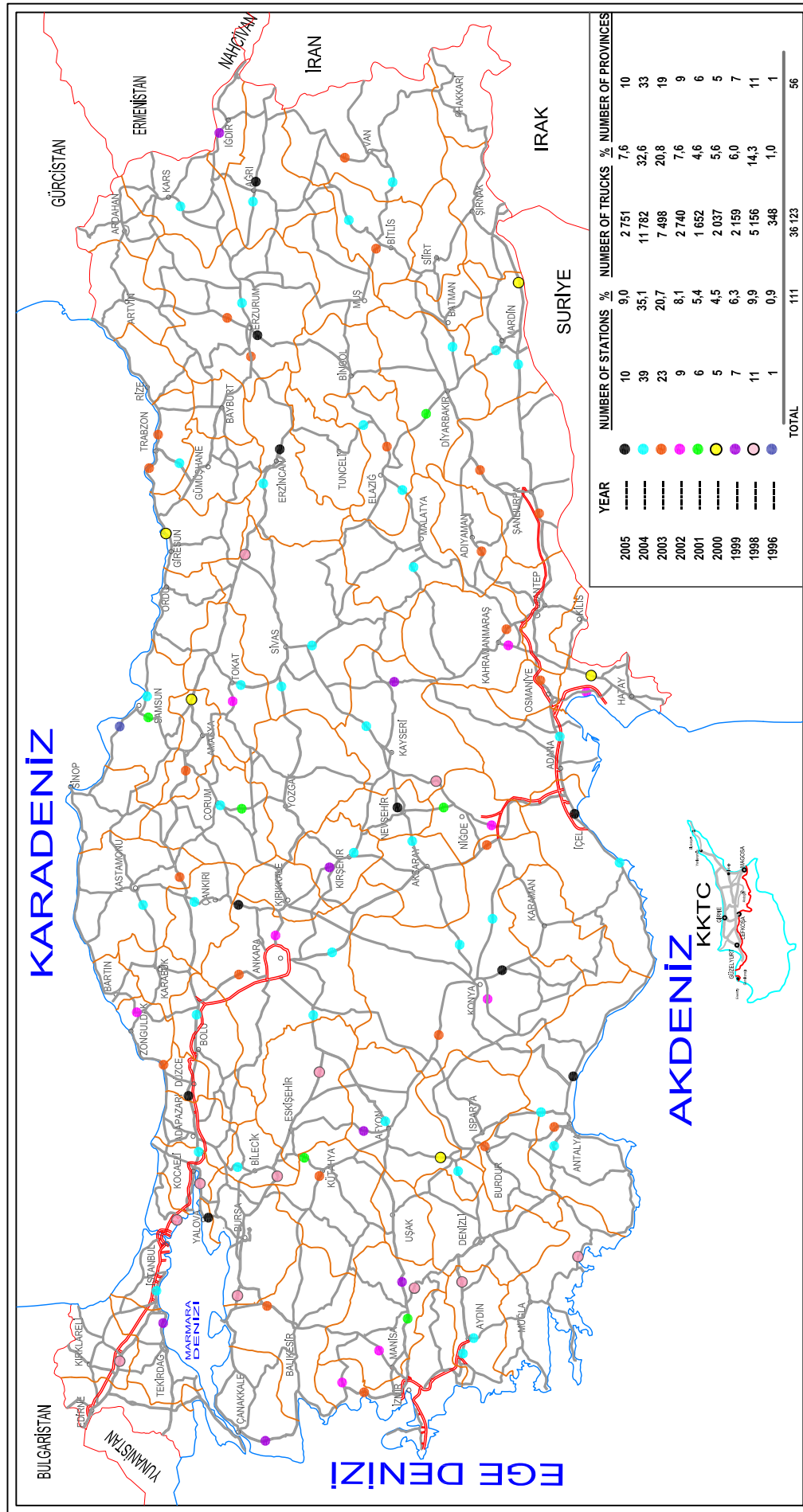


Figure 4.4 Road-Side Surveys on State Roads

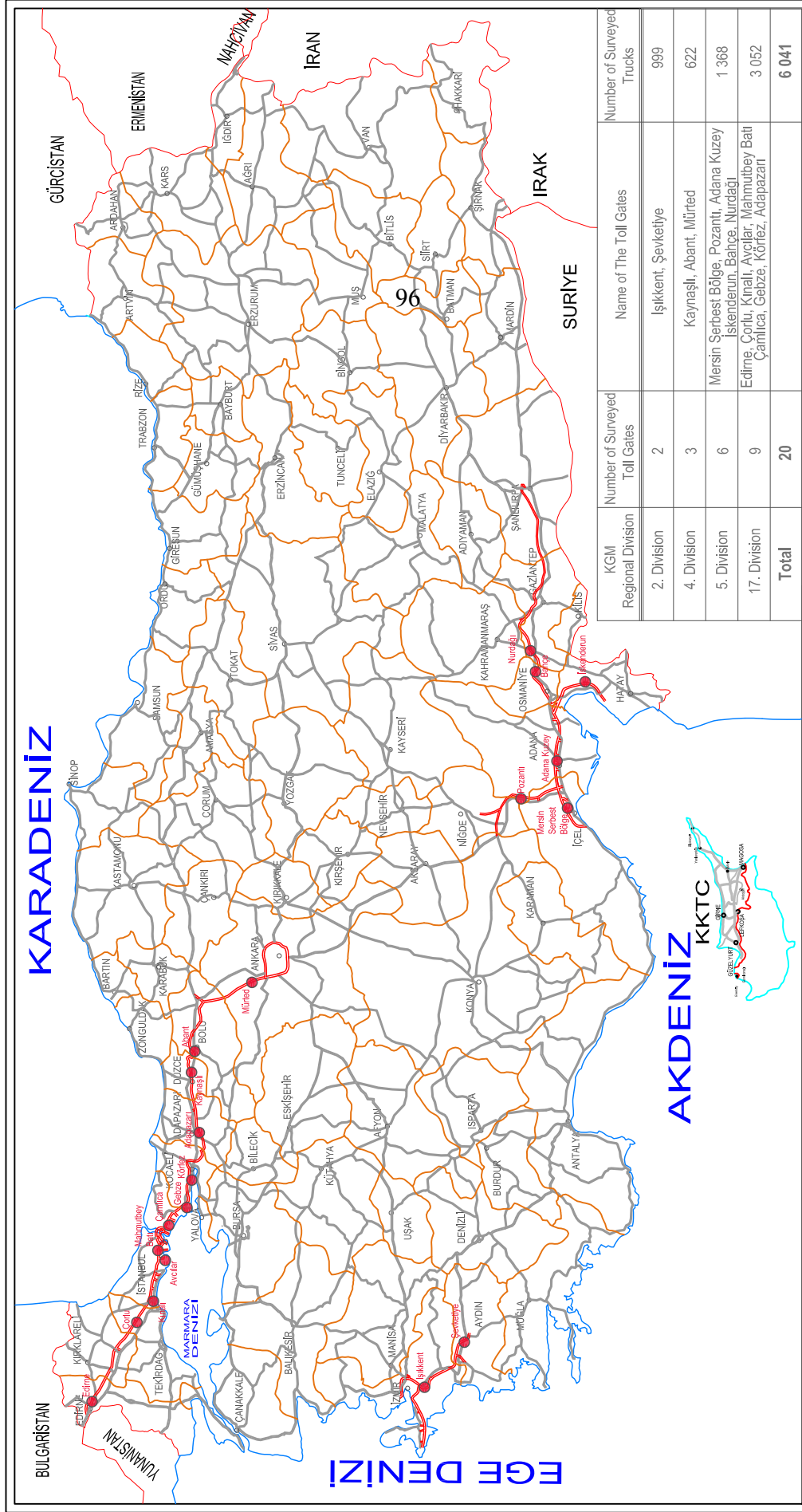


Figure 4.5 Toll-Gate Surveys on Motorways

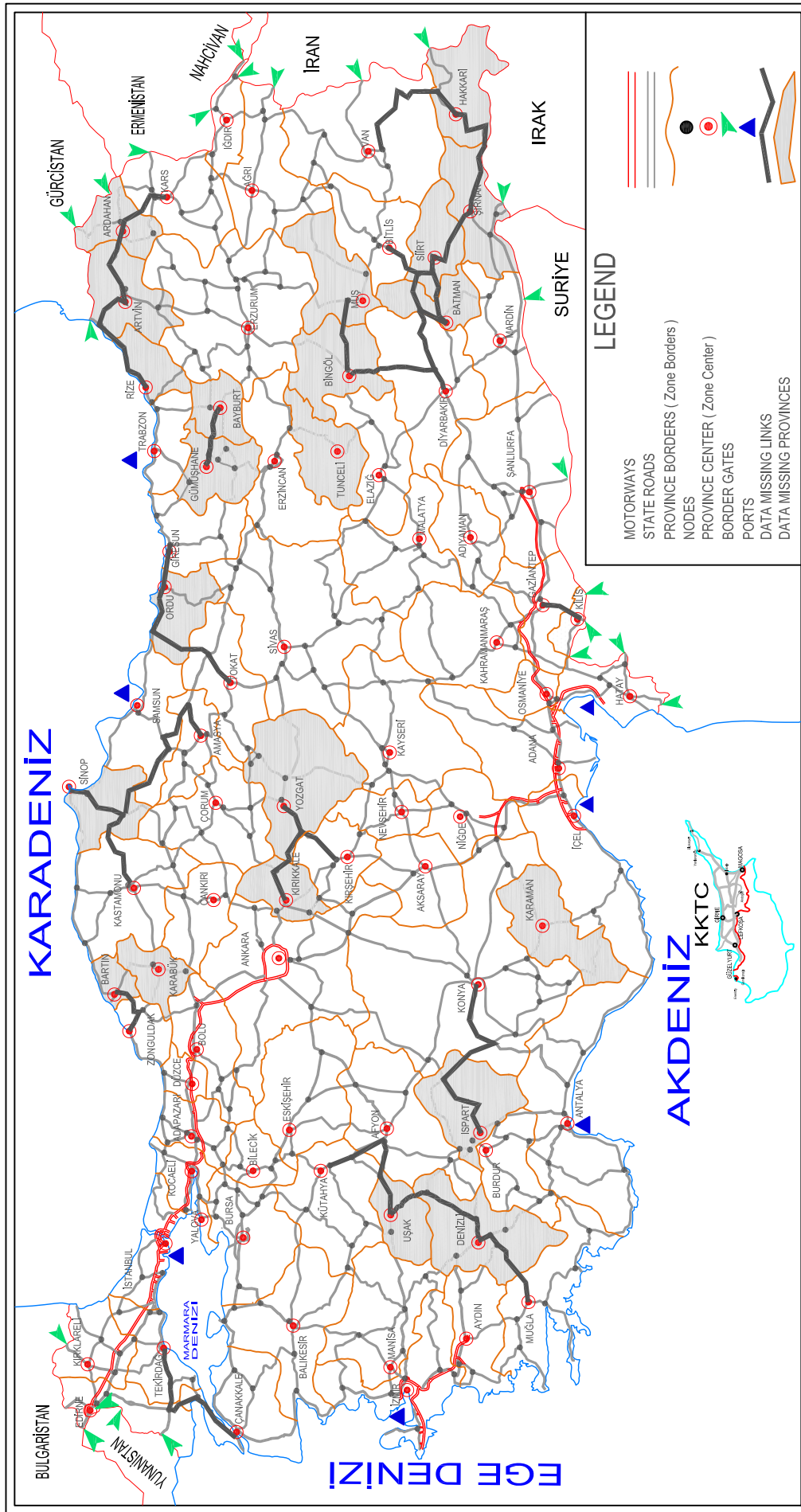


Figure 4.6 Data Missing Links and Zones

Also surveys on state roads are not available within the borders of the provinces; Artvin, Bingöl, Denizli, Edirne, Gaziantep, Gümüşhane, Hakkari, Isparta, Muş, Ordu, Rize, Sakarya, Siirt, Sinop, Tunceli, Uşak, Yozgat, Bayburt, Karaman, Kırıkkale, Batman, Şırnak, Bartın, Ardahan, Karabük, and Kilis, which amounts 26 of 81 provinces (see Figure 4.6). However by considering related surveys on motorways in Edirne, Gaziantep and Sakarya this number decreases to 23.

4.3.2 Overview of National Freight Flow Characteristics of Türkiye

A total number of 42,164 trucks surveyed at 131 stations between 1998 and 2005 (including one survey from 1996) are used to obtain the nationwide base O-D matrix (Figure 4.7). Of these trucks 36,123 were on state roads and 6,042 were on motorways. These truck trips are categorized in point of geographical classification of freight movements which are called in this research as external, internal and international.

Average Trip Lengths: As a result of aggregated surveys average trip length of trucks for internal (intra-provincial) movements is found to be 61 km. It is 452 km for external (inter-provincial) movements and 972 km for international movements. Regarding these three kinds of movement average trip lengths for all trucks in Türkiye is 406 km (Table 4.6). From this table it is also inferred that heavy trucks (articulated trucks) make longer trips than lighter trucks.

Geographical Classification of Freight Movements: Geographical classification of freight movements as internal (intra-provincial), external (inter-provincial), and international are analyzed by number of truck trips, tonnage of moved goods and tonxkm moved freight.

It is deduced from the aggregated surveys that 76% of trucks move externally, 19% move internally and 5% move internationally in terms of the number of moved vehicles. Additionally 79% of tonnage of goods move externally, 14% move internally and 7% move internationally. Moreover, in terms of tonxkm, 82% of trucks move externally, 2% move internally and 16% move internationally (Table 4.7). This is also supported by average trip length which is shorter for internal movement and longer for international movements.

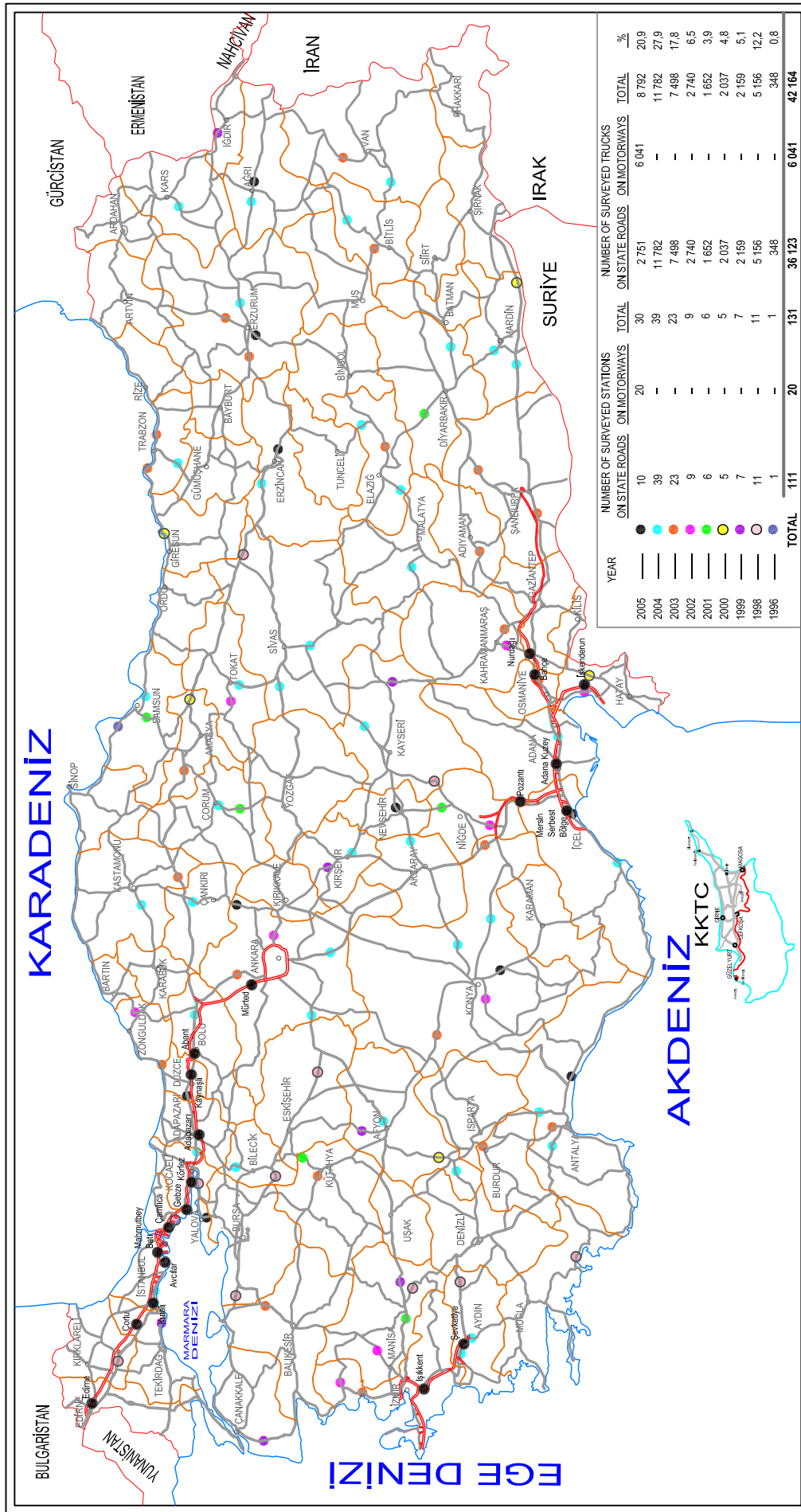


Figure 4.7 Nationwide Survey Stations

Table 4.6 Average Trip Lengths by Geographical Classification of Freight Movement

Geographical Classification	AVERAGE TRIP LENGTH (KM)								
	STATE ROADS			MOTORWAYS			AVERAGE (km)		
	Truck	Articulated Truck	Average	Truck	Articulated Truck	Average	Truck	Articulated Truck	Average
External (Inter-Provincial)	459	512	465	363	410	374	446	486	452
Internal (Intra-Provincial)	63	62	63	46	43	46	62	57	61
International	767	1082	995	694	944	917	757	1034	972
Overall	375	616	407	331	555	402	369	559	406

Data Source: KGM

Table 4.7 Geographical Classification of Freight Movement

Geographical Classification	STATE ROADS			MOTORWAYS			AVERAGE		
	Truck	Articulated Truck	Average	Truck	Articulated Truck	Average	Truck	Articulated Truck	Average
Geographical Classification of Freight Movement Distribution By Number of Moved Vehicle									
External (Inter-Provincial)	76,24%	68,95%	75,27%	86,35%	61,46%	78,51%	77,42%	66,83%	75,74%
Internal (Intra-Provincial)	22,37%	7,22%	20,35%	11,89%	6,68%	10,25%	21,14%	7,07%	18,90%
International	1,39%	23,83%	4,37%	1,76%	31,86%	11,24%	15,72%	26,11%	5,36%
Average	74,28%	11,40%	85,67%	9,82%	4,51%	14,33%	84,09%	15,91%	100,00%
Geographical Classification of Freight Distribution By Tons of Goods Movement									
External (Inter-Provincial)	80,71%	69,73%	78,54%	87,90%	63,70%	78,21%	81,59%	68,06%	78,48%
Internal (Intra-Provincial)	17,66%	7,26%	15,61%	9,96%	5,58%	8,21%	16,71%	6,79%	14,43%
International	1,63%	23,01%	5,86%	2,14%	30,72%	13,58%	1,69%	25,14%	7,08%
Average	67,51%	16,63%	84,15%	9,50%	6,35%	15,85%	77,02%	22,98%	100,00%
Geographical Classification of Freight Distribution By TonxKm Goods Movement									
External (Inter-Provincial)	94,51%	58,00%	84,94%	94,39%	46,10%	69,24%	94,49%	54,84%	82,53%
Internal (Intra-Provincial)	2,58%	0,73%	2,09%	1,28%	0,42%	0,83%	2,44%	0,65%	1,90%
International	2,92%	41,27%	12,96%	4,33%	53,48%	29,92%	3,06%	44,51%	15,57%
Average	62,45%	22,17%	84,61%	7,37%	8,01%	15,39%	69,82%	30,18%	100,00%

Data Source: KGM

Average Truck Weights: Average load weight for externally moving trucks is 11.5 tons/truck, internally moving trucks is 8.5 tons/truck and internationally moving trucks is 14.7 tons/truck. Regarding all kinds of geographical movements average load weight per truck is 11 tons (Table 4.8).

Table 4.8 Summary of Freight Movements

	Geographical Classification of Freight Movement	Truck	Articulated Truck	Average
Number of Vehicles	External (Inter-Provincial)	77,42%	66,83%	75,74%
	Internal (Intra-Provincial)	21,14%	7,07%	18,90%
	International	1,43%	26,11%	5,36%
	Average	84,09%	15,91%	100,00%
Tons of Goods Movement (Ton)	External (Inter-Provincial)	81,59%	68,06%	78,48%
	Internal (Intra-Provincial)	16,71%	6,79%	14,43%
	International	1,69%	25,14%	7,08%
	Average	77,02%	22,98%	100,00%
Total TonxKm	External (Inter-Provincial)	94,49%	54,84%	82,53%
	Internal (Intra-Provincial)	2,44%	0,65%	1,90%
	International	3,06%	44,51%	15,57%
	Average	69,82%	30,18%	100,00%
Average Load Per Vehicle (ton/Vehicle)	External (Inter-Provincial)	10,72	16,35	11,51
	Internal (Intra-Provincial)	8,04	15,43	8,48
	International	12,03	15,46	14,69
	Average	10,18	16,05	11,11

Data Source: KGM

This value is also supported by the data obtained from Weigh in Motion (WIM) stations of KGM and the data obtained from axle load surveys conducted annually by KGM.

According to 2004 axle load surveys average axle load is 10 tons for trucks and 17 tons for articulated trucks.

The survey results also show that the average load weight changes according to freight type, truck type, axle type and the type of movement (Table 4.9). Naturally trucks loaded by construction materials and mining are heavier than others.

Average Freight Weight per Truck by Commodity Type: Average freight load per truck by commodity type is given in Table 4.9. Moreover it is seen from Table 4.9 that truck drivers who stated their freight type as empty also carry small amount of load, which is about 2.53 tons per truck.

Table 4.9 Average Load Carried Per Vehicle by Tonnage of Moved Goods
(Tons/Vehicle)

FREIGHT TYPE	STATE ROADS			MOTORWAY			TOTAL (tons/vehicle)
	Truck	Articulated Truck	Average	Truck	Articulated Truck	Average	
empty	2,58	4,28	2,82	0,00	0,00	0,00	2,53
agricultural products	13,74	22,46	14,39	15,51	18,97	16,56	14,70
mining	17,40	25,51	18,64	16,55	24,97	19,26	18,79
construction materials	17,51	25,08	18,51	16,93	21,97	18,97	18,56
animal products	10,14	21,38	11,37	14,12	20,09	15,05	11,71
manufactured	12,68	22,26	14,04	14,03	18,60	15,67	14,34
live animal	8,32	21,15	8,64	11,58	17,98	12,55	8,85
forestry	13,25	22,13	14,23	15,44	19,78	16,41	14,56
other	10,43	18,82	11,73	12,80	19,07	14,66	12,10
Average (ton per vehicle)	10,10	16,22	10,91	10,76	15,63	12,29	11,11

Data Source: KGM

Axle Type Distribution: The majority axle type of trucks in Türkiye is 3 axles (64%). 5 axles are 13%, 4 axles are 11% and 2 axles are 12% (Table 4.10). This also supports that light trucks have higher average frequency than heavy trucks.

Table 4.10 Axle Type Distributions (%)

Number of Axles	AXLE TYPE	STATE ROADS			MOTORWAY			TOTAL
		Truck	Articulated Truck	Average	Truck	Articulated Truck	Average	(%)
6	1.22+111				1.02%	0.37%	0.83%	0.13%
6	1.22+222				0.46%		0.33%	0.05%
6	1.21+111					0.05%	0.01%	0.00%
6 Axles					1.48%	0.42%	1.18%	0.19%
5	1.2+111				59.46%	76.55%	64.31%	10.23%
5	1.2+122				0.04%	2.05%	0.61%	0.10%
5	1.2+222				6.93%	5.21%	6.44%	1.02%
5	1.22+22				13.61%	5.84%	11.41%	1.81%
5	1.2+112					0.21%	0.06%	0.01%
5	1.21+22					0.21%	0.06%	0.01%
5	1.1+111					0.16%	0.04%	0.01%
5	1.2+211					0.05%	0.01%	0.00%
5	1.2+221					0.05%	0.01%	0.00%
5	1.21+21					0.05%	0.01%	0.00%
5 Axles					80.04%	90.38%	82.97%	13.20%
4	1.2+21				0.12%	0.21%	0.15%	0.02%
4	1.2+22				18.27%	7.57%	15.24%	2.42%
4	11.22	7.20%	12.13%	7.78%				6.54%
4	1.121	0.76%	2.56%	0.97%				0.82%
4	11.21	0.05%	0.27%	0.07%				0.06%
4	1.1+22					0.68%	0.19%	0.03%
4	1.122		5.70%	0.67%				0.56%
4	1.2+11					0.32%	0.09%	0.01%
4	1.211		0.12%	0.01%				0.01%
4	1.221		0.12%	0.01%				0.01%
4	1.222		0.70%	0.08%				0.07%
4	12.22		0.68%	0.08%				0.07%
4	1.1+21					0.16%	0.04%	0.01%
4	1.112		0.02%					0.00%
4	1.22+2					0.05%	0.01%	0.00%
4 Axles		8.01%	22.30%	9.68%	18.40%	8.99%	15.73%	10.64%
3	1.2+2				0.08%	0.16%	0.10%	0.02%
3	1.22	64.95%	57.70%	64.10%				53.90%
3	1.21	12.14%	12.81%	12.22%				10.27%
3	1.12		0.14%	0.02%				0.01%
3	1.2+1					0.05%	0.01%	0.00%
3	11.2		0.02%					0.00%
3 Axles		77.09%	70.67%	76.33%	0.08%	0.21%	0.12%	64.21%
2	1.2	14.65%	6.55%	13.70%				11.52%
2	1.1	0.25%	0.48%	0.28%				0.23%
2 Axles		14.90%	7.03%	13.98%				11.76%

Data Source: KGM

Trucks Movements by Commodity Types: Commodity types by number of trucks, by tonnage of moved goods and by tonxkm are all given in Table 4.11. Results show that 29% of truck traffic is non-goods movement.

Empty moving trucks are 29% of all moving trucks (Table 4.11). This ratio is quite high, therefore it might be inferred that freight transportation by trucks in Türkiye has not been realized economically.

Table 4.11 Freight Type Distributions

FREIGHT TYPE	STATE ROADS			MOTORWAY			AVERAGE		TOTAL
	Truck	Articulated Truck	Average	Truck	Articulated Truck	Average	Truck	Articulated Truck	AVERAGE
Freight Type Distribution By Number of Moved Vehicle									
empty	28,87%	32,03%	29,29%	27,20%	21,71%	25,48%	28,67%	29,10%	28,74%
agricultural products	13,20%	6,91%	12,36%	12,64%	11,99%	12,43%	13,13%	8,35%	12,37%
mining	3,02%	3,54%	3,09%	6,06%	6,26%	6,12%	3,38%	4,31%	3,52%
construction materials	11,70%	11,63%	11,69%	8,36%	12,41%	9,63%	11,31%	11,85%	11,40%
animal products	1,98%	1,58%	1,93%	1,45%	0,58%	1,18%	1,92%	1,30%	1,82%
manufactured	19,64%	21,17%	19,85%	25,15%	30,65%	26,88%	20,29%	23,86%	20,85%
live animal	1,86%	0,31%	1,65%	0,68%	0,26%	0,55%	1,72%	0,30%	1,49%
forestry	2,31%	1,87%	2,25%	2,71%	1,68%	2,38%	2,35%	1,82%	2,27%
other	17,43%	20,96%	17,90%	15,75%	14,46%	15,35%	17,23%	19,11%	17,53%
Freight Type Distribution By Tons of Goods Movement									
empty	7,37%	8,45%	7,58%	1,25%	0,73%	1,04%	6,61%	6,32%	6,54%
agricultural products	17,95%	9,57%	16,29%	18,22%	14,55%	16,75%	17,98%	10,94%	16,37%
mining	5,20%	5,57%	5,28%	9,33%	10,00%	9,60%	5,71%	6,79%	5,96%
construction materials	20,28%	17,99%	19,83%	13,15%	17,44%	14,87%	19,40%	17,84%	19,04%
animal products	1,99%	2,08%	2,01%	1,90%	0,74%	1,44%	1,98%	1,71%	1,92%
manufactured	24,67%	29,06%	25,53%	32,79%	36,47%	34,26%	25,67%	31,10%	26,92%
live animal	1,53%	0,41%	1,31%	0,73%	0,30%	0,56%	1,43%	0,38%	1,19%
forestry	3,02%	2,56%	2,93%	3,88%	2,13%	3,18%	3,13%	2,44%	2,97%
other	17,99%	24,32%	19,24%	18,75%	17,64%	18,30%	18,08%	22,48%	19,09%
Freight Type Distribution By TonxKm Goods Movement									
empty	3,75%	6,75%	4,53%	0,42%	0,23%	0,32%	3,40%	5,02%	3,89%
agricultural products	21,13%	11,57%	18,63%	21,04%	24,97%	23,09%	21,12%	15,13%	19,31%
mining	4,36%	3,13%	4,04%	7,20%	6,01%	6,58%	4,66%	3,89%	4,43%
construction materials	12,66%	14,58%	13,16%	8,23%	12,71%	10,56%	12,19%	14,08%	12,76%
animal products	2,37%	2,54%	2,42%	2,33%	0,73%	1,49%	2,37%	2,06%	2,27%
manufactured	28,36%	30,78%	29,00%	37,15%	33,61%	35,30%	29,29%	31,53%	29,97%
live animal	2,11%	0,60%	1,71%	1,15%	0,29%	0,70%	2,01%	0,52%	1,56%
forestry	3,47%	2,81%	3,29%	4,58%	1,96%	3,22%	3,58%	2,58%	3,28%
other	21,79%	27,25%	23,22%	17,91%	19,49%	18,73%	21,38%	25,19%	22,53%

Data Source: KGM

Table 4.12 Freight Type Distributions by Number of Trucks According to Geographical Classification of Movement

		STATE ROADS			MOTORWAYS			TOTAL			
	FREIGHT TYPE	Truck	Articulated Truck	Total	Truck	Articulated Truck	Total	Truck	Articulated Truck	Total	TOTAL
External (Inter-Provincial)	empty	12.27%	3.38%	15.65%	2.06%	1.06%	3.12%	14.33%	4.44%	18.77%	25.00%
	agricultural products	7.54%	0.71%	8.25%	1.04%	0.27%	1.31%	8.59%	0.98%	9.56%	12.74%
	mining	1.79%	0.51%	2.30%	0.52%	0.35%	0.88%	2.31%	0.86%	3.18%	4.23%
	construction materials	5.16%	1.19%	6.35%	0.61%	0.48%	1.10%	5.77%	1.67%	7.44%	9.91%
	animal products	1.07%	0.16%	1.23%	0.12%	0.03%	0.15%	1.19%	0.18%	1.38%	1.83%
	manufactured	11.85%	2.43%	14.28%	1.93%	1.01%	2.94%	13.78%	3.45%	17.22%	22.94%
	live animal	0.97%	0.02%	0.99%	0.05%	0.00%	0.06%	1.02%	0.03%	1.05%	1.39%
	forestry	1.37%	0.18%	1.55%	0.23%	0.06%	0.29%	1.59%	0.24%	1.84%	2.45%
	other	10.44%	2.33%	12.77%	1.29%	0.59%	1.88%	11.73%	2.91%	14.64%	19.50%
Total External		52.46%	10.92%	63.38%	7.85%	3.85%	11.70%	60.31%	14.77%	75.08%	100%
Internal (Intra-Provincial)	empty	7.23%	0.53%	7.76%	0.38%	0.16%	0.55%	7.61%	0.70%	8.31%	46.08%
	agricultural products	1.42%	0.05%	1.47%	0.09%	0.01%	0.10%	1.51%	0.06%	1.57%	8.70%
	mining	0.29%	0.03%	0.32%	0.03%	0.02%	0.05%	0.31%	0.05%	0.36%	2.02%
	construction materials	2.78%	0.23%	3.01%	0.15%	0.07%	0.22%	2.93%	0.30%	3.23%	17.90%
	animal products	0.29%	0.01%	0.30%	0.01%	0.00%	0.01%	0.30%	0.01%	0.31%	1.71%
	manufactured	1.37%	0.09%	1.46%	0.26%	0.08%	0.34%	1.63%	0.16%	1.80%	9.97%
	live animal	0.31%	0.00%	0.31%	0.01%	0.00%	0.01%	0.32%	0.00%	0.32%	1.77%
	forestry	0.21%	0.01%	0.22%	0.02%	0.00%	0.02%	0.23%	0.02%	0.24%	1.36%
	other	1.49%	0.19%	1.69%	0.13%	0.07%	0.21%	1.63%	0.27%	1.89%	10.50%
Total Internal		15.39%	1.14%	16.53%	1.08%	0.42%	1.50%	16.47%	1.56%	18.03%	100%
international	empty	0.36%	1.16%	1.52%	0.03%	0.14%	0.17%	0.39%	1.30%	1.69%	24.52%
	agricultural products	0.12%	0.34%	0.46%	0.02%	0.47%	0.49%	0.13%	0.81%	0.94%	13.69%
	mining	0.00%	0.02%	0.02%	0.00%	0.02%	0.02%	0.00%	0.04%	0.04%	0.61%
	construction materials	0.11%	0.43%	0.53%	0.00%	0.22%	0.23%	0.11%	0.65%	0.76%	11.05%
	animal products	0.00%	0.08%	0.08%	0.00%	0.01%	0.01%	0.00%	0.09%	0.09%	1.37%
	manufactured	0.29%	0.83%	1.12%	0.10%	0.83%	0.93%	0.39%	1.66%	2.05%	29.83%
	live animal	0.00%	0.03%	0.03%	0.00%	0.01%	0.01%	0.00%	0.04%	0.04%	0.56%
	forestry	0.01%	0.10%	0.11%	0.00%	0.04%	0.04%	0.01%	0.14%	0.15%	2.22%
	other	0.06%	0.80%	0.86%	0.01%	0.25%	0.26%	0.07%	1.04%	1.11%	16.16%
Total International		0.96%	3.77%	4.73%	0.16%	2.00%	2.16%	1.12%	5.77%	6.89%	100%
TOTAL	empty	28.87%	32.03%	29.29%	27.20%	21.71%	25.48%	28.67%	29.10%	28.74%	28.74%
	agricultural products	13.20%	6.91%	12.36%	12.64%	11.99%	12.43%	13.13%	8.35%	12.37%	12.37%
	mining	3.02%	3.54%	3.09%	6.06%	6.26%	6.12%	3.38%	4.31%	3.52%	3.52%
	construction materials	11.70%	11.63%	11.69%	8.36%	12.41%	9.63%	11.31%	11.85%	11.40%	11.40%
	animal products	1.98%	1.58%	1.93%	1.45%	0.58%	1.18%	1.92%	1.30%	1.82%	1.82%
	manufactured	19.64%	21.17%	19.85%	25.15%	30.65%	26.88%	20.29%	23.86%	20.85%	20.85%
	live animal	1.86%	0.31%	1.65%	0.68%	0.26%	0.55%	1.72%	0.30%	1.49%	1.49%
	forestry	2.31%	1.87%	2.25%	2.71%	1.68%	2.38%	2.35%	1.82%	2.27%	2.27%
	other	17.43%	20.96%	17.90%	15.75%	14.46%	15.35%	17.23%	19.11%	17.53%	17.53%
Total		68.80%	15.83%	84.64%	9.09%	6.27%	15.36%	77.90%	22.10%	100%	100%

Data Source: KGM

Table 4.13 Freight Type Distributions by Tonnage of Goods Moved According to Geographical Classification of Movement

		STATE ROADS			MOTORWAYS			TOTAL			
	FREIGHT TYPE	Truck	Articulated Truck	Total	Truck	Articulated Truck	Total	Truck	Articulated Truck	Total	TOTAL
External (Inter-Provincial)	empty	3.14%	0.94%	4.07%	0.06%	0.03%	0.10%	3.20%	0.97%	4.17%	5.31%
	agricultural products	10.75%	1.04%	11.78%	1.59%	0.38%	1.97%	12.33%	1.42%	13.75%	17.52%
	mining	3.08%	0.86%	3.95%	0.84%	0.58%	1.42%	3.92%	1.44%	5.37%	6.84%
	construction materials	8.36%	1.96%	10.32%	1.00%	0.76%	1.76%	9.36%	2.72%	12.08%	15.39%
	animal products	1.18%	0.22%	1.40%	0.17%	0.04%	0.21%	1.35%	0.26%	1.61%	2.05%
	manufactured	14.94%	3.54%	18.48%	2.67%	1.39%	4.07%	17.62%	4.93%	22.55%	28.73%
	live animal	0.90%	0.03%	0.93%	0.06%	0.01%	0.06%	0.96%	0.03%	0.99%	1.26%
	forestry	1.79%	0.27%	2.06%	0.34%	0.09%	0.43%	2.13%	0.36%	2.49%	3.18%
	other	10.34%	2.74%	13.09%	1.62%	0.77%	2.39%	11.97%	3.51%	15.48%	19.72%
Total External		54.49%	11.60%	66.09%	8.35%	4.04%	12.40%	62.84%	15.64%	78.48%	100%
Internal (Intra-Provincial)	empty	1.79%	0.20%	1.98%	0.05%	0.01%	0.07%	1.84%	0.21%	2.05%	14.21%
	agricultural products	1.19%	0.07%	1.26%	0.12%	0.02%	0.14%	1.31%	0.09%	1.40%	9.71%
	mining	0.42%	0.04%	0.47%	0.05%	0.02%	0.07%	0.47%	0.07%	0.54%	3.71%
	construction materials	5.14%	0.46%	5.60%	0.25%	0.11%	0.36%	5.39%	0.57%	5.95%	41.26%
	animal products	0.16%	0.01%	0.17%	0.01%	0.00%	0.01%	0.17%	0.01%	0.18%	1.25%
	manufactured	1.16%	0.16%	1.32%	0.29%	0.09%	0.38%	1.45%	0.25%	1.70%	11.79%
	live animal	0.13%	0.00%	0.13%	0.01%	0.00%	0.02%	0.14%	0.00%	0.14%	1.00%
	forestry	0.22%	0.02%	0.24%	0.03%	0.01%	0.03%	0.25%	0.02%	0.27%	1.89%
	other	1.70%	0.26%	1.96%	0.14%	0.09%	0.23%	1.85%	0.35%	2.19%	15.19%
Total Internal		11.93%	1.21%	13.13%	0.95%	0.35%	1.30%	12.87%	1.56%	14.43%	100%
International	empty	0.05%	0.27%	0.32%	0.00%	0.00%	0.00%	0.05%	0.27%	0.32%	4.57%
	agricultural products	0.18%	0.49%	0.67%	0.03%	0.52%	0.55%	0.21%	1.01%	1.21%	17.15%
	mining	0.01%	0.02%	0.03%	0.00%	0.03%	0.03%	0.01%	0.05%	0.06%	0.79%
	construction materials	0.19%	0.58%	0.77%	0.00%	0.24%	0.25%	0.20%	0.82%	1.01%	14.30%
	animal products	0.00%	0.12%	0.12%	0.00%	0.01%	0.01%	0.00%	0.13%	0.13%	1.82%
	manufactured	0.55%	1.14%	1.68%	0.16%	0.83%	0.99%	0.70%	1.97%	2.67%	37.66%
	live animal	0.00%	0.04%	0.04%	0.00%	0.01%	0.01%	0.00%	0.05%	0.05%	0.75%
	forestry	0.03%	0.14%	0.16%	0.00%	0.04%	0.04%	0.03%	0.18%	0.20%	2.87%
	other	0.10%	1.04%	1.14%	0.01%	0.27%	0.28%	0.11%	1.31%	1.42%	20.09%
Total International		1.10%	3.83%	4.93%	0.20%	1.95%	2.15%	1.30%	5.78%	7.08%	100%
TOTAL	empty	7.37%	8.45%	7.58%	1.25%	0.73%	1.04%	6.61%	6.32%	6.54%	6.54%
	agricultural products	17.95%	9.57%	16.29%	18.22%	14.55%	16.75%	17.98%	10.94%	16.37%	16.37%
	mining	5.20%	5.57%	5.28%	9.33%	10.00%	9.60%	5.71%	6.79%	5.96%	5.96%
	construction materials	20.28%	17.99%	19.83%	13.15%	17.44%	14.87%	19.40%	17.84%	19.04%	19.04%
	animal products	1.99%	2.08%	2.01%	1.90%	0.74%	1.44%	1.98%	1.71%	1.92%	1.92%
	manufactured	24.67%	29.06%	25.53%	32.79%	36.47%	34.26%	25.67%	31.10%	26.92%	26.92%
	live animal	1.53%	0.41%	1.31%	0.73%	0.30%	0.56%	1.43%	0.38%	1.19%	1.19%
	forestry	3.02%	2.56%	2.93%	3.88%	2.13%	3.18%	3.13%	2.44%	2.97%	2.97%
	other	17.99%	24.32%	19.24%	18.75%	17.64%	18.30%	18.08%	22.48%	19.09%	19.09%
Total		67.51%	16.63%	84.15%	9.50%	6.35%	15.85%	77.02%	22.98%	100%	100%

Data Source: KGM

4.3.3 Formation of Base O-D matrix

In this part three O-D matrices are obtained in three dimensions: number of trucks, tonnage of moved goods and freight mobility (tonxkm). These matrices are observed sample matrices and need to be enlarged. The enlarging process is done regarding 2004 national freight flow concerning the mobility on state roads and motorways (tonxkm). The observed O-D matrix as freight volume and the O-D matrix as number of trucks per year are given in Appendix B.

From these matrices it is seen that intra-provincial (internal) freight flows do not reflect the actual case conditions. There is failure in capturing internal freight flows because of insufficient internal freight flow data. The provinces where the roadside surveys are not conducted within the borders are also the provinces where the internal flows are not captured. In addition in Burdur, Kastamonu, Mardin, Aksaray, Yalova and Düzce the internal freight flows are not obtained even there were conducted surveys within the provinces borders. The O-D matrices are also obtained for each commodity group even some commodity groups are interfered.

In addition to these matrices top 50 intercity freight flows between origin-destination pairs are obtained and listed as number of trucks (Trucks/day and trucks/year) in Table 4.14 and as freight volume (tons/year) in Table 4.15. Moreover top 50 intercity freight flows are also given for visual confirmation as number of trucks (trucks/day) in Figure 4.8 and as freight volume (tons/year) in Figure 4.9.

From these visual features it is confirmed that the largest flows occur among the largest and the most developed provinces which are İstanbul, Ankara, İzmir, Antalya, Adana and Mersin regardless of the distance.

They are also the provinces that have interaction not only with each other but also with the moderate sized provinces adjacent to them. Therefore it is noticed that freight flows densely occur between these provinces and their closest neighbors.

Table 4.14 Top 50 Intercity Freight Flows (trucks per day)

Highest Freight Flows				
	origin	destinations	trucks/day	trucks/year
1	kocaeli	istanbul	1227	447,855
2	istanbul	kocaeli	836	305,140
3	istanbul	antalya	672	245,280
4	aydın	izmir	657	239,805
5	antalya	istanbul	553	201,845
6	tekirdag	istanbul	547	199,655
7	istanbul	izmir	503	183,595
8	manisa	izmir	503	183,595
9	izmir	aydın	482	175,930
10	izmir	manisa	460	167,900
11	izmir	antalya	443	161,695
12	denizli	izmir	441	160,965
13	istanbul	tekirdag	420	153,300
14	izmir	denizli	410	149,650
15	balıkesir	bursa	405	147,825
16	istanbul	kayseri	366	133,590
17	kocaeli	sakarya	366	133,590
18	istanbul	sakarya	362	132,130
19	adana	mersin	351	128,115
20	diyarbakır	mardin	343	125,195
21	istanbul	ankara	339	123,735
22	hatay	adana	333	121,545
23	izmir	istanbul	316	115,340
24	ankara	istanbul	299	109,135
25	istanbul	adana	272	99,280
26	adana	istanbul	272	99,280
27	trabzon	samsun	262	95,630
28	mugla	izmir	252	91,980
29	adana	hatay	250	91,250
30	ankara	izmir	243	88,695
31	mersin	adana	241	87,965
32	izmir	balıkesir	233	85,045
33	izmir	mugla	231	84,315
34	izmir	ankara	222	81,030
35	kocaeli	eskişehir	218	79,570
36	gaziantep	hatay	214	78,110
37	bursa	bilecik	214	78,110
38	erzurum	agrı	214	78,110
39	gaziantep	istanbul	214	78,110
40	istanbul	edirne	212	77,380
41	sakarya	kocaeli	208	75,920
42	şırnak	gaziantep	208	75,920
43	eskişehir	ankara	206	75,190
44	mersin	istanbul	206	75,190
45	bursa	balıkesir	200	73,000
46	denizli	aydın	195	71,175
47	kayseri	istanbul	195	71,175
48	nevşehir	niğde	193	70,445
49	düzce	zonguldak	191	69,715
50	kocaeli	bilecik	187	68,255

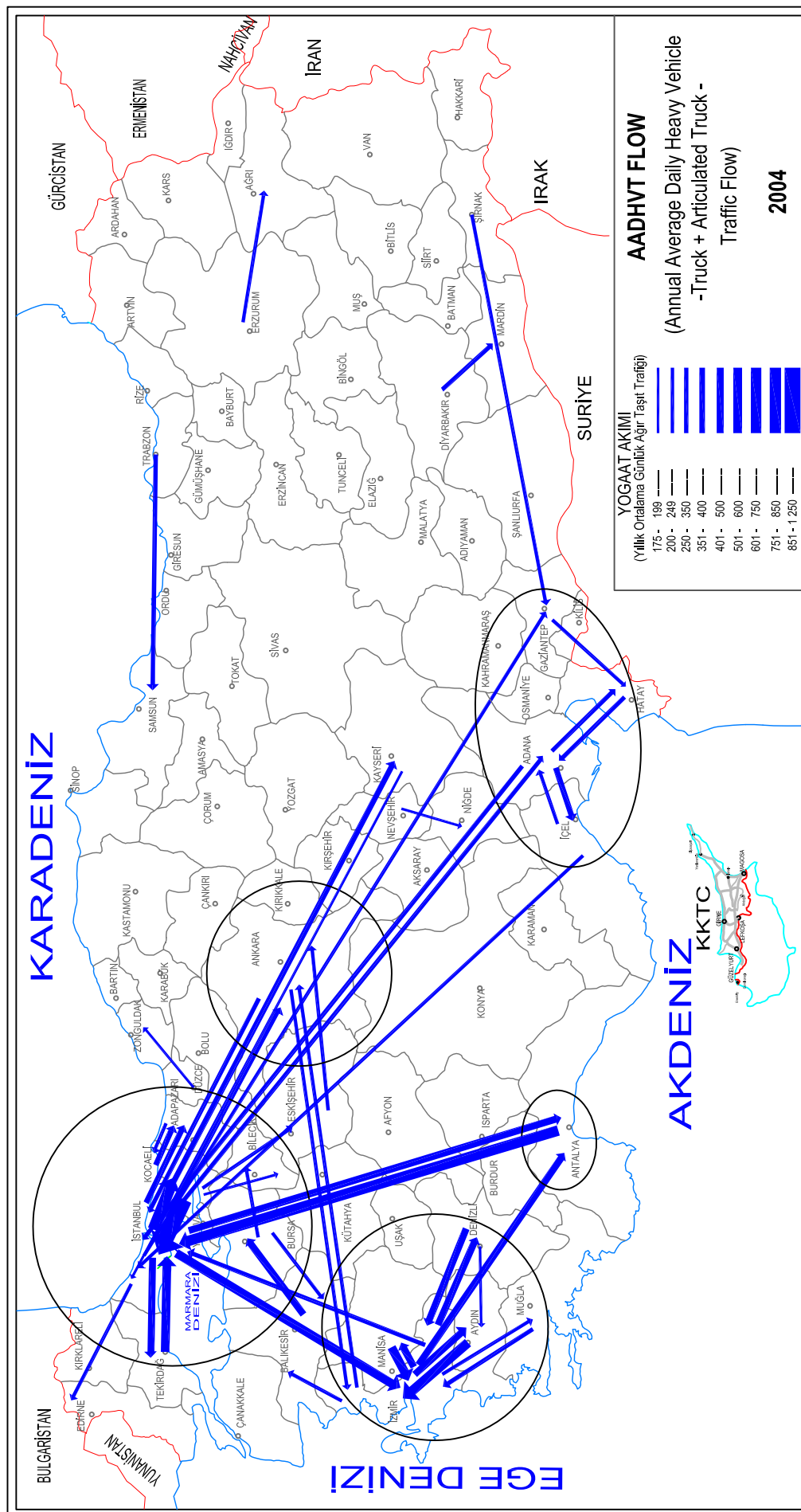


Figure 4.8 Top 50 Intercity Freight Flows (Number of Trucks per Day)

Table 4.15 Top 50 Intercity Freight Flows (tons per year)

Highest Freight Flows (Tons/Year)			
	origin	destinations	tons/year
1	kocaeli	istanbul	4,700,037
2	antalya	istanbul	3,407,677
3	istanbul	antalya	3,127,978
4	aydın	izmir	2,900,520
5	izmir	antalya	2,813,700
6	istanbul	izmir	2,544,287
7	istanbul	kocaeli	2,335,362
8	diyarbakır	mardin	2,245,781
9	manisa	izmir	2,175,655
10	tekirdağ	istanbul	2,117,678
11	izmir	denizli	2,065,649
12	istanbul	kayseri	1,981,723
13	izmir	manisa	1,888,475
14	istanbul	ankara	1,526,305
15	ankara	istanbul	1,501,304
16	denizli	izmir	1,488,067
17	izmir	aydın	1,487,719
18	kocaeli	sakarya	1,442,762
19	adana	istanbul	1,436,693
20	istanbul	tekirdağ	1,419,983
21	adana	hatay	1,311,116
22	mersin	istanbul	1,280,640
23	izmir	istanbul	1,277,366
24	şırnak	gaziantep	1,256,526
25	izmir	ankara	1,246,089
26	balıkesir	bursa	1,237,011
27	kocaeli	eskişehir	1,201,322
28	izmir	muğla	1,200,582
29	izmir	balıkesir	1,189,746
30	kmaraş	gaziantep	1,189,649
31	istanbul	adana	1,164,228
32	istanbul	sakarya	1,164,086
33	gaziantep	istanbul	1,132,840
34	ısparta	antalya	1,125,769
35	mardin	gaziantep	1,111,453
36	ankara	izmir	1,102,289
37	düzce	zonguldak	1,042,771
38	sinop	istanbul	1,037,486
39	kocaeli	bilecik	1,029,114
40	adana	mersin	1,025,097
41	muğla	izmir	998,979
42	mersin	konya	981,003
43	mersin	kayseri	974,578
44	mersin	diyarbakır	950,929
45	zonguldak	istanbul	921,331
46	batman	adana	866,639
47	bursa	balıkesir	856,360
48	mersin	adana	847,997
49	denizli	antalya	821,555
50	kocaeli	ankara	799,800

Visual representation of the highest freight flows of the most developed provinces and biggest metropolitan cities of Türkiye, i.e., İstanbul, Ankara and İzmir, as origin or as destination with other provinces are given in figures 4.10 through 4.12.

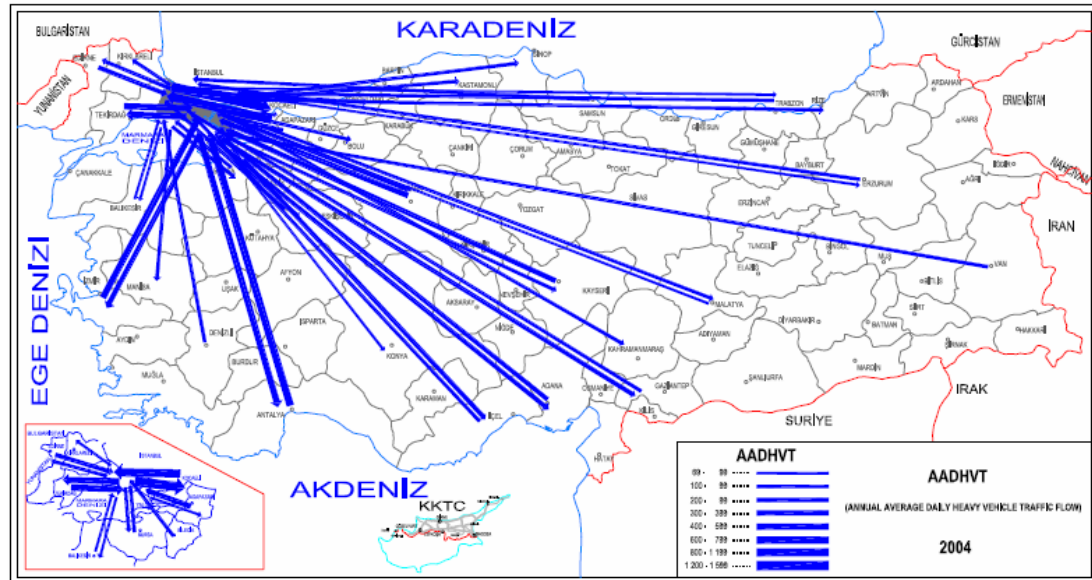


Figure 4.10 Highest Freight Flows of İstanbul as Origin or Destination

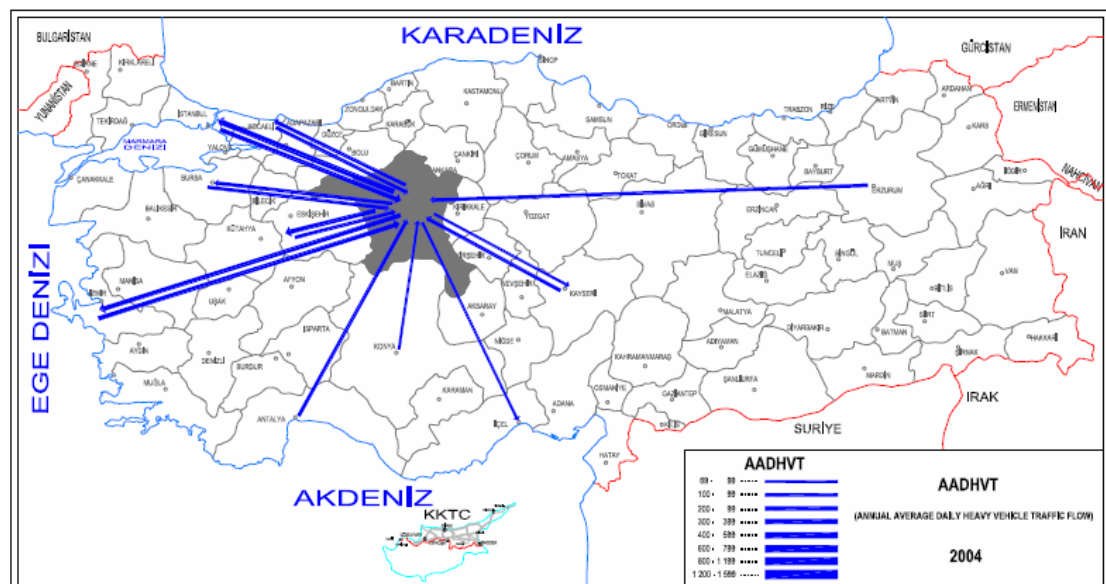
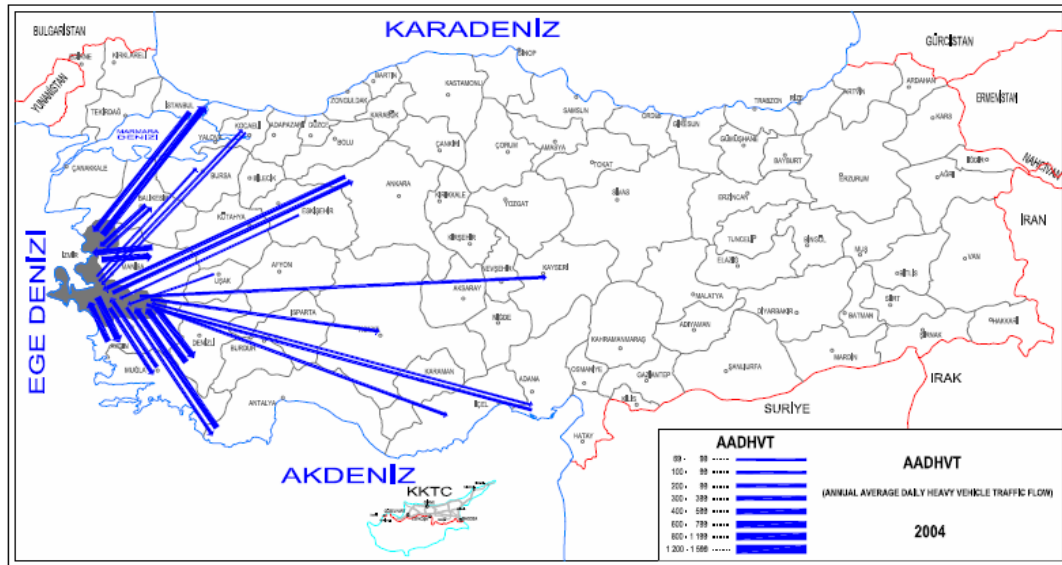


Figure 4.11 Highest Freight Flows of Ankara as Origin or Destination



4.4 Zonal Freight Trip Generation

The objective of zonal freight trip generation stage is to determine the magnitudes of the zonal (provincial) freight flows or vehicle flows both as freight production and attraction in terms of trip generation equations. The trip generation equations are generally developed locally by using truck trip table or commodity flow table which is formed employing truck trip surveys (Cambridge Systematics, Inc., 2007). In this research locally developed freight flow and also vehicle flow tables which are formed using roadside surveys performed by KGM are used. First total zonal freight travel as production and attraction are found in two dimensions, both as number of truck trips and tonnage of goods from the base O-D matrices. Sum of the rows of the O-D matrix gives zonal freight productions and sum of the columns of the O-D matrix gives zonal freight attractions. Empirically obtained values of zonal productions (Table 4.16) and attractions (Table 4.17) are given in three dimensions as number of truck trips, tonnage of goods, and tonxkm mobility.

In this study two kinds of freight trip generation models, which are production and attraction, are applied in two dimensions (number of truck trips and tonnage of moved goods). Each province's freight trip attraction and production values, which are obtained empirically, are explained by demographic and socioeconomic variables via regression

analysis. By this way future freight demand (horizon year demand) can be forecasted using future demographic and socioeconomic values which are also inputs for trip generation model.

$$P_i^t = f(x_i^t, y_i^t, z_i^t, \dots) \quad (4.2)$$

$$A_j^t = f(x_j^t, y_j^t, z_j^t, \dots) \quad (4.3)$$

Where;

P_i^t	total freight production of zone i at time t
A_j^t	total freight attraction of zone j at time t
i	origin of the zone,
j	destination of the zone,
$x, y, z, \dots$	independent variables
t	corresponding year

Independent variables of the regression analysis are the indicators on social and economic activities, and demographic and geographic structures of the provinces and are also defined as the inputs of the model. Trip production equations estimate the number of truck trips and total tonnage moved from regarded zone to all other zones ($i = j$, from 1... to n , n = number of zones, from 1 to 81). Trip attraction equations estimate the number of truck trips and total tonnage moved to regarded zone from all other zones ($i = j$, from 1... to n , n = number of zones, from 1 to 81). Even trip attraction models are more commonly referred in the literature as the more significant, in this research both freight trip production and freight trip attraction equations are developed and employed to test which one is more significant to develop national model in Türkiye (Mao and Demetsky, 2002).

Trip generation equations are developed by means of regression analysis. “The regression models for trip generation are generally developed when O-D surveys are conducted for relatively large sample sizes” (Cambridge Systematics, Inc., 2007). Therefore aggregated surveys are used to develop trip generation models. Selection of independent variables which explain the relation between freight trips and social and economic structures is one of the important points of this stage. Independent variables are population, number of households, number of employees, Gross Domestic Product,

number of total vehicles, number of passenger car, number of trucks and land square. On the other hand dependent variables are Number of Truck Trips as origin and destination and Tonnage of Moved Goods as origin and destination.

First simple linear regression analysis are performed. It is required to add the strong hypothesis that the dependent variables are distributed normal (Ortuzar and Willumsen, 2001). However when the sample size is higher than 30, the normality of dependent variable is taken as assumption at the beginning of the analysis. Sample sizes less than 30 should be expected to raise difficulties in assessing the normality assumption (Washington, Karlaftis and Mannering, 2003). In this research sample size which is the number of zones (provinces) is 81.

The summary of single regression analysis results is given in Table 4.18. As shown in the table, in freight attraction models, the number of households or population, in freight production models, income (Gross Domestic Product) or employment (number of employees) fits better. Moreover, correlation, covariance and descriptive statistics results are obtained for all independent and dependent variables. From these results it is observed that there are very high correlations between independent variables. The major disadvantage of the linear regression model is that the independent variables are often correlated (Cambridge Systematics, Inc., 2007). Furthermore curve fitting for all dependents and independent variables are performed to see which mathematical forms of independent variables explain the relation better.

Even though results for each independent variable (population, number of households, number of employees, GDP (Million TL), number of total vehicles, number of passenger car, number of total trucks) give high coefficient of determination (R^2), Morton's (1969) suggestion that two or three variables which give a better estimation than single variables is considered and at least two variables are included into the analyses. Whereupon all independent variables and their other mathematical forms to include nonlinear form of predictors are also put into the model and multiple regression analyses are performed, and stepwise regression analyses are conducted to select the most descriptive indicators. However as mentioned in the previous paragraphs there are very high correlations between independent variables and that may cause a multicollinearity problem.

Table 4.16 Zonal Freight Productions (Annual)

	Origin	Number of Trucks	Percent	Tons of Goods Movement	Percent	TonxKm.	Percent
adana	1	1,074,224	3.46	13,502,284	3.83	5,803,991,050	4.48
adıyaman	2	155,720	0.50	1,420,217	0.40	394,415,882	0.30
afyon	3	354,325	1.14	3,215,154	0.91	656,216,395	0.51
ağrı	4	365,574	1.18	3,112,306	0.88	1,798,536,978	1.39
amasya	5	64,678	0.21	899,486	0.25	323,371,250	0.25
ankara	6	1,450,695	4.68	16,267,876	4.61	7,319,422,554	5.65
antalya	7	867,534	2.80	11,162,926	3.16	4,145,158,699	3.20
artvin	8	69,600	0.22	599,148	0.17	339,708,222	0.26
aydın	9	695,996	2.24	7,321,601	2.07	1,474,719,487	1.14
balıkesir	10	545,197	1.76	6,014,573	1.70	1,593,228,218	1.23
bilecik	11	129,005	0.42	1,157,873	0.33	362,615,644	0.28
bingöl	12	70,303	0.23	1,108,466	0.31	353,438,381	0.27
bitlis	13	73,115	0.24	893,703	0.25	242,663,691	0.19
bolu	14	248,168	0.80	2,445,561	0.69	614,741,796	0.47
burdur	15	69,248	0.22	1,124,591	0.32	221,887,559	0.17
bursa	16	798,286	2.57	8,008,222	2.27	4,402,109,530	3.40
çanakkale	17	288,592	0.93	2,778,865	0.79	815,195,332	0.63
çankırı	18	111,430	0.36	1,265,795	0.36	256,003,467	0.20
çorum	19	172,944	0.56	2,682,320	0.76	783,783,637	0.61
denizli	20	493,173	1.59	5,184,002	1.47	1,514,784,750	1.17
diyarbakır	21	417,246	1.34	5,991,588	1.70	1,182,920,092	0.91
edirne	22	185,247	0.60	2,143,901	0.61	746,713,353	0.58
elazığ	23	286,132	0.92	3,208,170	0.91	726,544,935	0.56
erzincan	24	277,695	0.90	1,899,493	0.54	375,033,508	0.29
erzurum	25	826,407	2.66	7,190,404	2.04	1,635,857,845	1.26
eskişehir	26	518,130	1.67	4,932,934	1.40	1,660,793,619	1.28
gaziantep	27	559,960	1.80	6,118,684	1.73	3,180,966,398	2.46
giresun	28	264,689	0.85	4,118,562	1.17	440,424,313	0.34
gümüşhane	29	31,988	0.10	130,100	0.04	28,451,767	0.02
hakkari	30	20,739	0.07	160,446	0.05	106,820,341	0.08
hatay	31	730,796	2.36	8,482,862	2.40	3,653,231,494	2.82
isparta	32	143,066	0.46	2,134,285	0.60	452,828,783	0.35
mersin	33	1,293,568	4.17	18,741,332	5.31	11,483,724,685	8.87
istanbul	34	3,379,447	10.89	38,227,008	10.83	22,291,718,135	17.22
izmir	35	1,979,019	6.38	23,766,794	6.74	6,982,329,689	5.39
kars	36	272,423	0.88	2,652,671	0.75	924,520,122	0.71
kastamonu	37	128,302	0.41	1,777,715	0.50	494,627,146	0.38
kayseri	38	782,117	2.52	6,635,665	1.88	2,825,366,116	2.18
kırklareli	39	130,060	0.42	1,424,108	0.40	540,529,443	0.42
kişsehir	40	126,545	0.41	1,112,631	0.32	291,531,752	0.23
kocaeli	41	1,435,580	4.63	18,226,254	5.17	4,343,894,988	3.36
konya	42	718,844	2.32	6,872,439	1.95	2,547,955,748	1.97
kütahya	43	424,276	1.37	4,181,892	1.19	659,320,239	0.51
malatya	44	202,120	0.65	2,249,156	0.64	1,111,428,422	0.86
manisa	45	727,984	2.35	8,350,966	2.37	1,574,203,537	1.22
kmaraş	46	370,846	1.20	4,368,759	1.24	947,299,260	0.73
mardin	47	324,447	1.05	4,471,677	1.27	1,316,541,259	1.02
muğla	48	260,120	0.84	2,670,544	0.76	821,529,470	0.63
muş	49	105,805	0.34	1,195,477	0.34	383,593,490	0.30
nevşehir	50	320,580	1.03	3,084,186	0.87	773,064,015	0.60
niğde	51	173,999	0.56	1,408,017	0.40	400,388,920	0.31
ordu	52	103,696	0.33	1,489,349	0.42	1,053,946,407	0.81
rize	53	200,011	0.64	2,017,963	0.57	1,165,612,163	0.90
sakarya	54	344,483	1.11	3,803,337	1.08	1,274,709,770	0.98
samsun	55	532,191	1.72	8,006,872	2.27	1,677,213,186	1.30
siirt	56	25,309	0.08	349,034	0.10	115,807,408	0.09
sinop	57	89,284	0.29	1,715,304	0.49	732,963,515	0.57
sivas	58	304,059	0.98	2,022,955	0.57	406,380,258	0.31
tekirdağ	59	523,403	1.69	5,475,251	1.55	2,301,126,734	1.78
tokat	60	211,611	0.68	2,986,354	0.85	906,280,526	0.70
trabzon	61	597,924	1.93	5,319,905	1.51	1,615,375,040	1.25
tunceli	62	71,709	0.23	534,269	0.15	166,380,345	0.13
şurfa	63	201,417	0.65	1,751,183	0.50	691,359,550	0.53
uşak	64	45,345	0.15	460,358	0.13	168,734,747	0.13
van	65	423,222	1.36	3,280,624	0.93	1,149,293,407	0.89
yoğat	66	33,042	0.11	361,287	0.10	99,454,840	0.08
zonguldak	67	227,429	0.73	3,491,554	0.99	910,526,543	0.70
aksaray	68	92,096	0.30	802,156	0.23	192,688,822	0.15
bayburt	69	28,121	0.09	170,169	0.05	58,469,216	0.05
karaman	70	59,406	0.19	742,074	0.21	271,574,242	0.21
kırıkkale	71	108,618	0.35	1,727,843	0.49	399,976,518	0.31
batman	72	191,926	0.62	3,770,966	1.07	1,122,901,549	0.87
şırnak	73	361,707	1.17	6,556,645	1.86	2,850,363,103	2.20
bartın	74	111,078	0.36	1,258,062	0.36	274,687,067	0.21
ardahan	75	13,709	0.04	49,170	0.01	30,532,478	0.02
ığdır	76	275,938	0.89	2,980,185	0.84	716,972,568	0.55
yalova	77	52,024	0.17	503,906	0.14	185,135,322	0.14
karabük	78	70,654	0.23	799,145	0.23	189,533,324	0.15
kilis	79	3,164	0.01	27,694	0.01	12,024,209	0.01
osmaniye	80	88,230	0.28	759,977	0.22	179,831,710	0.14
düzce	81	119,163	0.38	1,554,299	0.44	218,309,320	0.17
TOTAL		31,025,957	100.00	352,861,582	100.00	129,458,309,293	100.00

Table 4.17 Zonal Freight Attractions (Annual)

	Destination	Number of Trucks	Percent	Tons of Goods Movement	Percent	TonxKm.	Percent
adana	1	1,076,091	3.52	10,084,954	2.95	3,837,691,898	3.50
adıyaman	2	130,060	0.42	1,383,993	0.40	367,124,521	0.34
afyon	3	273,126	0.89	2,554,916	0.75	445,391,717	0.41
ağrı	4	307,926	1.00	2,885,162	0.84	1,268,745,646	1.16
amasya	5	102,290	0.33	1,147,650	0.34	400,391,399	0.37
ankara	6	1,347,350	4.40	16,184,978	4.73	4,972,154,928	4.54
antalya	7	1,152,963	3.76	15,801,948	4.62	4,875,280,359	4.45
artvin	8	46,751	0.15	544,897	0.16	325,000,235	0.30
aydın	9	609,524	1.99	5,341,047	1.56	1,012,978,540	0.93
balıkesir	10	508,991	1.66	6,256,712	1.83	1,169,807,447	1.07
bilecik	11	268,908	0.88	2,805,953	0.82	388,499,102	0.35
bingöl	12	79,793	0.26	1,335,500	0.39	431,788,883	0.39
bitlis	13	91,393	0.30	1,111,103	0.32	393,254,380	0.36
bolu	14	213,368	0.70	2,170,129	0.63	680,828,162	0.62
burdur	15	134,981	0.44	1,892,252	0.55	640,143,799	0.58
bursa	16	823,244	2.69	8,084,867	2.36	2,839,602,831	2.59
çanakkale	17	283,671	0.93	2,510,569	0.73	597,096,790	0.55
çankırı	18	75,575	0.25	763,161	0.22	137,391,697	0.13
çorum	19	152,908	0.50	2,236,550	0.65	565,802,728	0.52
denizli	20	482,276	1.57	6,590,603	1.93	2,050,463,258	1.87
diyarbakır	21	522,349	1.70	7,056,048	2.06	1,975,338,674	1.80
edirne	22	171,538	0.56	1,546,617	0.45	492,444,977	0.45
elazığ	23	297,380	0.97	4,093,038	1.20	1,163,989,612	1.06
erzincan	24	243,247	0.79	2,245,501	0.66	578,201,512	0.53
erzurum	25	875,619	2.86	9,206,663	2.69	2,966,266,288	2.71
eskişehir	26	533,597	1.74	4,888,824	1.43	959,442,026	0.88
gaziantep	27	540,627	1.76	8,411,730	2.46	3,002,829,374	2.74
giresun	28	311,441	1.02	4,499,690	1.32	537,232,886	0.49
gümüşhane	29	39,018	0.13	313,475	0.09	66,830,100	0.06
hakkari	30	25,309	0.08	342,299	0.10	214,280,952	0.20
hatay	31	798,286	2.60	7,711,721	2.25	2,794,633,404	2.55
isparta	32	162,048	0.53	2,591,190	0.76	723,563,210	0.66
mersin	33	1,313,253	4.28	10,318,481	3.02	3,852,112,225	3.52
istanbul	34	3,160,806	10.31	39,587,981	11.57	18,593,081,032	16.98
izmir	35	2,085,528	6.80	23,133,588	6.76	6,919,892,312	6.32
kars	36	263,986	0.86	2,789,327	0.82	864,213,352	0.79
kastamonu	37	169,078	0.55	1,982,070	0.58	458,935,981	0.42
kayseri	38	878,431	2.87	9,836,304	2.88	3,640,637,376	3.32
kırklareli	39	105,454	0.34	999,752	0.29	227,986,539	0.21
kırşehir	40	98,775	0.32	857,446	0.25	176,413,338	0.16
kocaeli	41	922,019	3.01	8,174,888	2.39	2,639,846,629	2.41
konya	42	660,845	2.16	6,967,595	2.04	2,005,292,902	1.83
kütahya	43	512,155	1.67	3,967,165	1.16	518,938,148	0.47
malatya	44	194,738	0.64	2,641,551	0.77	1,299,004,375	1.19
manisa	45	602,142	1.96	5,184,670	1.52	712,624,758	0.65
kmaras	46	292,810	0.96	4,717,701	1.38	1,209,880,069	1.10
mardin	47	268,205	0.88	4,392,193	1.28	834,133,668	0.76
muğla	48	302,653	0.99	3,426,059	1.00	941,035,975	0.86
muş	49	98,424	0.32	1,457,872	0.43	573,643,547	0.52
nevşehir	50	288,944	0.94	1,953,353	0.57	479,130,387	0.44
niğde	51	201,417	0.66	1,522,938	0.45	249,508,413	0.23
ordu	52	79,090	0.26	884,416	0.26	420,553,590	0.38
rize	53	127,248	0.42	1,672,496	0.49	968,029,095	0.88
sakarya	54	475,246	1.55	4,837,583	1.41	906,657,740	0.83
samsun	55	666,469	2.17	8,414,872	2.46	2,166,079,391	1.98
siirt	56	57,648	0.19	860,341	0.25	424,204,016	0.39
sinop	57	27,418	0.09	253,076	0.07	85,204,005	0.08
sivas	58	374,362	1.22	4,183,555	1.22	1,270,484,565	1.16
tekirdağ	59	449,585	1.47	4,784,425	1.40	1,124,390,216	1.03
tokat	60	255,902	0.83	2,488,841	0.73	719,522,607	0.66
trabzon	61	682,639	2.23	7,715,017	2.26	3,426,339,889	3.13
tunceli	62	62,569	0.20	546,682	0.16	206,590,374	0.19
şurfa	63	202,120	0.66	2,857,414	0.84	904,071,431	0.83
uşak	64	67,842	0.22	870,969	0.25	223,426,536	0.20
van	65	460,482	1.50	5,524,050	1.61	2,906,746,761	2.65
yozgat	66	83,660	0.27	997,962	0.29	310,935,744	0.28
zonguldak	67	241,841	0.79	3,126,389	0.91	563,041,811	0.51
aksaray	68	103,696	0.34	1,081,027	0.32	237,855,223	0.22
bayburt	69	17,224	0.06	157,210	0.05	28,607,367	0.03
karaman	70	53,782	0.18	540,580	0.16	153,168,108	0.14
kırıkkale	71	163,805	0.53	1,469,938	0.43	407,641,029	0.37
batman	72	117,054	0.38	1,001,159	0.29	366,240,377	0.33
şırnak	73	113,539	0.37	1,269,360	0.37	497,341,191	0.45
bartın	74	111,430	0.36	1,449,117	0.42	333,189,139	0.30
ardahan	75	11,248	0.04	132,806	0.04	79,444,955	0.07
igdir	76	249,926	0.82	2,934,708	0.86	844,447,025	0.77
yalova	77	52,727	0.17	589,047	0.17	82,089,443	0.07
karabük	78	63,975	0.21	767,304	0.22	211,611,604	0.19
kilis	79	2,109	0.01	21,622	0.01	4,740,884	0.00
osmaniye	80	88,933	0.29	919,730	0.27	237,028,339	0.22
düzce	81	84,715	0.28	1,232,323	0.36	312,960,945	0.29
TOTAL		30,651,596	100.00	342,088,692	100.00	109,493,445,762	100.00

Table 4.18 Summary of the Single Linear Regression Analyses Results

	VARIABLE (X _i)	REGRESSION EQUATION (Y _i)	R ²	F	Sig
Tonnage of Moved Goods as Origin	Population	3.806 Xi + 983490	0.782	284	0.000
	Number of Households	15.357 Xi + 1331491	0.790	297	0.000
	Employment	12.601 Xi + 966293	0.769	262	0.000
	GDP (Million TL)	1.487 Xi + 1846877	0.800	317	0.000
	Number of Total Vehicles	9.739 Xi + 2040318	0.750	237	0.000
	Number of Passenger Cars	19.39 Xi + 1913580	0.753	241	0.000
	Number of Total Trucks	139.85 Xi + 2181118	0.762	253	0.000
Tonnage of Moved Goods as Destination	Population	3.852 Xi + 809640	0.864	501	0.000
	Number of Households	15.486 Xi + 1173153	0.866	509	0.000
	Employment	12.811 Xi + 776918	0.856	470	0.000
	GDP (Million TL)	1.457 Xi + 1764380	0.828	381	0.000
	Number of Total Vehicles	9.91 Xi + 1866562	0.837	405	0.000
	Number of Passenger Cars	19.654 Xi + 1739606	0.839	413	0.000
	Number of Total Trucks	142.402 Xi + 2008416	0.851	453	0.000
Number of Truck Trips as Origin	Population	0.332 Xi + 88828	0.824	369	0.000
	Number of Households	1.34 Xi + 119103	0.832	391	0.000
	Employment	1.102 Xi + 86543	0.813	344	0.000
	GDP (Million TL)	0.129 Xi + 165501	0.832	391	0.000
	Number of Total Vehicles	0.851 Xi + 180767	0.791	299	0.000
	Number of Passenger Cars	1.67 Xi + 169676	0.795	306	0.000
	Number of Total Trucks	12.208 Xi + 193152	0.803	323	0.000
Number of Truck Trips as Destination	Population	0.318 Xi + 96332	0.810	336	0.000
	Number of Households	1.284 Xi + 125481	0.817	353	0.000
	Employment	1.063 Xi + 92422	0.809	335	0.000
	GDP (Million TL)	0.121 Xi + 173483	0.790	297	0.000
	Number of Total Vehicles	0.817Xi + 184200	0.780	280	0.000
	Number of Passenger Cars	1.623 Xi + 173365	0.785	289	0.000
	Number of Total Trucks	11.771 Xi + 195337	0.799	313	0.000

Multicollinearity is not a problem if the research purpose is only to predict the dependent variable; however it is problem if the research purpose is to draw inferences about the relative contributions of each independent variable (ResearchConsultation, 2007). Since the purpose in this research is to find contributions of each independent variable for trip generation equations to be used for forecasts, multicollinearity tests are conducted to avoid this drawback. If Variance Inflation Factor (VIF) is higher than 2, tolerance is

smaller than 0.20, eigenvalue is close to zero and condition index is greater than 15, than there is a multicollinearity problem.

In order to eliminate this negative condition first application of principal component analyses are thought. Actually this method is used for data (number of independent variables) reduction (Washington, Karlaftis and Mannering, 2003). Hence this statistical method is eliminated regarding that principal components analysis is performed to reduce a relatively large multivariate data sets and to interpret data (Washington, Karlaftis and Mannering, 2003).

Following that other independent variables are formed combining initial variables in order to avoid correlation and by this way more than one independent variable are employed in regression analyses. Some of combined variables are GDP per capita, GDP per household, density, number of employees per 1000 inhabitants, passenger car ownership per 1000 inhabitants, and similar ones. In addition dummy arguments such as existence of international port in the province and existence of international border in the province are also included. All employed independent variables are given in Table 4.19.

At the beginning of the research it was expected to obtain trip generation equations depending on commodity types and especially on manufactured freight flows which reveal the relation between economy and freight flow better to find more accurate freight trip generation equations, however the used surveys are not very reliable to clarify these details as explained before. Therefore this detail is not used in regression analyses. The developed model is a single commodity model. Moreover for each province the attraction and production quantities of freight flows as tonnage of moved goods and number of trucks are given by commodity groups as percentages on Tables 4.20 to 4.23.

Some of the potential independent variables in this research are not available for 2004 which is selected as the base year. Land squares and vehicle ownership by vehicle types given by TÜİK and population for 2004 forecasted by TÜİK are directly found and used. However GDP, number of employees, and number of households are not found as of 2004, therefore by using trend extrapolations, unavailable variables were estimated by provinces as of 2004.

Table 4.19 Independent Variables Used in Stepwise Regression Analyses

1	POP	Population
2	POPSQ	Population Square
3	POP3	Cubic Population
4	LNPOP	Logarithmic Transformation of Population
5	NHH	Number of Households
6	NHHSQ	Number of Households Square
7	NHH3	Cubic Number of Households
8	LNNHH	Logarithmic Transformation of Number of Households
9	LS	Land Square
10	DENSITY	Density
11	NHHPLS	Number of Households Per Land Square
12	EMP	Number of Employees
13	EMPSQ	Number of Employees Square
14	EMP3	Cubic Number of Employees
15	LNEMP	Logarithmic Transformation of Number of Employees
16	EMPPLS	Number of Employees Per Land Square
17	EMPP1000PER	Number of Employees Per 1000 Persons
18	POPPEMP	Population Per Number of Employees
19	NHHPEMP	Number of Households Per Number of Employees
20	EMPP1000NHH	Number of Employees Per 1000 Households
21	EMPPPC	Number of Employees Per Passenger Car Ownership
22	EMPPTT	Number of Employees Per Total Truck Ownership
23	EPNTV	Number of Employees Per Total Vehicle Ownership
24	EEXCAGR	Number of Employees Excluding Agricultural Employment
25	EEXCAGRSQ	Number of Employees Excluding Agricultural Employment Square
26	EEMPAGRPLS	Number of Employees Excluding Agricultural Employment Per Land Square
27	PPEEXCAGR	Population Per Number of Employees Excluding Agricultural Employment
28	EEXCAGRP1000POP	Number of Employees Excluding Agricultural Employment Per 1000 Persons
29	NHHPEEXCAGR	Number of Households Per Number of Employees Excluding Agriculture
30	EEXCAGRP1000NHH	Number of Employees Excluding Agricultural Employment Per 1000 Households
31	EEXCAGRPPC	Number of Employees Excl. Agricul. Employment Per Passenger Car Ownership
32	EEXCAGRPTT	Number of Employees Excl. Agricul. Employment Per Truck Ownership
33	EEXCAGRPN TV	Number of Employees Excl. Agricul. Employ. Per Number of Vehicle Ownership
34	PERCENT	Percent of Agricultural Employment Within Total Employment
35	GDP (Million TL)	Gross Domestic Product
36	GDPSQ	Gross Domestic Product Square
37	GDP3	Cubic Gross Domestic Product
38	LNGDP	Logarithmic Transformation of Gross Domestic Product
39	GDPPERCAPITA	Gross Domestic Product Per Capita
40	GDPPNHH	Gross Domestic Product Per Households
41	GDPLS	Gross Domestic Product Per Land Square
42	GDPEMP	Gross Domestic Product Per Number of Employees
43	GDPEEXCAGR	Gross Domestic Product Per Number of Employees Excluding Agriculture
44	GDPPTT	Gross Domestic Product Per Total Truck Ownership
45	GDPPNTV	Gross Domestic Product Per Number of Total Vehicle
46	GDPLSSQ	Gross Domestic Product Per Land Square Square
47	NTV	Number of Registered Total Vehicles
48	NTVP1000NHH	Number of Total Vehicles Per 1000 Households
49	PC	Number of Registered Passenger Car
50	TT	Number of Registered Total Truck
51	TTP1000PER	Number of Registered Total Truck Per 1000 Persons
52	TTP1000HH	Number of Registered Total Truck Per 1000 Households
53	TTSQ	Number of Registered Total Truck Square
54	TT3	Cubic Number of Registered Total Truck
55	PCP1000PER	Passenger Car Per 1000 Persons
56	PCP1000NHH	Passenger Car Per 1000 Households

Table 4.20 Trip Production Table of Inter-Provincial Freight Flow of Provinces by
Commodity Groups (Number of Truck Trips)

Freight Type of Vehicles (Number of Truck Trips)										
Origin	empty	agricultural products	mining	construction materials	animal products	manufactured	live animal	forestry	other	Total
adana	17.58%	27.95%	4.30%	6.07%	1.31%	25.13%	0.34%	2.53%	14.80%	100%
adiyaman	37.99%	14.59%	3.04%	6.69%	1.22%	17.63%	0.61%	3.04%	15.20%	100%
afyon	33.51%	16.08%	0.54%	12.13%	1.63%	21.66%	1.09%	1.50%	11.85%	100%
agrı	43.04%	13.15%	0.26%	1.79%	1.28%	5.36%	6.13%	1.02%	27.97%	100%
amasya	20.69%	41.38%	4.02%	4.60%	4.60%	8.05%	2.30%	0.00%	14.37%	100%
ankara	18.99%	11.71%	1.97%	13.35%	0.97%	21.83%	0.32%	1.55%	29.31%	100%
antalya	12.59%	48.01%	0.46%	3.53%	1.25%	21.47%	0.34%	1.65%	10.71%	100%
artvin	45.13%	3.59%	0.00%	1.54%	0.00%	7.69%	1.03%	13.33%	27.69%	100%
aydın	29.32%	17.72%	13.33%	6.70%	0.79%	14.19%	2.59%	1.01%	14.34%	100%
bahçeşehir	24.92%	23.92%	5.42%	3.33%	10.00%	10.67%	5.33%	3.00%	13.42%	100%
bilecik	36.18%	4.84%	5.70%	15.10%	1.14%	10.83%	0.57%	10.26%	15.38%	100%
bingöl	8.50%	14.00%	4.50%	7.00%	11.00%	5.00%	30.00%	3.00%	17.00%	100%
bitlis	37.62%	5.94%	1.98%	18.81%	5.94%	9.90%	2.97%	4.95%	11.88%	100%
bolu	23.63%	8.65%	3.49%	12.81%	5.16%	11.65%	2.00%	8.82%	23.79%	100%
burdur	7.11%	14.72%	1.52%	34.01%	12.69%	15.23%	0.00%	6.09%	8.63%	100%
bursa	26.29%	8.21%	3.02%	4.91%	1.37%	24.59%	1.04%	5.62%	24.96%	100%
çanakkale	23.46%	8.53%	6.87%	31.75%	1.66%	9.48%	0.00%	7.58%	10.66%	100%
çankırı	16.61%	29.96%	3.61%	10.11%	4.33%	15.52%	0.00%	2.17%	17.69%	100%
çorum	6.43%	23.10%	0.95%	38.33%	5.24%	9.05%	0.48%	3.33%	13.10%	100%
denizli	37.82%	6.99%	2.35%	11.04%	0.29%	23.47%	0.00%	1.40%	16.63%	100%
diyarbakır	26.17%	20.20%	1.85%	24.43%	3.91%	6.84%	0.87%	0.22%	15.53%	100%
edirne	18.48%	23.05%	2.10%	4.76%	3.24%	21.33%	0.38%	2.86%	23.81%	100%
elazığ	22.98%	7.92%	4.75%	23.30%	3.65%	14.58%	3.49%	1.43%	17.91%	100%
erzincan	58.81%	8.47%	1.37%	5.26%	1.37%	5.26%	4.12%	0.92%	14.42%	100%
erzurum	43.97%	10.93%	0.80%	8.12%	2.33%	4.50%	5.23%	1.61%	22.51%	100%
eskişehir	21.90%	13.14%	0.59%	14.63%	1.56%	24.57%	0.45%	1.86%	21.31%	100%
gaziantep	37.97%	11.01%	0.54%	5.34%	1.49%	22.09%	0.81%	0.68%	20.07%	100%
giresun	33.99%	30.07%	1.31%	0.00%	0.00%	10.46%	2.61%	7.84%	13.73%	100%
gümüşhane	60.44%	4.40%	0.00%	0.00%	0.00%	4.40%	6.59%	4.40%	19.78%	100%
hakkari	13.56%	3.39%	0.00%	5.08%	0.00%	16.95%	54.24%	0.00%	6.78%	100%
hatay	37.60%	8.56%	3.80%	10.43%	0.52%	29.04%	0.13%	0.52%	9.40%	100%
isparta	14.11%	10.15%	2.97%	30.69%	0.99%	25.50%	0.00%	4.70%	10.89%	100%
mersin	14.76%	15.63%	1.94%	5.29%	1.12%	44.40%	0.08%	0.91%	15.87%	100%
istanbul	17.06%	4.55%	3.09%	8.50%	1.10%	26.34%	0.24%	1.97%	37.15%	100%
izmir	17.98%	8.39%	2.48%	7.63%	1.81%	40.50%	0.45%	1.52%	19.23%	100%
kars	35.18%	6.53%	2.26%	5.78%	4.52%	6.78%	19.60%	2.01%	17.34%	100%
kastamonu	6.85%	14.52%	1.10%	33.97%	1.64%	7.95%	2.74%	13.42%	17.81%	100%
kayseri	28.24%	7.15%	1.64%	5.62%	1.17%	24.90%	0.59%	4.92%	25.78%	100%
kırklareli	24.86%	10.69%	2.31%	16.18%	3.47%	26.01%	0.58%	2.89%	13.01%	100%
kırşehir	36.95%	27.71%	0.00%	5.62%	0.80%	9.24%	0.00%	1.61%	18.07%	100%
kocaeli	16.17%	4.32%	10.06%	9.12%	0.84%	32.78%	0.16%	3.04%	23.51%	100%
konya	30.76%	21.75%	1.07%	6.15%	3.15%	22.75%	0.57%	2.22%	11.59%	100%
kütahya	17.54%	1.81%	35.08%	12.12%	2.89%	10.85%	1.08%	5.61%	13.02%	100%
malatya	23.68%	13.48%	0.73%	11.66%	2.19%	20.22%	0.73%	5.10%	22.22%	100%
manisa	20.33%	9.87%	18.10%	20.18%	1.78%	11.65%	0.82%	1.26%	16.02%	100%
kmaras	54.77%	3.40%	0.88%	11.64%	1.10%	14.38%	1.10%	0.66%	12.07%	100%
mardin	37.57%	33.80%	0.47%	13.43%	2.12%	4.36%	2.83%	0.24%	5.18%	100%
muğla	28.75%	14.81%	11.46%	12.17%	1.76%	14.29%	1.76%	1.94%	13.05%	100%
muş	24.25%	13.29%	1.33%	3.32%	1.33%	23.92%	7.97%	0.00%	24.58%	100%
nevşehir	34.38%	29.20%	0.63%	19.47%	2.20%	5.81%	0.00%	1.57%	6.75%	100%
niğde	44.34%	31.60%	2.36%	6.37%	2.83%	5.66%	3.07%	0.00%	3.77%	100%
ordu	11.79%	21.40%	0.00%	11.35%	0.00%	22.27%	5.24%	8.73%	19.21%	100%
rize	42.53%	36.91%	0.00%	5.45%	0.00%	4.39%	0.00%	4.22%	6.50%	100%
sakarya	19.20%	14.46%	2.37%	16.07%	4.10%	15.53%	0.22%	5.29%	22.76%	100%
samsun	12.01%	21.42%	17.46%	9.00%	1.36%	20.05%	0.55%	2.86%	15.28%	100%
siirt	19.44%	5.56%	0.00%	19.44%	0.00%	43.06%	8.33%	0.00%	4.17%	100%
sinop	3.94%	1.57%	1.18%	78.74%	0.79%	2.36%	0.79%	4.72%	5.91%	100%
sivas	54.62%	5.62%	1.81%	7.23%	1.61%	8.43%	2.81%	2.81%	15.06%	100%
tekirdağ	20.18%	11.88%	1.33%	12.96%	1.83%	36.13%	0.17%	1.83%	13.70%	100%
tokat	17.18%	18.85%	0.48%	22.43%	0.00%	15.75%	1.43%	5.25%	18.62%	100%
trabzon	51.28%	5.62%	7.86%	3.06%	0.99%	10.42%	0.33%	1.65%	18.78%	100%
tunceli	38.73%	2.94%	5.88%	5.88%	6.86%	3.92%	6.86%	1.96%	26.96%	100%
şurfa	47.90%	27.35%	0.40%	2.00%	3.59%	6.39%	2.20%	0.00%	10.18%	100%
uşak	35.34%	9.48%	0.00%	9.48%	1.72%	17.24%	0.00%	1.72%	25.00%	100%
van	53.09%	1.84%	1.05%	5.78%	3.02%	7.62%	12.88%	0.53%	14.19%	100%
yozgat	25.53%	14.89%	0.00%	10.64%	4.26%	29.79%	2.13%	2.13%	10.64%	100%
zonguldak	6.69%	0.31%	9.95%	14.15%	1.87%	52.72%	0.00%	3.58%	10.73%	100%
aksaray	44.14%	16.80%	0.78%	7.03%	3.13%	13.28%	1.56%	2.73%	10.55%	100%
bayburt	51.25%	15.00%	0.00%	5.00%	2.50%	8.75%	0.00%	5.00%	12.50%	100%
karaman	19.88%	25.30%	3.61%	1.20%	1.20%	21.08%	0.00%	9.64%	18.07%	100%
kırıkkale	6.80%	6.80%	0.97%	8.09%	0.65%	42.39%	0.00%	0.65%	33.66%	100%
batman	9.16%	0.73%	0.00%	1.47%	0.37%	81.14%	0.00%	0.55%	6.59%	100%
şırnak	20.70%	4.96%	20.80%	0.78%	0.19%	43.25%	2.72%	0.78%	5.83%	100%
bartın	18.04%	4.43%	2.53%	28.48%	3.80%	31.33%	0.00%	4.75%	6.65%	100%
ardahan	48.72%	0.00%	0.00%	0.00%	0.00%	5.13%	30.77%	0.00%	15.38%	100%
iğdır	45.74%	16.76%	0.53%	5.05%	1.60%	14.63%	1.06%	0.80%	13.83%	100%
yalova	18.62%	5.52%	4.14%	4.14%	6.90%	22.76%	0.00%	5.52%	32.41%	100%
karabük	14.93%	4.98%	6.97%	31.34%	2.99%	8.46%	0.00%	6.97%	23.38%	100%
kilis	77.78%	22.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100%
osmaniye	51.72%	4.93%	3.45%	3.94%	2.96%	20.20%	0.99%	3.45%	8.37%	100%
düzce	9.52%	13.10%	26.49%	7.14%	1.19%	14.29%	0.00%	6.85%	21.43%	100%
Total	25.00%	12.74%	4.23%	9.91%	1.83%	22.94%	1.39%	2.45%	19.50%	100.00%

Table 4.21 Freight Production Table of Inter-Provincial Freight Flow of Provinces by
Commodity Groups (Tonnage of Goods)

Origin of Inter-Provincial Freight Movement (External Movement)	Freight Type (Tonnage of Goods)									
	empty	agricultural products	mining	construction materials	animal products	manufactured	live animal	forestry	other	Total
adana	2.36%	33.88%	6.85%	9.43%	1.48%	29.55%	0.32%	2.77%	13.35%	100%
adiyaman	14.27%	20.18%	4.77%	14.50%	1.92%	27.31%	0.15%	3.17%	13.73%	100%
afyon	10.03%	21.30%	0.50%	23.87%	1.07%	29.94%	0.31%	1.44%	11.54%	100%
agrı	10.69%	20.48%	0.46%	1.18%	0.78%	6.39%	8.01%	0.30%	51.70%	100%
amasya	4.34%	50.73%	6.00%	6.95%	4.49%	10.79%	2.53%	0.00%	14.18%	100%
ankara	4.89%	16.22%	3.20%	20.09%	0.79%	24.68%	0.35%	1.73%	28.04%	100%
antalya	2.30%	62.57%	0.61%	4.17%	1.09%	18.56%	0.29%	1.72%	8.70%	100%
artvin	12.75%	5.30%	0.00%	3.16%	0.00%	12.66%	0.33%	28.25%	37.56%	100%
aydın	4.33%	24.07%	21.41%	11.80%	1.29%	16.60%	1.69%	1.49%	17.31%	100%
balıkesir	5.22%	37.65%	6.93%	4.65%	12.20%	13.77%	2.65%	4.23%	12.69%	100%
bilecik	9.51%	6.03%	11.59%	32.93%	0.27%	11.42%	0.38%	11.27%	16.59%	100%
bingöl	2.95%	17.43%	4.98%	7.94%	12.06%	5.21%	35.07%	2.25%	12.12%	100%
bitlis	19.99%	6.62%	3.01%	28.72%	4.55%	13.48%	3.59%	5.54%	14.50%	100%
bolu	4.14%	11.40%	4.36%	23.23%	5.30%	12.54%	2.61%	12.75%	23.67%	100%
burdur	1.51%	15.85%	2.59%	44.38%	12.68%	10.76%	0.00%	6.20%	6.03%	100%
bursa	8.09%	11.64%	4.98%	7.06%	1.24%	28.29%	1.02%	8.12%	29.56%	100%
çanakkale	4.36%	10.37%	8.78%	45.41%	1.32%	7.49%	0.00%	9.98%	12.29%	100%
çankırı	2.59%	37.81%	6.61%	12.00%	4.95%	19.90%	0.00%	3.12%	13.03%	100%
çorum	0.81%	26.25%	1.35%	46.76%	4.95%	6.90%	0.13%	4.50%	8.34%	100%
denizli	9.22%	9.28%	4.76%	22.94%	0.40%	33.65%	0.00%	1.82%	17.95%	100%
diyarbakır	5.72%	28.96%	1.36%	37.41%	4.48%	7.60%	0.53%	0.28%	13.66%	100%
edirne	3.47%	34.94%	1.64%	6.50%	3.81%	23.59%	0.04%	4.87%	21.13%	100%
elazığ	4.96%	9.38%	5.29%	39.02%	4.57%	18.02%	4.20%	1.35%	13.21%	100%
erzincan	23.91%	18.87%	4.32%	14.26%	2.57%	10.59%	6.03%	3.48%	15.98%	100%
erzurum	17.63%	18.04%	2.34%	16.90%	3.87%	6.17%	5.81%	1.97%	27.27%	100%
eskişehir	5.97%	20.31%	0.31%	25.07%	1.72%	25.80%	0.14%	2.93%	17.73%	100%
gaziantep	8.26%	17.90%	0.85%	10.41%	2.47%	34.06%	0.80%	0.83%	24.43%	100%
giresun	7.90%	44.12%	2.89%	0.00%	0.00%	15.70%	3.43%	13.67%	12.29%	100%
gümüşhane	36.05%	2.04%	0.00%	0.00%	0.00%	16.53%	2.71%	10.26%	32.41%	100%
hakkari	7.07%	4.88%	0.00%	7.23%	0.00%	22.82%	49.29%	0.00%	8.70%	100%
hatay	6.83%	12.94%	6.96%	18.91%	0.91%	43.27%	0.16%	0.57%	9.46%	100%
isparta	2.88%	10.51%	3.48%	41.27%	0.86%	24.22%	0.00%	5.97%	10.80%	100%
mersin	2.19%	18.43%	2.39%	6.43%	1.37%	52.30%	0.10%	0.92%	15.88%	100%
istanbul	2.70%	5.79%	4.92%	11.94%	1.45%	29.95%	0.24%	3.05%	39.96%	100%
izmir	2.96%	10.24%	3.31%	10.26%	1.68%	50.41%	0.31%	1.62%	19.21%	100%
kars	12.58%	12.28%	4.56%	8.22%	8.08%	7.77%	26.21%	3.41%	16.89%	100%
kastamonu	1.37%	13.17%	0.69%	42.95%	1.55%	8.41%	0.65%	17.78%	13.43%	100%
kayseri	8.35%	12.18%	3.79%	10.96%	1.35%	30.95%	0.49%	4.08%	27.84%	100%
kırklareli	6.57%	16.73%	5.45%	24.44%	2.46%	27.13%	0.22%	5.84%	11.16%	100%
kırşehir	10.47%	45.46%	0.00%	7.27%	1.69%	12.00%	0.00%	1.07%	22.05%	100%
kocaeli	1.72%	4.78%	14.07%	11.93%	0.89%	38.35%	0.08%	4.18%	24.01%	100%
konya	8.25%	33.54%	1.70%	8.85%	4.28%	27.15%	0.30%	2.14%	13.80%	100%
kütahya	3.59%	2.27%	49.49%	15.73%	1.47%	10.45%	0.69%	4.27%	12.05%	100%
malatya	5.78%	19.88%	0.73%	14.15%	2.12%	26.83%	0.64%	6.52%	23.36%	100%
manisa	4.81%	10.92%	25.33%	28.04%	1.52%	11.77%	0.57%	1.65%	15.39%	100%
kmaraş	15.51%	5.52%	1.17%	37.06%	1.92%	22.80%	0.63%	1.13%	14.25%	100%
mardin	6.00%	53.85%	0.83%	20.55%	3.19%	5.59%	3.70%	0.31%	5.98%	100%
müğla	5.32%	18.00%	19.92%	17.65%	1.15%	18.70%	1.60%	2.36%	15.29%	100%
muş	10.04%	14.85%	1.24%	4.54%	1.73%	39.22%	11.73%	0.00%	16.66%	100%
nevşehir	8.28%	39.53%	1.43%	36.78%	2.06%	5.31%	0.00%	1.28%	5.34%	100%
niğde	12.28%	48.57%	4.71%	16.11%	3.65%	8.05%	3.87%	0.00%	2.75%	100%
ordu	1.86%	23.68%	0.00%	16.35%	0.00%	26.51%	2.77%	12.76%	16.07%	100%
rize	8.61%	58.77%	0.00%	14.98%	0.00%	4.48%	0.00%	7.57%	5.59%	100%
sakarya	2.93%	17.23%	4.05%	22.34%	5.22%	18.38%	0.30%	8.80%	20.75%	100%
samsun	2.28%	21.69%	23.49%	12.07%	1.88%	20.16%	0.39%	4.93%	13.12%	100%
silir	3.66%	6.77%	0.00%	23.64%	0.00%	55.55%	5.80%	0.00%	4.58%	100%
sinop	0.29%	1.40%	1.11%	85.05%	0.83%	1.45%	0.09%	5.55%	4.24%	100%
sivas	20.96%	9.37%	5.20%	15.91%	2.77%	17.27%	3.13%	6.87%	18.52%	100%
tekirdağ	5.71%	16.16%	2.36%	19.46%	1.10%	37.58%	0.03%	2.15%	15.45%	100%
tokat	3.28%	22.78%	0.38%	31.16%	0.00%	16.93%	0.59%	7.63%	17.25%	100%
trabzon	14.23%	9.51%	21.84%	5.75%	1.93%	13.61%	0.31%	3.18%	29.65%	100%
tunceli	22.54%	2.88%	7.47%	10.85%	16.17%	5.84%	8.84%	1.42%	23.98%	100%
şurfa	8.74%	55.81%	0.76%	2.74%	5.83%	11.84%	3.12%	0.00%	11.17%	100%
uşak	9.23%	12.32%	0.00%	19.30%	2.24%	21.37%	0.00%	3.02%	32.52%	100%
van	29.38%	2.39%	2.18%	11.18%	4.30%	14.65%	16.37%	1.39%	18.16%	100%
yozgat	7.65%	18.70%	0.00%	23.06%	4.07%	36.39%	1.06%	3.51%	5.55%	100%
zonguldak	0.99%	0.08%	11.03%	17.25%	0.23%	57.06%	0.00%	3.59%	9.76%	100%
aksaray	15.52%	28.10%	2.15%	10.70%	5.90%	16.48%	2.04%	1.38%	17.73%	100%
bayburt	18.92%	26.92%	0.00%	8.45%	7.02%	17.23%	0.00%	8.13%	13.34%	100%
karaman	5.20%	31.06%	6.77%	0.48%	1.09%	20.48%	0.00%	16.46%	18.47%	100%
kırkkale	1.28%	6.23%	0.98%	7.48%	0.08%	48.13%	0.00%	0.96%	34.85%	100%
batman	0.95%	0.67%	0.00%	1.31%	0.26%	90.23%	0.00%	0.53%	6.04%	100%
şırnak	2.13%	4.71%	29.16%	1.09%	0.14%	53.17%	2.78%	0.91%	5.90%	100%
bartın	3.37%	3.96%	3.06%	42.84%	0.58%	31.97%	0.00%	8.81%	5.41%	100%
ardahan	24.95%	0.00%	0.00%	0.00%	0.00%	8.21%	59.61%	0.00%	7.22%	100%
iğdır	18.77%	24.84%	0.82%	7.93%	4.00%	20.60%	0.54%	0.51%	21.98%	100%
yalova	4.01%	8.25%	8.15%	5.28%	9.35%	23.69%	0.00%	5.92%	35.35%	100%
karabük	2.54%	2.90%	12.91%	40.20%	0.98%	10.55%	0.00%	10.22%	19.70%	100%
kilis	49.69%	50.31%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100%
osmaniye	12.93%	9.32%	6.57%	10.76%	4.75%	38.87%	0.88%	7.76%	8.16%	100%
düzce	0.76%	14.02%	43.83%	8.81%	0.86%	12.13%	0.00%	7.68%	11.91%	100%
Total	5.31%	17.52%	6.84%	15.39%	2.05%	28.73%	1.26%	3.18%	19.72%	100%

Table 4.22 Trip Attraction Table of Inter-Provincial Freight Flow of Provinces by
Commodity Groups (Number of Truck Trips)

Destination of Inter-Provincial Freight Movement (External Movement)	Freight Type of Vehicles (Number of Truck Trips)									
	empty	agricultural products	mining	construction materials	animal products	manufactured	live animal	forestry	other	Total
adana	39.91%	9.38%	1.81%	3.78%	1.62%	21.50%	1.08%	2.16%	18.76%	100%
adıyaman	15.20%	3.60%	8.80%	11.20%	0.00%	17.60%	1.60%	4.80%	37.20%	100%
afyon	20.12%	10.35%	11.52%	13.67%	1.56%	25.59%	3.91%	2.34%	10.94%	100%
ağrı	17.96%	15.70%	2.59%	13.92%	1.78%	13.59%	5.50%	3.88%	25.08%	100%
amasya	38.10%	19.41%	5.86%	2.93%	0.00%	9.16%	2.20%	1.47%	20.88%	100%
ankara	17.26%	12.84%	3.40%	7.75%	3.26%	24.70%	1.73%	3.87%	25.18%	100%
antalya	5.78%	8.79%	1.46%	17.84%	1.50%	47.98%	0.39%	3.89%	12.37%	100%
artvin	10.77%	18.46%	0.00%	21.54%	0.00%	15.38%	1.54%	6.92%	25.38%	100%
aydın	40.24%	11.50%	1.31%	5.40%	0.52%	22.13%	0.52%	0.61%	17.77%	100%
balıkesir	20.82%	16.91%	2.09%	12.00%	1.82%	20.82%	0.91%	2.27%	22.36%	100%
bilecik	36.17%	2.13%	11.57%	7.31%	1.20%	16.22%	1.33%	2.26%	21.81%	100%
bingöl	7.05%	4.41%	5.29%	36.56%	0.88%	22.47%	10.57%	3.52%	9.25%	100%
bitlis	30.71%	10.24%	1.57%	17.32%	2.36%	23.62%	1.57%	0.79%	11.81%	100%
bolu	22.90%	15.55%	4.41%	7.56%	2.10%	18.07%	1.26%	3.78%	24.37%	100%
burdur	12.24%	10.42%	6.51%	13.54%	2.08%	41.67%	0.52%	2.34%	10.68%	100%
bursa	25.01%	17.59%	3.40%	7.59%	2.36%	19.34%	2.79%	4.15%	17.77%	100%
çanakkale	15.71%	9.52%	16.90%	5.48%	4.29%	25.24%	0.00%	2.14%	20.71%	100%
çankırı	13.61%	20.71%	10.06%	11.24%	2.37%	18.34%	0.00%	1.18%	22.49%	100%
çorum	20.69%	18.57%	22.81%	2.65%	1.06%	16.18%	0.53%	1.59%	15.92%	100%
denizli	18.25%	9.27%	4.41%	9.50%	1.05%	36.65%	0.45%	1.05%	19.37%	100%
diyarbakır	26.13%	9.58%	1.31%	9.83%	2.05%	33.17%	4.01%	1.06%	12.86%	100%
edirne	25.26%	17.60%	2.07%	4.55%	1.45%	32.92%	0.83%	3.52%	11.80%	100%
elazığ	8.02%	14.22%	7.41%	13.01%	6.05%	26.63%	4.24%	2.57%	17.85%	100%
erzincan	18.88%	9.44%	3.54%	10.62%	3.83%	19.47%	2.36%	2.36%	29.50%	100%
erzurum	22.69%	11.52%	1.93%	7.02%	1.86%	15.82%	2.72%	2.86%	33.57%	100%
eskişehir	34.56%	5.85%	7.55%	7.33%	1.48%	19.25%	0.56%	1.27%	22.14%	100%
gaziantep	18.83%	21.41%	1.70%	8.09%	1.36%	27.53%	7.89%	2.38%	10.81%	100%
giresun	30.42%	19.58%	0.70%	10.84%	0.00%	16.08%	0.70%	0.70%	20.98%	100%
gümüşhane	51.35%	7.21%	8.11%	9.01%	0.00%	9.01%	0.00%	1.80%	13.51%	100%
hakkari	0.00%	16.67%	5.56%	25.00%	0.00%	23.61%	0.00%	2.78%	26.39%	100%
hatay	51.95%	10.19%	6.54%	6.10%	0.25%	11.70%	0.94%	3.14%	9.18%	100%
isparta	5.42%	13.88%	10.41%	7.38%	0.00%	45.55%	0.43%	3.04%	13.88%	100%
mersin	44.67%	13.14%	1.57%	8.21%	1.41%	15.04%	0.33%	2.53%	13.10%	100%
istanbul	12.73%	18.65%	5.09%	12.82%	2.28%	23.66%	0.64%	2.11%	22.02%	100%
izmir	26.14%	13.26%	7.24%	7.37%	1.39%	17.23%	0.92%	1.73%	24.72%	100%
kars	15.42%	18.77%	0.51%	12.85%	1.54%	16.20%	0.51%	2.06%	32.13%	100%
kastamonu	5.82%	14.55%	3.12%	19.13%	4.57%	18.71%	0.83%	5.41%	27.86%	100%
kayseri	21.33%	10.57%	4.06%	6.86%	2.35%	26.29%	1.90%	4.36%	22.28%	100%
kırklareli	37.07%	5.44%	4.08%	4.76%	2.72%	29.59%	0.00%	2.04%	14.29%	100%
kırşehir	25.14%	16.76%	6.70%	5.59%	1.12%	22.35%	0.00%	1.12%	21.23%	100%
kocaeli	38.44%	10.20%	3.79%	10.33%	0.54%	15.20%	0.50%	3.00%	17.99%	100%
konya	22.24%	12.22%	5.01%	10.26%	1.57%	30.85%	2.51%	2.19%	13.16%	100%
kütahya	42.84%	4.61%	4.23%	5.35%	0.75%	24.16%	0.50%	2.24%	15.32%	100%
malatya	11.88%	10.54%	5.36%	10.15%	4.41%	24.71%	1.53%	1.92%	29.50%	100%
manisa	40.96%	4.57%	1.52%	6.61%	0.61%	24.70%	0.81%	1.12%	19.11%	100%
kmaraş	20.72%	13.62%	4.20%	11.74%	1.45%	30.72%	1.16%	1.74%	14.64%	100%
mardin	14.41%	17.15%	0.58%	26.66%	4.03%	23.49%	1.73%	2.02%	9.94%	100%
muğla	16.50%	6.31%	5.88%	13.63%	1.43%	35.58%	0.29%	3.16%	17.22%	100%
muş	14.64%	7.14%	1.43%	23.57%	2.14%	25.00%	5.71%	2.14%	18.21%	100%
nevşehir	48.31%	12.12%	4.81%	4.81%	1.78%	20.68%	0.36%	1.43%	5.70%	100%
niğde	53.31%	11.87%	3.31%	13.04%	0.78%	9.14%	0.00%	0.78%	7.78%	100%
ordu	30.00%	17.62%	0.95%	11.90%	3.33%	17.14%	1.90%	0.95%	16.19%	100%
rize	3.06%	16.99%	1.95%	12.81%	5.57%	33.98%	0.00%	0.56%	25.07%	100%
sakarya	33.64%	7.84%	3.81%	6.16%	2.44%	18.87%	0.46%	1.67%	25.11%	100%
samsun	29.49%	17.95%	1.54%	8.46%	0.68%	16.92%	0.34%	2.39%	22.22%	100%
siirt	21.95%	6.10%	0.00%	2.44%	0.00%	51.22%	0.00%	0.00%	18.29%	100%
sinop	20.51%	23.08%	0.00%	0.00%	0.00%	24.36%	0.00%	0.00%	32.05%	100%
sivas	22.21%	11.61%	5.66%	9.58%	1.74%	22.50%	3.19%	1.45%	22.06%	100%
tekirdağ	25.40%	12.37%	3.40%	10.86%	2.55%	25.31%	0.00%	2.08%	18.04%	100%
tokat	44.49%	8.64%	3.68%	4.78%	1.47%	7.72%	1.10%	0.74%	27.39%	100%
trabzon	23.14%	21.38%	1.23%	10.48%	2.18%	15.11%	1.43%	1.43%	23.62%	100%
tunceli	11.24%	7.87%	0.00%	16.85%	8.99%	10.11%	4.49%	9.55%	30.90%	100%
şurfa	13.46%	10.77%	2.07%	10.14%	3.31%	38.30%	3.73%	2.48%	15.73%	100%
uşak	21.43%	0.00%	8.79%	7.69%	1.65%	31.32%	3.30%	0.00%	25.82%	100%
van	10.87%	13.53%	3.82%	11.68%	1.39%	25.55%	1.04%	2.08%	30.06%	100%
yozgat	27.31%	17.65%	2.52%	6.72%	1.68%	20.17%	2.52%	0.84%	20.59%	100%
zonguldak	10.57%	14.83%	14.98%	16.74%	2.64%	17.47%	0.00%	6.02%	16.74%	100%
aksaray	34.58%	10.51%	0.68%	11.19%	0.68%	30.51%	2.03%	0.68%	9.15%	100%
bayburt	30.61%	24.49%	4.08%	4.08%	4.08%	8.16%	0.00%	0.00%	24.49%	100%
karaman	27.33%	4.00%	0.00%	14.67%	0.00%	42.67%	0.00%	4.67%	6.67%	100%
kırıkkale	46.14%	7.73%	2.15%	6.22%	0.86%	12.02%	0.43%	0.00%	24.46%	100%
batman	60.36%	9.61%	0.00%	9.91%	0.00%	14.11%	0.00%	0.00%	6.01%	100%
şırnak	52.63%	4.95%	0.00%	10.53%	1.24%	15.79%	2.48%	2.48%	9.91%	100%
bartın	5.68%	10.09%	7.89%	20.50%	4.42%	31.86%	0.00%	9.78%	9.78%	100%
ardahan	25.00%	18.75%	0.00%	6.25%	0.00%	6.25%	0.00%	0.00%	43.75%	100%
ığdır	23.18%	13.25%	4.64%	13.91%	2.65%	16.56%	2.65%	2.65%	20.53%	100%
yalova	23.33%	13.33%	6.67%	19.33%	1.33%	17.33%	1.33%	2.67%	14.67%	100%
karabük	11.54%	14.29%	7.14%	14.84%	2.20%	19.78%	5.49%	2.75%	21.98%	100%
kilis	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	66.67%	100%
osmaniye	53.17%	3.90%	0.00%	7.80%	0.00%	23.90%	0.00%	1.95%	9.27%	100%
düzce	10.13%	7.05%	7.49%	22.03%	1.76%	26.43%	0.00%	3.52%	21.59%	100%
Total	25.00%	12.74%	4.23%	9.91%	1.83%	22.94%	1.39%	2.45%	19.50%	100.00%

Table 4.23 Freight Attraction Table of Inter-Provincial Freight Flow of Provinces by Commodity Groups (Tonnage of Goods)

Destination of Inter-Provincial Freight Movement (External Movement)	Freight Type (Tonnage of Goods)									
	empty	agricultural products	mining	construction materials	animal products	manufactured	live animal	forestry	other	Total
adana	9.89%	14.73%	3.76%	7.58%	2.35%	32.69%	1.51%	3.49%	24.00%	100%
adiyaman	4.73%	5.92%	11.86%	17.10%	0.00%	27.07%	0.89%	5.72%	26.70%	100%
afyon	5.80%	12.51%	15.62%	20.85%	1.03%	26.13%	2.80%	2.56%	12.70%	100%
agri	5.29%	15.08%	5.61%	20.27%	2.10%	18.72%	2.90%	3.84%	26.20%	100%
amasya	10.54%	30.62%	10.15%	3.63%	0.00%	13.76%	3.32%	0.36%	27.62%	100%
ankara	4.35%	17.14%	5.04%	10.34%	4.07%	28.18%	1.52%	5.07%	24.30%	100%
antalya	0.86%	10.19%	2.14%	24.96%	1.51%	47.08%	0.23%	3.86%	9.17%	100%
artvin	2.31%	17.82%	0.00%	36.03%	0.00%	17.83%	0.38%	7.60%	18.02%	100%
aydin	6.32%	17.48%	3.12%	11.92%	0.45%	36.90%	0.44%	1.29%	22.07%	100%
bahkesir	4.78%	22.62%	3.10%	17.15%	1.16%	27.15%	0.68%	1.95%	21.41%	100%
bilecik	7.35%	1.96%	19.75%	11.81%	1.35%	22.44%	1.87%	2.23%	31.24%	100%
bingol	1.65%	3.39%	6.91%	45.14%	0.11%	24.94%	10.37%	2.21%	5.28%	100%
bitlis	11.72%	13.16%	2.16%	22.43%	3.85%	36.91%	0.75%	1.24%	7.78%	100%
bolu	2.97%	24.90%	8.55%	8.65%	2.25%	20.01%	0.89%	6.96%	24.83%	100%
burdur	1.77%	8.66%	11.76%	18.46%	3.27%	41.93%	0.45%	2.68%	11.02%	100%
bursa	7.39%	27.39%	5.50%	12.07%	2.09%	23.44%	1.75%	4.59%	15.79%	100%
canakkale	2.38%	11.59%	22.27%	5.81%	2.96%	31.35%	0.00%	1.86%	21.78%	100%
canikiri	2.80%	23.27%	15.60%	14.69%	0.89%	19.43%	0.00%	0.58%	22.74%	100%
corum	4.24%	24.66%	31.21%	2.00%	0.83%	18.66%	0.55%	2.04%	15.82%	100%
denizli	3.17%	10.77%	6.58%	14.12%	1.56%	41.30%	0.12%	1.34%	21.05%	100%
diyarbakir	5.31%	13.24%	2.25%	13.06%	2.68%	47.05%	1.25%	1.25%	12.41%	100%
edirne	3.80%	23.50%	4.69%	6.75%	1.30%	42.34%	0.20%	4.39%	13.01%	100%
elazig	2.75%	18.50%	9.75%	14.24%	6.80%	29.34%	4.91%	2.61%	11.11%	100%
erzincan	4.74%	10.66%	7.44%	10.98%	5.67%	24.20%	1.11%	3.85%	31.36%	100%
erzurum	5.87%	18.48%	4.04%	11.17%	2.83%	17.34%	1.61%	4.47%	34.18%	100%
eskisehir	9.23%	9.18%	13.09%	12.99%	0.91%	25.75%	0.23%	0.62%	28.01%	100%
gaziantep	3.35%	26.86%	2.29%	15.94%	1.61%	31.06%	7.50%	2.94%	8.44%	100%
giresun	6.08%	27.50%	1.79%	19.68%	0.00%	20.86%	0.18%	1.68%	22.23%	100%
gumushane	14.89%	6.93%	23.44%	19.01%	0.00%	8.20%	0.00%	0.89%	26.65%	100%
hakkari	0.00%	14.94%	7.90%	31.28%	0.00%	25.03%	0.00%	4.23%	16.62%	100%
hatay	12.95%	17.33%	16.35%	13.94%	0.64%	18.98%	0.51%	7.12%	12.17%	100%
isparta	0.99%	11.63%	15.89%	10.08%	0.00%	43.21%	0.21%	4.06%	13.92%	100%
mersin	8.29%	24.41%	3.28%	16.06%	2.63%	24.85%	0.65%	5.08%	14.74%	100%
istanbul	2.25%	24.60%	6.42%	17.02%	2.52%	24.38%	0.55%	2.26%	20.00%	100%
izmir	5.79%	19.62%	11.41%	10.86%	1.47%	20.63%	0.93%	2.10%	27.20%	100%
kars	5.81%	24.81%	0.62%	14.91%	1.13%	16.30%	0.18%	3.80%	32.43%	100%
kastamonu	0.91%	13.48%	4.95%	22.94%	3.86%	24.56%	0.27%	7.63%	21.40%	100%
kayseri	4.42%	13.09%	6.50%	10.02%	2.99%	33.84%	1.52%	5.15%	22.46%	100%
kirkklareli	14.86%	8.49%	11.46%	8.56%	1.19%	36.88%	0.00%	1.58%	16.98%	100%
kirsehir	4.94%	23.98%	12.62%	10.32%	1.31%	23.94%	0.00%	0.27%	22.63%	100%
kocaeli	6.29%	18.22%	6.40%	16.46%	0.71%	22.11%	0.79%	5.63%	23.39%	100%
konya	4.28%	15.88%	8.63%	14.54%	1.73%	37.82%	1.86%	2.15%	13.10%	100%
kutahya	12.21%	6.99%	9.24%	11.79%	0.21%	37.25%	0.33%	3.51%	18.47%	100%
malatya	3.56%	11.27%	8.58%	10.48%	4.06%	33.09%	0.61%	0.83%	27.52%	100%
manisa	12.73%	7.31%	3.66%	13.67%	0.68%	37.68%	0.56%	1.86%	21.85%	100%
maras	4.61%	14.42%	6.82%	19.59%	1.33%	37.87%	0.96%	2.16%	12.25%	100%
mardin	2.58%	20.08%	0.89%	33.36%	4.53%	27.19%	1.87%	2.36%	7.13%	100%
muqla	3.63%	6.84%	9.93%	18.96%	1.32%	41.64%	0.37%	3.33%	13.99%	100%
mus	4.51%	7.95%	1.89%	29.44%	1.41%	30.78%	5.43%	3.01%	15.57%	100%
nevsehir	17.98%	18.34%	11.08%	7.11%	2.42%	32.54%	0.99%	2.64%	6.90%	100%
niqde	14.96%	14.40%	9.90%	36.60%	0.42%	15.52%	0.00%	1.81%	6.38%	100%
ordu	5.57%	29.08%	1.23%	19.25%	2.85%	18.38%	2.28%	2.09%	19.28%	100%
rize	0.62%	22.05%	2.93%	18.45%	4.13%	30.17%	0.00%	0.63%	21.03%	100%
sakarya	6.00%	11.83%	6.11%	10.05%	3.33%	28.22%	0.58%	2.37%	31.51%	100%
samsun	6.03%	28.16%	3.27%	14.28%	0.58%	20.23%	0.24%	4.45%	22.77%	100%
siirt	6.40%	9.11%	0.00%	2.28%	0.00%	71.02%	0.00%	0.00%	11.19%	100%
sinop	3.69%	18.45%	0.00%	0.00%	0.00%	31.99%	0.00%	0.00%	45.87%	100%
sivas	4.76%	12.48%	9.51%	14.47%	1.28%	26.73%	2.27%	1.07%	27.42%	100%
tekirdaq	5.35%	17.30%	5.42%	20.03%	1.84%	30.01%	0.00%	2.82%	17.23%	100%
tokat	16.19%	14.31%	7.84%	4.46%	2.51%	9.38%	1.75%	1.70%	41.84%	100%
trabzon	4.30%	29.88%	1.97%	19.73%	2.31%	17.34%	1.32%	2.07%	21.08%	100%
tunceli	1.66%	9.36%	0.00%	21.93%	11.29%	13.85%	5.98%	11.64%	24.29%	100%
surfa	2.00%	11.29%	3.11%	12.39%	3.36%	48.86%	2.66%	3.07%	13.25%	100%
usak	6.76%	0.00%	12.21%	10.30%	2.04%	38.65%	2.27%	0.00%	27.78%	100%
van	4.78%	14.72%	4.97%	13.73%	1.56%	29.84%	1.24%	2.44%	26.73%	100%
yozgat	5.86%	22.44%	5.01%	9.20%	2.69%	29.39%	1.32%	1.69%	22.40%	100%
zonguldak	1.32%	14.19%	23.95%	21.78%	1.11%	16.49%	0.00%	8.37%	12.79%	100%
aksaray	9.29%	9.73%	1.35%	19.27%	0.81%	44.94%	0.63%	1.45%	12.52%	100%
bayburt	5.48%	25.78%	12.45%	7.61%	2.26%	8.68%	0.00%	0.00%	37.74%	100%
karaman	6.34%	4.64%	0.00%	28.69%	0.00%	43.33%	0.00%	8.28%	8.72%	100%
kirkkale	16.16%	11.56%	4.74%	8.61%	1.50%	21.06%	0.23%	0.00%	36.15%	100%
batman	16.55%	21.19%	0.00%	23.15%	0.00%	32.34%	0.00%	0.00%	6.76%	100%
sirnak	15.78%	10.44%	0.00%	22.26%	2.54%	26.70%	3.79%	4.51%	13.97%	100%
bartin	0.86%	8.64%	10.16%	28.74%	2.32%	25.15%	0.00%	14.07%	10.07%	100%
ardahan	11.19%	16.24%	0.00%	9.78%	0.00%	7.40%	0.00%	0.00%	55.39%	100%
iqdir	6.86%	18.91%	9.39%	21.12%	1.57%	17.38%	1.28%	2.96%	20.52%	100%
yalova	3.85%	17.23%	11.72%	26.94%	0.26%	18.66%	0.22%	3.07%	18.04%	100%
karabuk	3.60%	12.37%	10.90%	28.84%	0.79%	21.52%	2.16%	3.41%	16.40%	100%
kilis	11.48%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	88.52%	100%
osmaniye	15.64%	7.17%	0.00%	17.17%	0.00%	47.35%	0.00%	3.02%	9.66%	100%
duzce	1.83%	7.35%	10.09%	29.25%	0.12%	32.06%	0.00%	3.21%	16.09%	100%
Total	5.31%	17.52%	6.84%	15.39%	2.05%	28.73%	1.26%	3.18%	19.72%	100%

An extensive number of multiple regression analyses are performed to find the most significant and not correlated independent variables. In addition within the results the one which fits the best to observed zonal freight production and attraction values based on socioeconomic factors in point of number of truck trips and tonnage of goods is selected examining all statistical tests: R-square (the percent of the dependent explained by the independent), adjusted R-square, F-value (significance of the model), t-tests (significance of the individual independents in the model) and other goodness-of-fit (GOF) tests). Moreover multiple regression assumptions: linearity (the relationship between the predictors and the outcome be linear), normality (the residuals be normally distributed), homogeneity (the error variance should be constant), independence (the errors of observations are not correlated), model specification (model should be properly defined) are tested (Washington, Karlaftis and Mannering, 2003).

In this research graphical, nongraphical and non-parametric methods for assessing normality and linearity are employed and given in Appendix F. As graphical methods, histogram of residuals and normal probability plot (P-P plot of residuals) are applied. As non-parametric test Kolmogorov-Smirnov GOF test is applied to test the normality of residuals. Besides statistical GOF tests the ratio between observed and simulated freight productions and attractions of each province, groups of provinces according to the level of development, and average of provinces are found regarded as one of the factors to decide on generation equations.

In this research outliers (an observation with large residuals) are not removed from regression “since removing outliers without proper justification raises the possibility that data have been manipulated to support a particular hypothesis or model” (Washington, Karlaftis and Mannering, 2003).

According to Ortuzar and Willumsen (2001) the production and attraction models do not guarantee that the total number of originating trips at all zones is equal to the total number of attracted trips. However this condition is implicitly required at the next step which is trip distribution.

Freight production and attraction modeling regression analyses results, obtained equations and their significance tests are given as follows for the one that fits the best.

Freight Production Equations

$$\text{Freight Trip Production} = f(\text{Number of Employees, (4.4)} \\ \text{(Number of Trucks)} \quad \text{DUMMY (INTERNATIONAL PORT EXISTENCE)})$$

$$\begin{aligned} \text{Number of Trucks as Origin} &= 70,498.06 + 0.981 \text{ Number of Employees} \\ \text{(NOTor)} &+ \text{DUMMY (INTPORT) (If exist add 302,163.4)} \end{aligned}$$

The best fit production equation in terms of number of trucks (4.4) is a function of number of employees that produce goods and international port existence that cause freight increase as a result of import. The regression is statistically significant. Obtained R-square is 0.854 and adjusted R-square is 0.850 with standard error of the estimate 193,302. F-test or named as Analysis of Variance (ANOVA) test result is given in Table 4.24 and it is read from this table that F-value is 227 with significance (probability value, p) 0.000 (less than 0.005). Regression coefficients (Beta) for each independent and their significance are given in Table 4.25 and it is read from this table that explanatory variables, number of employees and international port existence as dummy argument, are significant according to t-test (significance, p values, are less than 0.005). Table 4.25 and Table 4.26 also show multicollinearity test results (VIF is less than 2, tolerance is higher than 0.20, Condition Index is less than 15 and eigenvalue is not close to zero) and according to this result there is not a multicollinearity problem.

Table 4.24 F-test Results (ANOVA Test) for Trip Generation Equation 4.4

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.7E+013	2	8.497E+012	227.397	.000 ^a
	Residual	2.9E+012	78	3.737E+010		
	Total	2.0E+013	80			

a. Predictors: (Constant), INTPORT, Number of Employees

b. Dependent Variable: Number.Of.Trucks.(Origin)

Table 4.25 Regression Coefficients (Beta) and t-test Results for
Trip Generation Equation 4.4

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	70498.060	26003.152		2.711	.008		
	Number of Employees	.981	.059	.803	16.636	.000	.805	1.242
	INTPORT2	302163.394	65201.340	.224	4.634	.000	.805	1.242

a. Dependent Variable: Number.Of.Trucks.(Origin)

Table 4.26 Collinearity Diagnostics of Trip Generation Equation 4.4

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	Number of Employees	INTPORT
1	1	2.011	1.000	.11	.10	.11
	2	.599	1.832	.58	.00	.55
	3	.390	2.272	.31	.90	.34

a. Dependent Variable: Number.Of.Trucks.(Origin)

Regression assumptions checks of equation (4.4) are, however, given in Appendix F. These checks are on linearity (Figure F.1), homoscedastic residuals (Figure F.1), and normally distributed residuals (Figure F.3 and Table F.1). As it is seen in Appendix F all regression assumptions are provided.

$$\text{Freight Trip Production (Tons of Moved Goods)} = f(\text{Gross Domestic Products} + \text{DUMMY (INTERNATIONAL PORT EXISTENCE)}) \quad (4.5)$$

$$\text{Tons of Moved Goods as Origin (TOMGor)} = 1,542,173 + 1.294 (\text{Gross Domestic Product Million TL}) + \text{DUMMY (INTPORT)} \text{ (If exit and 3,928,667)}$$

Other production equation (4.5) given in terms of tonnage of moved goods is a function of Gross Domestic Product (Million TL) which is the value of produced goods and international port existence that cause freight increase as a result of import. The regression is statistically significant. Obtained R-square is 0.848 and adjusted R-square

is 0.844 with standard error of the estimate 1,317,105. F-test or named as ANOVA test results are given in Table 4.27 and it is read from this table that F-value is 217 with significance (probability value, p) 0.000 (less than 0.005). Regression coefficients (Beta) for each independent variables and their significance for the equation (4.5) are given in Table 4.28 and it is read from this table that explanatory variables, Gross Domestic Product (Million TL) and international port existence as dummy argument, are significant according to t-test (significance, p values, are less than 0.005). Table 4.28 and Table 4.29 also show multicollinearity test results and according to this result there is not a multicollinearity problem for the equation (4.5).

Table 4.27 F-test Results (ANOVA Test) for Trip Generation Equation 4.5

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.3E+015	2	1.168E+015	217.501	.000 ^a
	Residual	4.2E+014	78	5.369E+012		
	Total	2.8E+015	80			

a. Predictors: (Constant), INTPORT, Gross Domestic Product (Million TL)

b. Dependent Variable: Tons.of.Moved.Goods.(Origin)

Table 4.28 Regression Coefficients (Beta) and t-test Results for Trip Generation Equation 4.5

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1542173	292265.7		5.277	.000		
	Gross Domestic Product (Million TL)	1.294	.083	.778	15.565	.000	.779	1.283
	INTPORT	3928667	794478.6	.247	4.945	.000	.779	1.283

a. Dependent Variable: Tons.of.Moved.Goods.(Origin)

Regression assumptions checks for equation (4.5) are also given in Appendix F. These checks are on linearity (Figure F.4), homoscedastic disturbances (Figure F.5), and normal distribution of residuals (Figure F.6 and Table F.2). As it seen in Appendix F all regression assumptions for equation (4.5) are also provided.

Table 4.29 Collinearity Diagnostics of Trip Generation Equation 4.5

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	Gross Domestic Product (Million TL)	INTPORT
1	1	1.934	1.000	.11	.12	.12
	2	.630	1.753	.87	.09	.21
	3	.436	2.105	.01	.79	.67

a. Dependent Variable: Tons.of.Moved.Goods.(Origin)

Freight Attraction Equations

$$\text{Freight Trip Attraction} = f(\text{Population, Passenger Car Ownership}) \quad (4.6)$$

(Number of Truck Trips) per 1000 Households

$$\begin{aligned} \text{Number of Trucks as Destination} &= -25,454 + 0.287\text{Population} + \\ \text{(NOTdes)} &672.976 \text{ Passenger Car Ownership per} \\ &1000 \text{ Households} \end{aligned}$$

The attraction equation (4.6) in terms of number of trucks is obtained as a function of population which is an indicator on consumption of goods and passenger car ownership per 1000 households which is a parameter on income. This one is also statistically significant. Obtained R-square is 0.826 and adjusted R-square is 0.821 with standard error of the estimate 204,011. F-test or named as ANOVA test results are given in Table 4.30 and it is read from this table that F-value is 185 with significance (probability value, p) 0.000 (less than 0.005). Regression coefficients (Beta) for each independent and their significance are given in Table 4.31 and it is read from this table that explanatory variables, population and passenger car ownership per 1000 households, are significant according to t-test (significance, p values, are less than 0.005). Table 4.31 and Table 4.32 also show multicollinearity test results and according to this result there is not a multicollinearity problem for equation (4.6).

Table 4.30 F-test Results (ANOVA Test) for Trip Generation Equation 4.6

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.5E+013	2	7.684E+012	184.617	.000 ^a
	Residual	3.2E+012	78	4.162E+010		
	Total	1.9E+013	80			

a. Predictors: (Constant), PCP1000NHH, Population

b. Dependent Variable: Number.Of.Trucks.(Destination)

Table 4.31 Regression Coefficients (Beta) and t-test Results for Trip Generation Equation 4.6

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-25454.1	53192.489		-.479	.634		
	Population	.287	.020	.811	14.006	.000	.667	1.499
	PCP1000NHH	672.976	252.979	.154	2.660	.009	.667	1.499

a. Dependent Variable: Number.Of.Trucks.(Destination)

Table 4.32 Collinearity Diagnostics for Trip Generation Equation 4.6

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	Population	PCP1000 NHH
1	1	2.442	1.000	.03	.05	.02
	2	.480	2.256	.11	.66	.01
	3	.078	5.594	.87	.29	.97

a. Dependent Variable: Number.Of.Trucks.(Destination)

Regression assumptions checks for equation (4.6) are also given in Appendix F. These checks are also on linearity (Figure F.7), homoscedastic disturbances (Figure F.8), and normally distributed disturbances (residuals) (Figure F.9 and Table F.3). As it is seen in Appendix F all regression assumptions for equation (4.6) are also provided.

$$\text{Freight Trip Attraction} = f(\text{Population, Passenger Car Ownership}) \quad (4.7)$$

(Tons of Moved Goods) per 1000 Households

$$\text{Tons of Moved Goods as Destination} = -333,701 + 3.556 \text{ Population} + 6317.94 \text{ Passenger Car Ownership per 1000 Households}$$

(TOMGdes)

Other attraction equation (4.7) given in terms of tonnage of moved goods is also a function of population which is a indicator on consumption and passenger car ownership per 1000 households which is an indicator on income. The regression is statistically significant. Obtained R-square is 0.874 and adjusted R-square is 0.871 with standard error of the estimate 2,032,380. F-test or named as ANOVA test results are given in Table 4.33 and it is read from this table that F-value is 271 with significance (probability value, p) 0.000 (less than 0.005). Regression coefficients (Beta) for each independent variables and their significance for the equation (4.7) are given in Table 4.34 and it is read from this table that explanatory variables, population and passenger car ownership per 1000 households, are significant for this case also according to t-test (significance, p values, are less than 0.005). Table 4.34 and Table 4.35 also show multicollinearity test results and according to this result there is not a multicollinearity problem for the equation (4.7).

Table 4.33 F-test Results (ANOVA Test) for Trip Generation Equation 4.7

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.2E+015	2	1.117E+015	270.357	.000 ^a
	Residual	3.2E+014	78	4.131E+012		
	Total	2.6E+015	80			

a. Predictors: (Constant), PCP1000NHH, Population

b. Dependent Variable: Tons.of.Moved.Goods.(Destination)

Moreover regression assumptions checks for equation (4.7) are also given in Appendix F. These checks are also on linearity (Figure F.10), homoscedastic residuals (Figure F.11), and normally distributed residuals (Figure F.12 and Table F.4). As it is seen in Appendix F all regression assumptions for equation (4.7) are also provided.

Table 4.34 Regression Coefficients (Beta) and t-test Results for
Trip Generation Equation 4.7

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-333701	529908.6		-.630	.531		
	Population	3.556	.204	.858	17.432	.000	.667	1.499
	PCP1000NHH	6317.942	2520.199	.123	2.507	.014	.667	1.499

a. Dependent Variable: Tons.of.Moved.Goods.(Destination)

Table 4.35 Collinearity Diagnostics for Trip Generation Equation 4.7

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	Population	PCP1000 NHH
1	1	2.442	1.000	.03	.05	.02
	2	.480	2.256	.11	.66	.01
	3	.078	5.594	.87	.29	.97

a. Dependent Variable: Tons.of.Moved.Goods.(Destination)

When the above freight production and attraction equations are applied to the base year (2004), there are some predictions which are not reasonable (Table 4.36 and Table 4.37). In this research if the ratio of the predicted value divided by observed value in the base year is bigger than 2.0 and less than 0.5, the corresponding province is assumed to be outlier similar to the research performed by Mao and Demetsky (2002). The observed and predicted values for each model are given in two dimensions in Table 4.36 and Table 4.37.

All freight movements, external (inter-provincial), internal (intra-provincial), and international, are regarded to obtain freight production and attraction equations. It is shown in Table 4.36 and Table 4.37 that the outlier provinces are the ones where the internal freight movements are not captured because of the survey locations (see Figure 4.6) and the ones became province after 1989. In addition the ratio between observed and predicted values and the model results (production and attraction models) are illustrated in Table 4.36 and Table 4.37.

Table 4.36 Observed and Predicted Productions and Attractions by Provinces
(Number of Truck Trips)

Province	Number of Trucks Trips as Origin (GENERATION)			Number of Trucks Trips as Destination (ATTRACTION)			Generation/Attraction	
	Observed	Predicted	Predicted/ Observed	Observed	Predicted	Predicted/ Observed	Observed	Predicted
adana	1074224	882890	0.82	1078091	761152	0.71	1.00	1.16
adiyaman	155720	273387	1.76	130060	271856	2.09	1.20	1.01
afyon	354325	338589	0.96	273126	344224	1.26	1.30	0.98
agri	365574	247700	0.68	307926	188308	0.61	1.19	1.32
amasya	64678	162175	2.51	102290	247210	2.42	0.63	0.66
ankara	1450695	1304015	0.90	1347350	1628245	1.21	1.08	0.80
antalya	867534	1029292	1.19	1152963	831607	0.72	0.75	1.24
artvin	69600	52915	0.76	46751	131264	2.81	1.49	0.40
aydin	695996	410250	0.59	609524	451886	0.74	1.14	0.91
balikesir	545197	720061	1.32	508991	470174	0.92	1.07	1.53
bilecik	129005	92794	0.72	268908	177765	0.66	0.48	0.52
bingöl	70303	162184	2.31	79793	87297	1.09	0.88	1.86
bitlis	73115	220206	3.01	91393	141980	1.55	0.80	1.55
bolu	248168	146777	0.59	213368	245224	1.15	1.16	0.60
burdur	69248	122685	1.77	134981	256241	1.90	0.51	0.48
bursa	798286	1149787	1.44	823244	875976	1.06	0.97	1.31
canakkale	288592	500380	1.73	283671	257017	0.91	1.02	1.95
cankiri	111430	181254	1.63	75575	110549	1.46	1.47	1.64
corum	172944	252650	1.46	152908	294055	1.92	1.13	0.86
denizli	493173	374584	0.76	482276	476155	0.99	1.02	0.79
diyarbakir	417246	418362	1.00	522349	457090	0.88	0.80	0.92
edirne	185247	173134	0.93	171538	256687	1.50	1.08	0.67
elazığ	286132	254671	0.89	297380	295097	0.99	0.96	0.86
erzincan	277695	149029	0.54	243247	188461	0.77	1.14	0.79
erzurum	826407	371527	0.45	875619	352721	0.40	0.94	1.05
eskisehir	518130	299465	0.58	533597	423434	0.79	0.97	0.71
gaziantep	559960	427195	0.76	540627	572803	1.06	1.04	0.75
giresun	264689	227951	0.86	311441	212722	0.68	0.85	1.07
gümüşhane	31988	66963	2.09	39018	99203	2.54	0.82	0.68
hakkari	20739	193299	9.32	25309	86632	3.42	0.82	2.23
hatay	730796	719046	0.98	798286	541595	0.68	0.92	1.33
isparta	143066	237822	1.66	162048	319212	1.97	0.88	0.75
icel	1293568	894961	0.69	1313253	668248	0.51	0.99	1.34
istanbul	3379447	3663442	1.08	3160806	3539212	1.12	1.07	1.04
izmir	1979019	1491292	0.75	2085528	1275819	0.61	0.95	1.17
kars	272423	164344	0.60	263986	130002	0.49	1.03	1.26
kastamonu	128302	187512	1.46	169078	244952	1.45	0.76	0.77
kayseri	782117	366108	0.47	878431	550464	0.63	0.89	0.67
kırklareli	130060	145476	1.12	105454	223783	2.12	1.23	0.65
kişsehir	126545	157314	1.24	98775	200587	2.03	1.28	0.78
kocaeli	1435580	734742	0.51	922019	532040	0.58	1.56	1.38
konya	718844	751725	1.05	660845	845350	1.28	1.09	0.89
kütahya	424276	287153	0.68	512155	365179	0.71	0.83	0.79
malatya	202120	331383	1.64	194738	376364	1.93	1.04	0.88
manisa	727984	499139	0.69	602142	509446	0.85	1.21	0.98
kahramanmaraş	370846	354279	0.96	292810	409843	1.40	1.27	0.86
mardin	324447	288426	0.89	268205	255327	0.95	1.21	1.13
mugla	260120	335745	1.29	302653	457963	1.51	0.86	0.73
mus	105805	229632	2.17	98424	156935	1.59	1.07	1.46
nevşehir	320580	161021	0.50	288944	231297	0.80	1.11	0.70
niğde	173999	183040	1.05	201417	204493	1.02	0.86	0.90
ordu	103696	401501	3.87	79090	332805	4.21	1.31	1.21
rize	200011	157358	0.79	127248	194073	1.53	1.57	0.81
sakarya	344483	376640	1.09	475246	455549	0.96	0.72	0.83
samsun	532191	697771	1.31	666469	426169	0.64	0.80	1.64
siirt	25309	186176	7.36	57648	111281	1.93	0.44	1.67
sinop	89284	150892	1.69	27418	169884	6.20	3.26	0.89
sivas	304059	293188	0.96	374362	318673	0.85	0.81	0.92
tekirdağ	523403	582688	1.11	449585	302451	0.67	1.16	1.93
tokat	211611	360966	1.71	255902	360359	1.41	0.83	1.00
trabzon	597924	453736	0.76	682639	400205	0.59	0.88	1.13
tunceli	71709	61388	0.86	62569	38828	0.62	1.15	1.58
şanlı urfa	201417	389445	1.93	202120	596755	2.95	1.00	0.65
uşak	45345	170288	3.76	67842	278456	4.10	0.67	0.61
van	423222	321789	0.76	460482	340690	0.74	0.92	0.94
yoğat	33042	288190	8.72	83660	269315	3.22	0.39	1.07
zonguldak	227429	254155	1.12	241841	365080	1.51	0.94	0.70
aksaray	92096	207388	2.25	103696	265043	2.56	0.89	0.78
bayburt	28121	32673	1.16	17224	94318	5.48	1.63	0.35
karaman	59406	150100	2.53	53782	214558	3.99	1.10	0.70
kırıkkale	108618	210846	1.94	163805	174148	1.06	0.66	1.21
batman	191926	238938	1.24	117054	187649	1.60	1.64	1.27
şirnak	361707	212908	0.59	113539	137904	1.21	3.19	1.54
bartın	111078	94743	0.85	111430	190867	1.71	1.00	0.50
ardahan	13709	77602	5.66	11248	49742	4.42	1.22	1.56
igdir	275938	152338	0.55	249926	97901	0.39	1.10	1.56
yalova	52024	433510	8.33	52727	182699	3.46	0.99	2.37
karabük	70654	161680	2.29	63975	236136	3.69	1.10	0.68
kilis	3164	112777	35.64	2109	106355	50.43	1.50	1.06
osmaniye	88230	234849	2.66	88933	296682	3.34	0.99	0.79
düzce	119163	169658	1.42	84715	225876	2.67	1.41	0.75

missing internal
freight flow

outlier

outlier

Table 4.37 Observed and Predicted Productions and Attractions by Provinces
(Tonnage of Moved Goods)

Province	Tonnage of Moved Goods as Origin (GENERATION)			Tonnage of Moved Goods as Destination (ATTRACTION)			Generation/Attraction	
	Observed	Predicted	Predicted/ Observed	Observed	Predicted	Predicted/O bserved	Observed	Predicted
adana	13,502,284	10,369,114	0.77	10,084,954	8,738,300	0.87	1.34	1.19
adiyaman	1,420,217	2,374,777	1.67	1,383,993	3,031,317	2.19	1.03	0.78
afyon	3,215,154	2,894,026	0.90	2,554,916	3,854,368	1.51	1.26	0.75
agri	3,112,306	1,850,722	0.59	2,885,162	2,157,847	0.75	1.08	0.86
amasya	899,486	2,175,593	2.42	1,147,650	2,537,691	2.21	0.78	0.86
ankara	16,267,876	14,122,831	0.87	16,184,978	18,896,681	1.17	1.01	0.75
antalya	11,162,926	9,984,089	0.89	15,801,948	9,406,266	0.60	0.71	1.06
artvin	599,148	2,048,475	3.42	544,897	1,291,602	2.37	1.10	1.59
aydin	7,321,601	4,298,341	0.59	5,341,047	5,003,476	0.94	1.37	0.86
balikesir	6,014,573	8,277,444	1.38	6,256,712	5,271,823	0.84	0.96	1.57
bilecik	1,157,873	2,484,581	2.15	2,805,953	1,746,146	0.62	0.41	1.42
bingöl	1,108,466	1,755,534	1.58	1,335,500	941,512	0.70	0.83	1.86
bitlis	893,703	1,796,037	2.01	1,111,103	1,590,935	1.43	0.80	1.13
bolu	2,445,561	2,770,869	1.13	2,170,129	2,439,706	1.12	1.13	1.14
burdur	1,124,591	2,204,334	1.96	1,892,252	2,529,040	1.34	0.59	0.87
bursa	8,008,222	12,446,324	1.55	8,084,867	10,142,281	1.25	0.99	1.23
canakkale	2,778,865	6,956,170	2.50	2,510,569	2,725,038	1.09	1.11	2.55
çankiri	1,265,795	1,928,931	1.52	763,161	1,180,489	1.55	1.66	1.63
corum	2,682,320	2,858,634	1.07	2,236,550	3,166,629	1.42	1.20	0.90
denizli	5,184,002	4,157,550	0.80	6,590,603	5,135,191	0.78	0.79	0.81
diyarbakir	5,991,588	3,695,720	0.62	7,056,048	5,457,902	0.77	0.85	0.68
edirne	2,143,901	2,661,469	1.24	1,546,617	2,655,081	1.72	1.39	1.00
elazığ	3,208,170	2,571,465	0.80	4,093,038	3,186,782	0.78	0.78	0.81
erzincan	1,899,493	1,944,029	1.02	2,245,501	1,949,902	0.87	0.85	1.00
erzurum	7,190,404	2,569,113	0.36	9,206,663	4,046,307	0.44	0.78	0.63
eskisehir	4,932,934	3,593,463	0.73	4,888,824	4,504,379	0.92	1.01	0.80
gaziantep	6,118,684	3,893,690	0.64	8,411,730	6,482,132	0.77	0.73	0.60
giresun	4,118,562	2,462,054	0.60	4,499,690	2,355,561	0.52	0.92	1.05
gümüşhane	130,100	1,758,969	13.52	313,475	1,002,194	3.20	0.42	1.76
hakkari	160,446	1,682,191	10.48	342,299	944,812	2.76	0.47	1.78
hatay	8,482,862	8,518,053	1.00	7,711,721	6,109,458	0.79	1.10	1.39
isparta	2,134,285	2,523,103	1.18	2,591,190	3,368,867	1.30	0.82	0.75
icel	18,741,332	9,849,777	0.53	10,318,481	7,732,412	0.75	1.82	1.27
istanbul	38,227,008	42,792,138	1.12	39,587,981	42,756,363	1.08	0.97	1.00
izmir	23,766,794	18,353,842	0.77	23,133,588	15,010,195	0.65	1.03	1.22
kars	2,652,671	1,877,862	0.71	2,789,327	1,388,406	0.50	0.95	1.35
kastamonu	1,777,715	2,350,386	1.32	1,982,070	2,503,425	1.26	0.90	0.94
kayseri	6,635,665	3,436,714	0.52	9,836,304	6,017,899	0.61	0.67	0.57
kirklareli	1,424,108	3,071,025	2.16	999,752	2,291,889	2.29	1.42	1.34
kirsehir	1,112,631	2,006,730	1.80	857,446	2,001,376	2.33	1.30	1.00
kocaeli	18,226,254	13,032,593	0.72	8,174,888	6,036,875	0.74	2.23	2.16
konya	6,872,439	5,541,913	0.81	6,967,595	9,875,266	1.42	0.99	0.56
kütahya	4,181,892	3,006,521	0.72	3,967,165	3,921,690	0.99	1.05	0.77
malatya	2,249,156	3,138,758	1.40	2,641,551	4,221,737	1.60	0.85	0.74
manisa	8,350,966	6,835,717	0.82	5,184,670	5,797,617	1.12	1.61	1.18
kahramanmaraş	4,368,759	3,477,116	0.80	4,717,701	4,645,270	0.98	0.93	0.75
mardin	4,471,677	2,538,130	0.57	4,392,193	2,958,664	0.67	1.02	0.86
muğla	2,670,544	4,082,384	1.53	3,426,059	4,871,991	1.42	0.78	0.84
muş	1,195,477	1,830,992	1.53	1,457,872	1,793,854	1.23	0.82	1.02
neveşehir	3,084,186	2,412,141	0.78	1,953,353	2,347,320	1.20	1.58	1.03
niğde	1,408,017	2,308,454	1.64	1,522,938	2,138,519	1.40	0.92	1.08
ordu	1,489,349	2,974,551	2.00	884,416	3,805,865	4.30	1.68	0.78
rize	2,017,963	2,353,148	1.17	1,672,496	2,043,979	1.22	1.21	1.15
sakarya	3,803,337	3,608,061	0.95	4,837,583	4,851,649	1.00	0.79	0.74
samsun	8,006,872	7,822,713	0.98	8,414,872	4,949,190	0.59	0.95	1.58
siirt	349,034	1,923,287	5.51	860,341	1,181,390	1.37	0.41	1.63
sinop	1,715,304	1,937,194	1.13	253,076	1,675,079	6.62	6.78	1.16
sivas	2,022,955	2,821,020	1.39	4,183,555	3,531,470	0.84	0.48	0.80
tekirdağ	5,475,251	8,032,258	1.47	4,784,425	3,335,272	0.70	1.14	2.41
tokat	2,986,354	2,883,731	0.97	2,488,841	4,033,576	1.62	1.20	0.71
trabzon	5,319,905	2,811,213	0.53	7,715,017	4,560,538	0.59	0.69	0.62
tunceli	534,269	1,650,035	3.09	546,682	340,651	0.62	0.98	4.84
şanlı urfa	1,751,183	3,717,350	2.12	2,857,414	6,908,579	2.42	0.61	0.54
uşak	460,358	2,170,900	4.72	870,969	2,805,209	3.22	0.53	0.77
van	3,280,624	2,334,465	0.71	5,524,050	3,943,792	0.71	0.59	0.59
yoğat	361,287	2,317,793	6.42	997,962	3,053,945	3.06	0.36	0.76
zonguldak	3,491,554	3,209,183	0.92	3,126,389	3,838,354	1.23	1.12	0.84
aksaray	802,156	2,021,202	2.52	1,081,027	2,755,348	2.55	0.74	0.73
bayburt	170,169	1,644,394	9.66	157,210	869,107	5.53	1.08	1.89
karaman	742,074	2,200,498	2.97	540,580	2,136,790	3.95	1.37	1.03
kırıkkale	1,727,843	2,557,484	1.48	1,469,938	1,878,265	1.28	1.18	1.36
batman	3,770,966	2,168,464	0.58	1,001,159	2,099,186	2.10	3.77	1.03
şirnak	6,556,645	1,772,778	0.27	1,269,360	1,535,847	1.21	5.17	1.15
bartın	1,258,062	1,747,864	1.39	1,449,117	1,844,289	1.27	0.87	0.95
ardahan	49,170	1,654,111	33.64	132,806	479,442	3.61	0.37	3.45
ığdır	2,980,185	1,698,298	0.57	2,934,708	977,671	0.33	1.02	1.74
yalova	503,906	6,462,635	12.83	589,047	1,776,734	3.02	0.86	3.64
karabük	799,145	2,625,105	3.28	767,304	2,304,959	3.00	1.04	1.14
kilis	27,694	1,875,531	67.72	21,622	994,587	46.00	1.28	1.89
osmaniye	759,977	2,201,754	2.90	919,730	3,109,168	3.38	0.83	0.71
düzce	1,554,299	2,093,671	1.35	1,232,323	2,308,284	1.87	1.26	0.91

missing internal
freight flow

outlier

outlier

4.5 Freight Trip Distribution between Traffic Analysis Zones (TAZ)

The objective of this stage is to simulate origin-destination matrix regarding the reflection of zonal demographic and socioeconomic changes, and these changes alter the choice of destination in point of freight movement. In this research Gravity Model is employed for trip distribution stage. This model explains the number of freight trips from one zone (province) to another zone by means of the gravity between these two zones, in other words with the magnitude of one zone freight trip production and the other zone freight trip attraction (derived from trip generation model) and the accessibility between these two zones. It requires an impedance matrix (distance, time or cost), and productions and attractions of zones. The accessibility (or named as separation or impedance) between these two zones in this research is explained with the distance between them. The trips between origin and destination zones vary directly with a certain function of the distance between these zones.

After determining freight trips productions and attractions of each province as given in the previous section, it is needed to distribute these freight trips between production and attraction zones. The result of this stage is a trip matrix. By this way gravity model is calibrated.

It is possible to add intra-zonal freight movements in trip generation as production and attraction model, however for trip distribution only inter-zonal freight movements are relevant. Thus intra-provincial freight flows are excluded to distribute freight trips only inter-provincial freight flows are regarded in trip distribution stage.

In this research TRANPLAN, one of the conventional travel demand modeling packages, is used to distribute truck trip productions and attractions between provinces. Initially aggregated surveys (includes 42,164 truck trips) are used. Fourteen iterations for the distribution of truck trip productions and attractions are performed to obtain simulated O-D matrix. The observed Trip Length Distribution (TLD) is used in TRANPLAN and the best value for β which reproduces as closely as possible simulated TLD as a result of iterations is found. The approach of this task is simply to guess a value for β , run the gravity model and then obtain the simulated TLD. This task is employed as many times as observed TLD is close to simulated TLD.

In order to find simulated O-D matrix doubly constrained gravity model is used i.e., “ $T_{ij} = A_i O_i B_j D_j f(d_{ij})$ ”. The coefficients “A” and “B” are used to balance productions and attractions of each zone. Here exponential form of distance is used as impedance and deterrence function for doubly constrained condition and the value of constant β is found by means of TRANPLAN as a result of fourteen iterations.

$$f(d_{ij}) = e^{-\beta d_{ij}} \quad (4.8)$$

the coefficient β in equation (3.8) is found as 0.0216

$$A_i = 1 / (\sum B_j D_j f(d_{ij})) \quad j = 1 \dots J$$

$$B_j = 1 / (\sum A_i O_i f(d_{ij})) \quad i = 1 \dots I$$

The most standard validation check of trip distribution models used as part of calibration is comparisons of observed and simulated trip length frequency distributions. Plot trip length frequency distribution shows how well the model can simulate observed trip lengths. The frequencies of the observed truck trips according to binned travel distances are given in Table 4.38. This table is also converted to plot of observed trip length distribution in Figure 4.13 According to this figure trucks travel distances are mostly (77% of the truck trips) less than 700 km. Moreover almost 31% of the trucks travel around 200 km. Furthermore the frequencies of the simulated (synthetic) truck trips by binned travel distances are given in Table 4.39. This table is also illustrated by plot of simulated trip length distribution in Figure 4.14. This figure is read as around 77% of trucks travel with the distance less than 700 km. In this figure there is not a steep peak as the observed one. Instead of this there are five descending peak values. These are in order of 200 km, 300 km, 400 km, 500 km and 600 km travel distances with each of them around 12% to 14%. However both figures explain the gravity in point of freight transportation.

In addition coincidence ratio is used to calibrate the distributions. “Mathematically, the sum of the lower value of the two distributions at each increment of X is divided by the sum of the higher value of the two distributions at each increment of X” (Cambridge Systematics, Inc., 2007). Generally, the coincidence ratio measures the percent of area

that “coincides” for the two curves (observed and simulated) which is measured as a percentage of the total area of these two distributions. In this case it is found as 0.71.

Table 4.38 Truck Trips Distance Distribution (Observed)

OBSERVED TRUCK MATRIX							
Trip Distance (Km)	Average Trip Distance	Trip Distance (Km) (For Graph)	No. of Trips/Day	%	Cumulative Trips	Cumulative %	Vehicle-Km.
0	0	0	0	0	0	0	0
0 - 100	50	100	5540	8	5540	8	277,000
100 - 200	150	200	15121	23	20661	31	2,268,150
200 - 300	250	300	9586	14	30247	46	2,396,500
300 - 400	350	400	6621	10	36868	56	2,317,350
400 - 500	450	500	5475	8	42343	64	2,463,750
500 - 600	550	600	5177	8	47520	72	2,847,350
600 - 700	650	700	3344	5	50864	77	2,173,600
700 - 800	750	800	4374	7	55238	84	3,280,500
800 - 900	850	900	2724	4	57962	88	2,315,400
900 - 1000	950	1000	2315	4	60277	91	2,199,250
1000 - 1100	1050	1100	1603	2	61880	94	1,683,150
1100 - 1200	1150	1200	1573	2	63453	96	1,808,950
1200 - 1300	1250	1300	1106	2	64559	98	1,382,500
1300 - 1400	1350	1400	414	1	64973	98	558,900
1400 - 1500	1450	1500	565	1	65538	99	819,250
1500 - 1600	1550	1600	198	0	65736	99	306,900
1600 - 1700	1650	1700	290	0	66026	100	478,500
1700 - 1800	1750	1800	77	0	66103	100	134,750
1800 - 1900	1850	1900	10	0	66113	100	18,500
1900 - 2000	1950	2000	0	0	66113	100	0
Total			66113	100.00			29,730,250

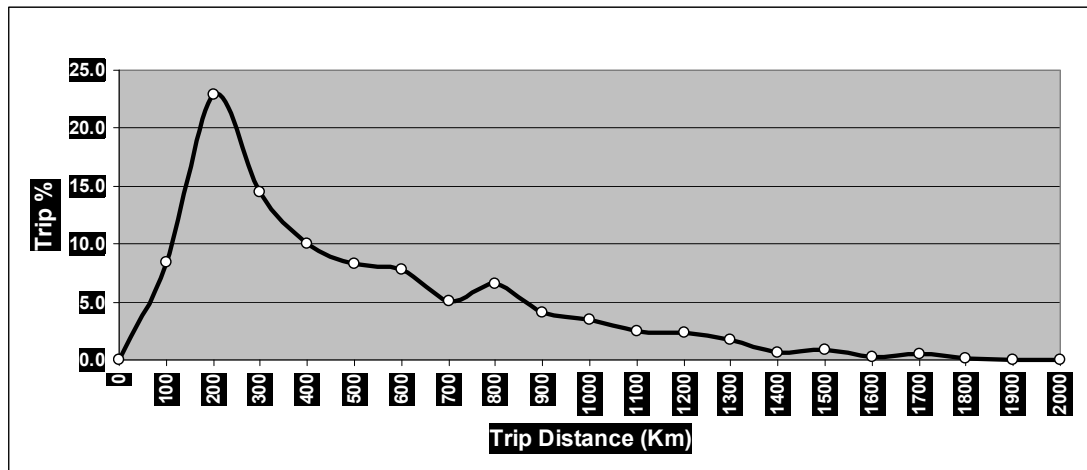


Figure 4.13 Trip Length Frequency Distribution (Observed)

Table 4.39 Truck Trips Distance Distribution (Simulated)

SYNTHESIZED TRUCK MATRIX							
Trip Distance (Km)	Average Trip Distance	Trip Distance (Km) (For Graph)	No. of Trips/Day	%	Cumulative Trips	Cumulative %	Vehicle-Km.
0	0	0	0	0	0	0	0
0 - 100	50	100	2391	4	2391	4	119,550
100 - 200	150	200	8605	13	10996	17	1,290,750
200 - 300	250	300	9131	14	20127	31	2,282,750
300 - 400	350	400	9010	14	29137	44	3,153,500
400 - 500	450	500	8538	13	37675	57	3,842,100
500 - 600	550	600	8040	12	45715	69	4,422,000
600 - 700	650	700	5171	8	50886	77	3,361,150
700 - 800	750	800	4454	7	55340	84	3,340,500
800 - 900	850	900	3386	5	58726	89	2,878,100
900 - 1000	950	1000	2303	3	61029	93	2,187,850
1000 - 1100	1050	1100	1691	3	62720	95	1,775,550
1100 - 1200	1150	1200	1032	2	63752	97	1,186,800
1200 - 1300	1250	1300	845	1	64597	98	1,056,250
1300 - 1400	1350	1400	447	1	65044	99	603,450
1400 - 1500	1450	1500	517	1	65561	99	749,650
1500 - 1600	1550	1600	171	0	65732	100	265,050
1600 - 1700	1650	1700	181	0	65913	100	298,650
1700 - 1800	1750	1800	54	0	65967	100	94,500
1800 - 1900	1850	1900	10	0	65977	100	18,500
1900 - 2000	1950	2000	0	0	65977	100	0
Total			65977	100.00			32,926,650

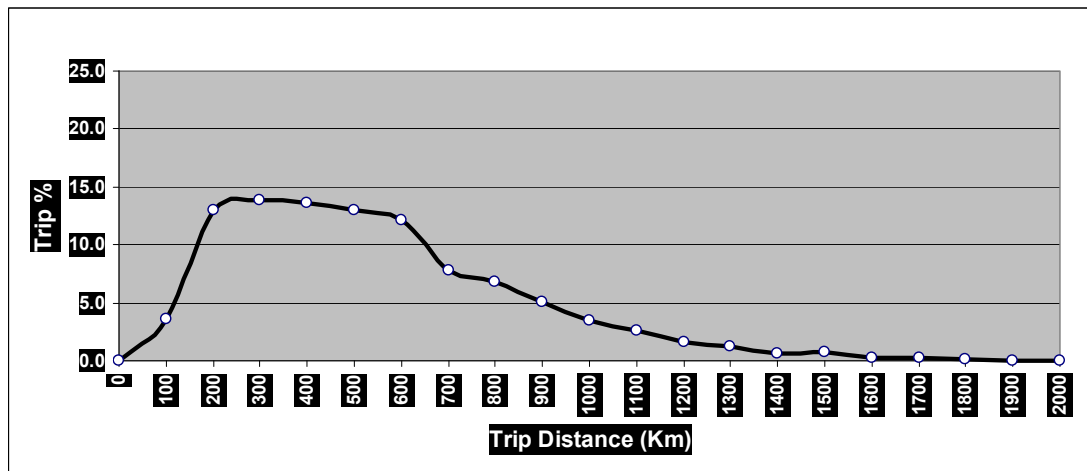


Figure 4.14 Trip Length Frequency Distribution (Simulated)

Moreover average trip length for all truck trips interchanges are found as 450 km for observed and 499 km for simulated truck trips. The included trips are only the trips between provinces and do not include intra-provincial and international trips.

Another calibration test is plotting simulated O-D pairs versus observed O-D pairs and finding Coefficient of determination (R-square) which indicates how well simulated O-D pairs fit observed O-D pairs (Figure 4.15).

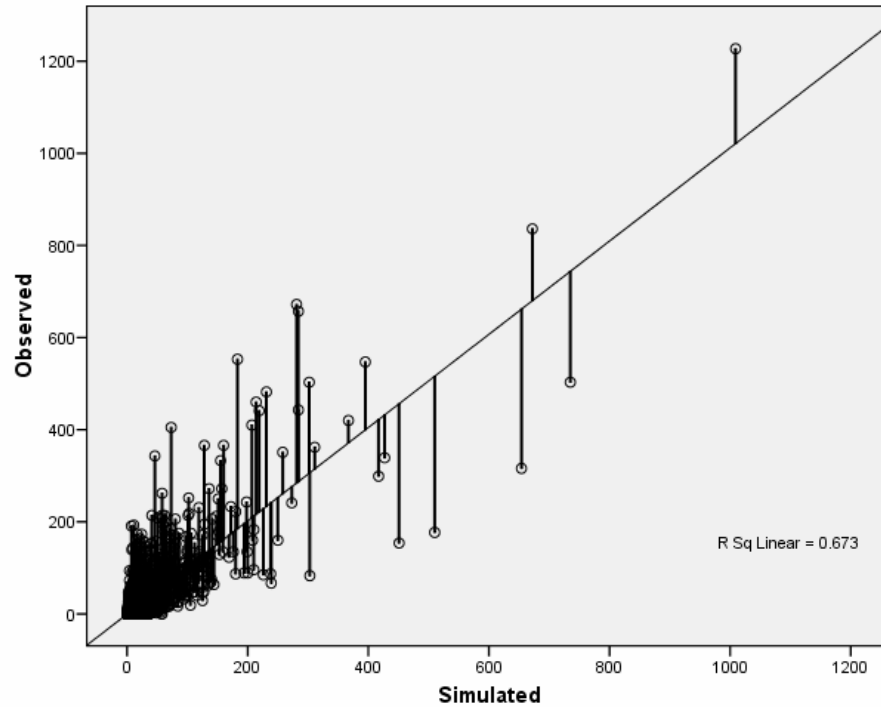


Figure 4.15 Scatter Dot Plots of Observed and Simulated O-D Pairs

The result is statistically significant. Obtained Coefficient of determination (R-square) is 0.673 and adjusted R-square is 0.673 with standard error of the estimate 22 trucks. In addition F-value is 217 with significance (probability value, p) 0.000 (less than 0.005). Regression coefficient (Beta) is found 1.012 as given in equation (4.9).

$$Y (\text{Observed O-D Pairs}) = -0.113 + 1.012 X (\text{Predicted O-D Pairs}) \quad (4.9)$$

The regression model for trip generation is generally employed on large scale; therefore aggregated O-D surveys are employed in trip generation stage in this research. Aggregated surveys (first case) are also employed in trip distribution stage. However for trip distribution stage large scale data may not be necessary and one year data may be

sufficient to calibrate the gravity model and to obtain simulated O-D matrix. Therefore 2004 data including toll gate surveys on motorways (conducted in 2005) are employed and gravity model is recalibrated (second case). This test is also performed to validate Gravity Model. By this way Gravity Model's reasonableness is checked. Again doubly constrained condition and exponential deterrence function is again employed and TRANPLAN package is rerun.

In this case the coefficient β is found as 0.0239 as a result of three iterations. The observed truck trip length distribution for this case is given in Figure 4.16 According to this figure trucks travel distances are mostly (77% of the trucks) less than 700 km. Moreover almost 30% of the trucks travel around 200 km. Furthermore the simulated (synthetic) truck trip length distribution for the second case is given in Figure 4.17. This figure is read as around 80% of trucks travels with the distance less than 700 km. In this figure there is a peak around 200 km and slightly decreasing four peaks at 300 km, 400 km, 500 km and 600 km travel distances with each of them is around 12% to 14%. These figures also explain the gravity in point of freight transportation. In this case coincidence ratio is found as 0.70 and average trip length for all truck trips interchanges are found as 455 km for observed and 469 km for simulated truck trips.

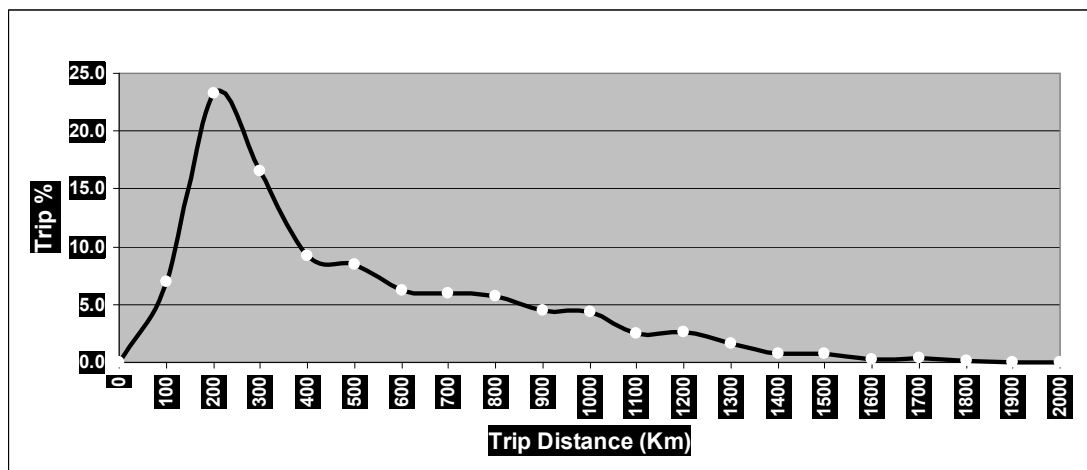


Figure 4.16 Trip Length Frequency Distribution for the Limited Data
(Second Case) (Observed)

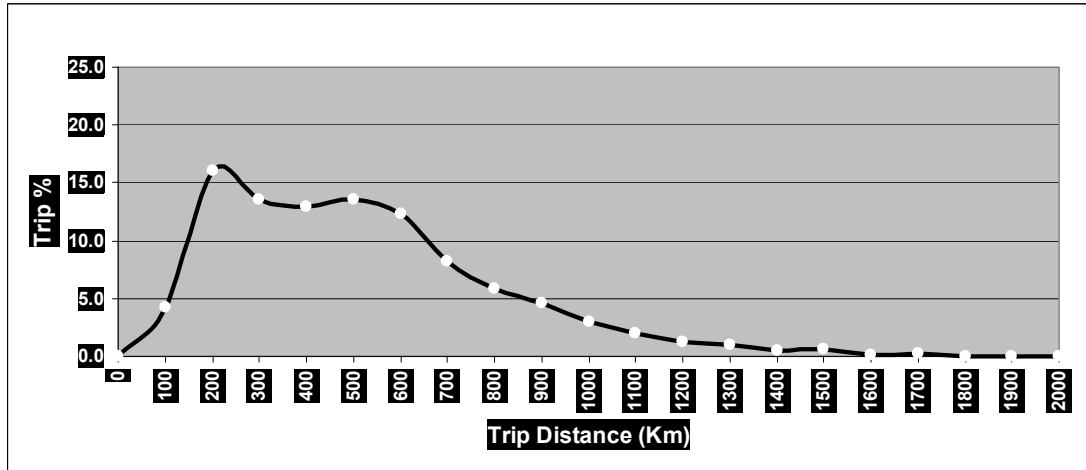


Figure 4.17 Trip Length Frequency Distribution for the Limited Data
(Second Case) (Simulated)

In addition deterrence function and also other related parameters are determined and calibrated by regression analysis using logarithmic transformation of gravity equation (4.10) (also see equation 2.7).

$$T_{ij} = k O_i^\lambda D_j^\alpha / (d_{ij}^\beta) \quad (4.10)$$

Where;

T_{ij} flow from place i to place j

k a proportionality constant

O_i flow originating from place i

D_j flow terminating at place j

(d_{ij}) distance between places i and j

β a parameter of transport friction related to the efficiency of the transportation system between two locations.

λ potential to generate movements (emissiveness)

α potential to attract movements (attractiveness)

$$\ln (T_{ij}) = \ln (k) + \lambda \ln (O_i) + \alpha \ln (D_j) - \beta \ln (d_{ij}) \quad (4.11)$$

The regression analysis is employed to equation (4.11) to find the parameters and to test statistical significance. The results are, R-square is 0.527, and adjusted R-square is 0.527 with 0.875 standard error of the estimation. All regression analysis assumptions are provided and there is not a multicollinearity problem (Table 4.10 and Table 4.41). One of the assumptions that standardized regression residuals show normal distribution is provided (Figure 4.18 and Figure 4.19). According to regression equation k is 0.498, λ is 0.641, α is 0.628 and β is found 0.894.

The value of parameters λ , α , and β may change in time as a result of technological inventions and economic development since these values influence the estimated spatial interactions (Rodrigue, Comtois and Slack, 2006). For instance improvements in transport efficiency reduce the value of beta exponent and economic development is likely to influence the values of λ , and α reflecting a growth in mobility.

Table 4.40 Coefficients of Correlation

		LnTij	LnOi	LnDj	LnDij
Pearson Correlation	LnTij	1.000	.345	.348	-.381
	LnOi	.345	1.000	-.195	.119
	LnDj	.348	-.195	1.000	.092
	LnDij	-.381	.119	.092	1.000
Sig. (1-tailed)	LnTij	.	.000	.000	.000
	LnOi	.000	.	.000	.000
	LnDj	.000	.000	.	.000
	LnDij	.000	.000	.000	.
N	LnTij	3010	3010	3010	3010
	LnOi	3010	3010	3010	3010
	LnDj	3010	3010	3010	3010
	LnDij	3010	3010	3010	3010

Table 4.41 Coefficients of Regression Equation for the Logarithmic Transformation of Gravity Equation

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-.698	.206		-3.384	.001					
	LnOi	.641	.017	.498	38.553	.000	.345	.575	.484	.943	1.060
	LnDj	.628	.017	.489	37.998	.000	.348	.570	.477	.949	1.054
	LnDij	-.894	.023	-.486	-38.174	.000	-.381	-.571	-.479	.972	1.029

a. Dependent Variable: LnTij

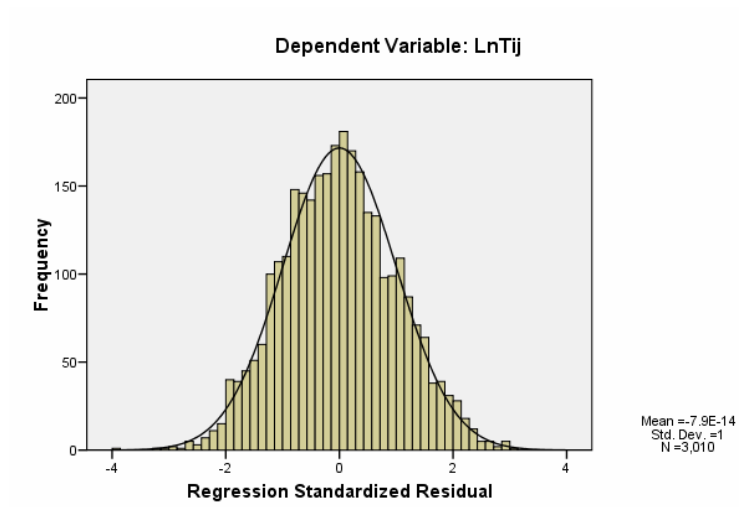


Figure 4.18 Histogram of Regression Standardized Residuals for Logarithmic Transformation of Gravity Function

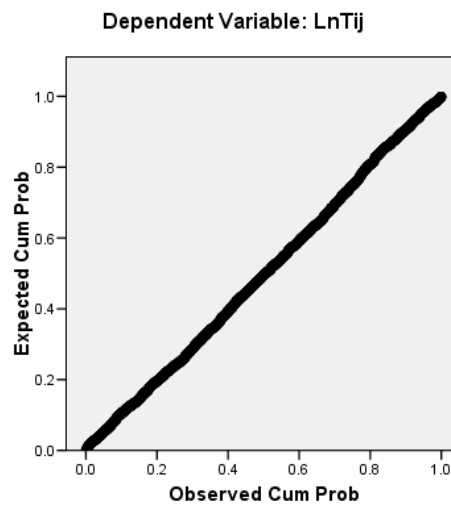


Figure 4.19 Normal P-P Plot of Regression Standardized Residual for Logarithmic Transformation of Gravity Function

CHAPTER 5

RESULTS

In this chapter research outcomes are illustrated and evaluated. The results of the empirical matrices are submitted as national freight flow characteristics in the first part of the results. In addition results on trip generation analysis are presented as second part and outcomes on trip distribution stage is given as the third part of the research results. Some of the referring figures and tables in this chapter are presented in Chapter 4.

Freight demand is mostly derived from developments in other sectors of the economy. Figure D.2 and D.3 (Appendix D) show that increase in economy (increase in employment and increase in Gross Domestic Product) cause increase in freight transport.

Transport modes can compete with each other in terms of cost, speed, reliability, frequency, etc. (Rodrigue, Comtois and Slack, 2006). Each mode has its own price and performance profile therefore actual competition between the modes depends on traveled distance (Rodrigue, Comtois and Slack, 2006). According to observed freight flows average truck traveling distance in Türkiye is around 400 km including all trips: intra-provincial, inter-provincial and international (Table 4.5 and Table 4.6). As shown in Figure 5.1 road transport mode is the most efficient and economic when the freight travel distance is less than 500 km (or sometimes 750 km) (Rodrigue, Comtois and Slack, 2006). However when freight travel distance is between 500 (or 750 km) and 1500 km rail transportation is more efficient (Figure 5.1). On the other hand if transportation distance is higher than 1500 km maritime is more economic and more efficient (Figure 5.1). Road transport also enable direct loading from origin and direct unloading to destination (door-to-door service), therefore it does not need transfer cost (Rodrigue, Comtois and Slack, 2006). Other reason on choice of mode is existing flexibility of route choice, infrastructure and supply characteristics. Freight transportation is highly sensitive to available physical and transport structures services (Garrido, 2003). Road transportation is well-developed and efficient in Türkiye with higher level of accessibility to a wider range of suppliers and consumers comparing to

other modes. The result on truck traveling distance reveals why the road transport is the most widely preferred mode (more than 90%) for freight transportation in Türkiye. In addition average truck travel distance for intra-provincial freight movement is around 60 km, for inter-provincial freight movement is approximately 400 km, and for international freight movement is 1000 km (within Turkish borders).



Source: Rodrigue, Comtois and Slack, 2006

Figure 5.1 Distances and Mode Choices

Moreover according to aggregated surveys and in terms of number of truck trips 19% of freight movements are intra-provincial, 76% are inter-provincial and 5% are international. However in terms of tonnage of moved goods 14% are intra-provincial, 79% are inter-provincial and 7% are international. These figures validity, reliability and timeliness are tested using 2007 and 2008 roadside surveys (axle load surveys). According to surveys between 2007 and 2008, 19% of trucks move intra-provincial, 75% of trucks move inter-provincial and 6% of trucks move international. In terms of tonnage of moved goods, however, 15% of trucks move intra-provincial, 77% of trucks move inter-provincial and 8% of trucks move international. All these results show that the majority of freight flows on the Turkish highway network is between provinces (inter-provincial). Within internationally moving trucks 10-20% is transit traffic and the rest is originating or ending within Turkish borders.

Payload (tons per truck) of trucks on the other hand changes by movement type. Average payload of a truck is 11 tons and for intra-provincial movement it is around 8.5 tons, for inter-provincial movement it is around 11.5 tons, and for international movement it is approximately 14.7 tons. Furthermore average load per truck also changes according to commodity type (see Table 4.9). The heaviest commodity type is mining with 18.79 tons per truck and the second heaviest is construction materials with 18.56 tons per truck.

However the lightest one is live animals with 8.85 tons per truck. In addition 29% of all moving trucks are empty, but they carry a small amount of load 2.53 tons per truck on the average. This figure is 5.4 tons per truck in USA (USDOT-FHWA, 1999). The empty truck ratio in Türkiye is very similar for 2007, 30% and 2008, 32%, (KGM, 2008; KGM, 2009). This high ratio reveals that there are problems on freight transportation in terms of logistic issues. In addition empty trucks payload is 2.56 tons in 2007 and 3.41 tons in 2008 (KGM, 2008; KGM, 2009). This difference may be formed as a consequence of global financial crisis.

Moreover the majority of moving trucks within provinces are empty as 46% (Table 4.12). The reason for this high ratio may be that internally (intra-provincial) moving trucks are mostly carrying construction materials (Table 4.12) and moving in short distances. These trucks carry load on the way going and are empty on the way returning. In other words they carry freight on one way. However out of empty trucks the majority of inter-provincial and international trucks carry manufactured materials, which corresponds to about 20% and 30% of all truck trips (Table 4.12).

These results show that it is necessary to check the freight movements in terms of trucking operators. It is seen from Table 5.1 that according to 2007 roadside surveys, 49% of shipping is done by for-hire trucking operators (individual operators) and 49% by private firm operators. On the other hand 56% of shipping is done by private firm operators and 43% by for-hire trucking operators according to 2008 surveys.

Table 5.1 Trucking Operators by Truck Types

Type of Trucking Operations	Vehicle Type (%)		
	Truck	Articulated Truck	Total
Private (Firm)	39	75	49
For-Hire (Individual)	58	24	49
Official	3	1	2
Total	100	100	100

Data Source: KGM, 2007 Axle Load Surveys

The law on goods and passenger transportation (Law numbered 4925) is re-issued in July 2003 to reduce similar problems (individual shippers, empty trucks, overloading etc.) of transportation in Türkiye. As it is seen from Table 5.2 share of articulated trucks in freight mobility has been increased after this year, 2003. It may be inferred that besides other economic reasons, Law 4925 might cause this change. Because of having organizational and management problems in logistic arena in Türkiye, it is not sure that this change might have affected the ratio of empty trucks in near future (Table 4.4).

Table 5.2 Distribution of tonxkm by Truck Types

Year	Truck (Million tonxkm)	Percent (%)	Articulated Truck (Million tonxkm)	Percent (%)	Total (Million tonxkm)
1997	123.784	89	16.005	11	139.789
1998	134.075	88	18.135	12	152.210
1999	132.194	88	18.780	12	150.974
2000	139.152	86	22.400	14	161.552
2001	129.901	86	21.520	14	151.421
2002	128.225	85	22.688	15	150.912
2003	128.799	85	23.364	15	152.163
2004	121.952	78	34.901	22	156.853
2005	127.297	76	39.534	24	166.831
2006	130.853	74	46.547	26	177.399
2007	128.751	71	52.579	29	181.330
2008	124.190	68	57.745	32	181.935

Data Source: KGM

Regarding the quantity of freight majority of the goods as tonnage (27%) is manufactured (Table 4.13). In addition for inter-provincial and international moved goods majority is also manufactured. However majority of intra-provincial goods (41%) is construction materials. In addition, in terms of axle type, majority (64%) of the trucks is 3-axle (see Table 4.10).

By examining Table 4.16 on observed provincial freight productions, İstanbul generates the highest freight flow in terms of number of truck trips, tonnage of moved goods and tonxkm freight mobility. İzmir is the second, Ankara is the third, Kocaeli is the fourth

and Mersin is the fifth province in the tonnage of moved goods. In terms of tonxkm freight mobility (as generation) Mersin is the second province, Ankara is the third, İzmir is the fourth and Kocaeli is the fifth one. Table 4.17 shows that on provincial freight attractions, the result is very similar for İstanbul but for other provinces results change slightly. In terms of number of trucks attracted İzmir is the second, Ankara is the third, Mersin is the fourth and Antalya is the fifth one. In point of tonnage of moved goods attracted İzmir is the second, Ankara is the third, Antalya is the fourth and Mersin is the fifth one. In addition in point of tonxkm freight mobility attraction İzmir is the second, Ankara is the third, Antalya is the fourth and Mersin is the fifth one. Highest freight flows of first level economy dominating provinces is given in Figure 5.2 and Highest Freight flows of second level economy dominating provinces is given in Figure 5.3.

Figure 5.2 and 5.3 offers that provinces mostly trade with the nearby provinces and with the economically more developed and wealthy provinces. In addition the visual representations of provincial freight productions and attractions are given between figures 5.4 through 5.9 in three dimensions as number of truck trips per year, tonnage of moved goods per year, and tonxkm freight mobility per year. From these figures it is inferred that İstanbul is the predominant province of the nation mostly in point of freight mobility and therefore in point of trade and economy. Antalya on the other hand is the province fostering İstanbul.

As it is seen from Table 4.14 and Figure 4.8 out of top 50 inter-provincial freight flows in terms of number of trucks (trucks/year), and Table 4.15 and Figure 4.9 out of top 50 inter-provincial freight flows in terms of tonnage of moved goods, the highest freight flows occur around İstanbul, Ankara, İzmir, Bursa, Adana, Mersin, and Antalya which are the biggest provinces of Türkiye in terms of socioeconomic and demographic magnitudes. “All transport demand forecast must begin with some knowledge of geographic or spatial distributions of economic activities” (Meyer and Straszheim, 1971).

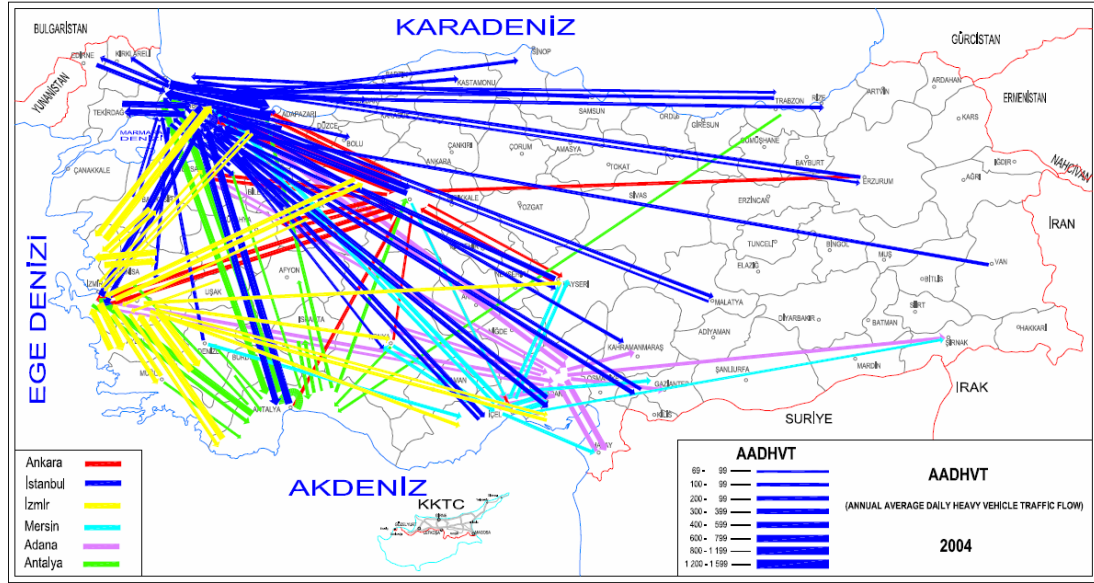


Figure 5.2 Highest Freight Flows of First Level Important Provinces of Türkiye:
Ankara, İstanbul, İzmir, Adana, Mersin, Antalya
(Annual Average Daily Trucks per day)

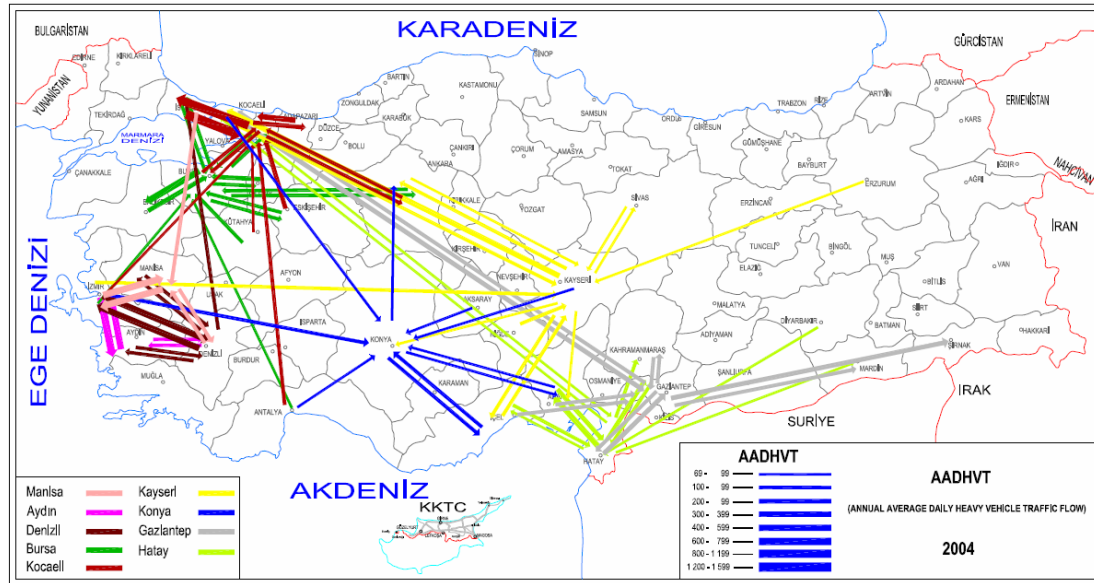


Figure 5.3 Highest Freight Flows of Second Level Important Provinces of Türkiye:
Kocaeli, Bursa, Kayseri, Aydın, Denizli, Konya, Kayseri, Hatay, Gaziantep
(Annual Average Daily Trucks per day)

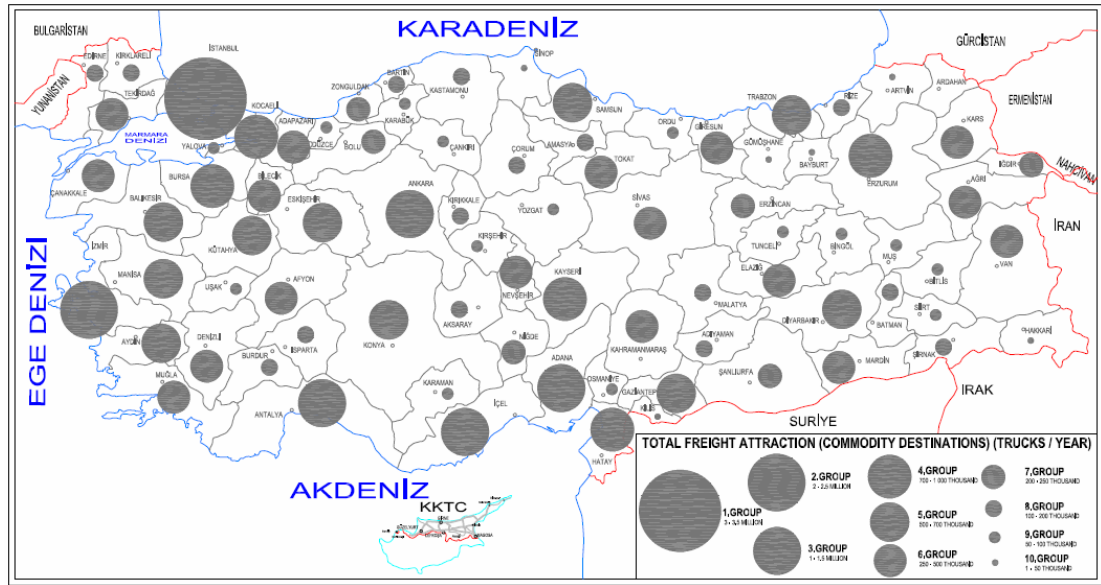


Figure 5.4 Total Freight Attractions of Provinces (Trucks/year)

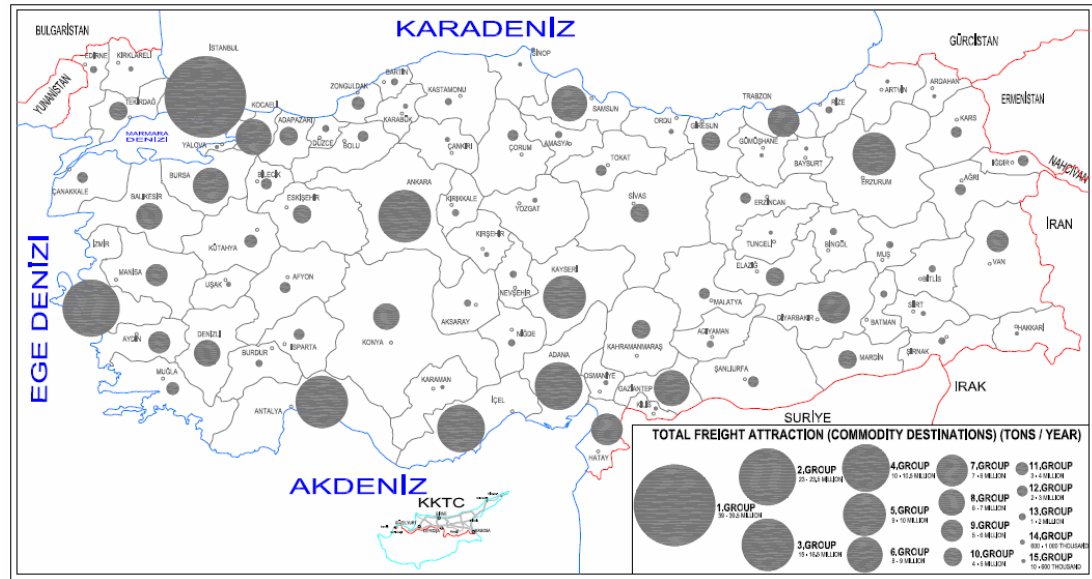


Figure 5.5 Total Freight Attractions of Provinces (Ton/year)

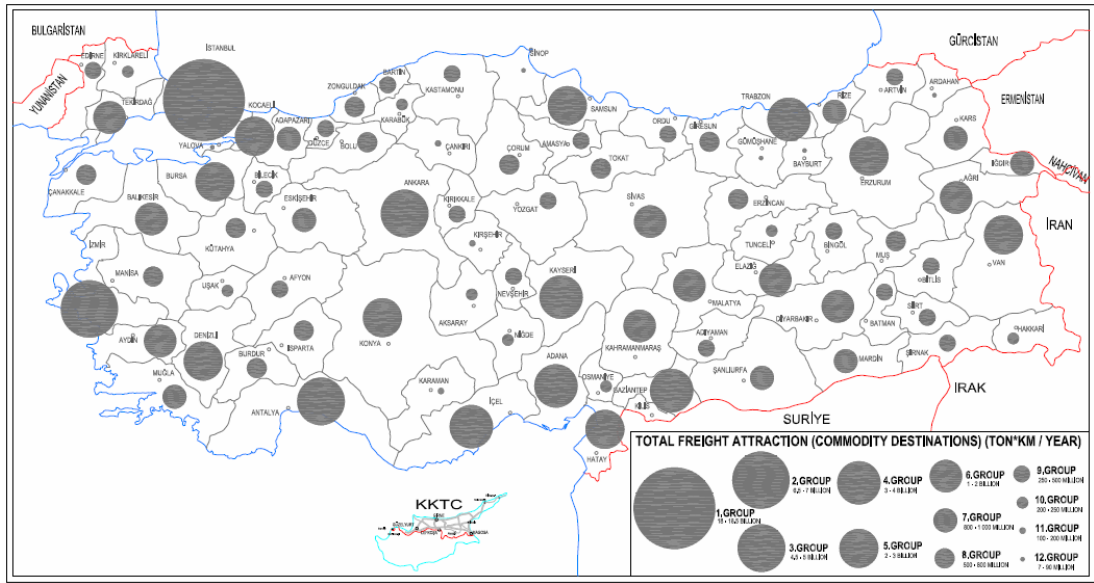


Figure 5.6 Total Freight Attractions of Provinces (Tonxkm/year)

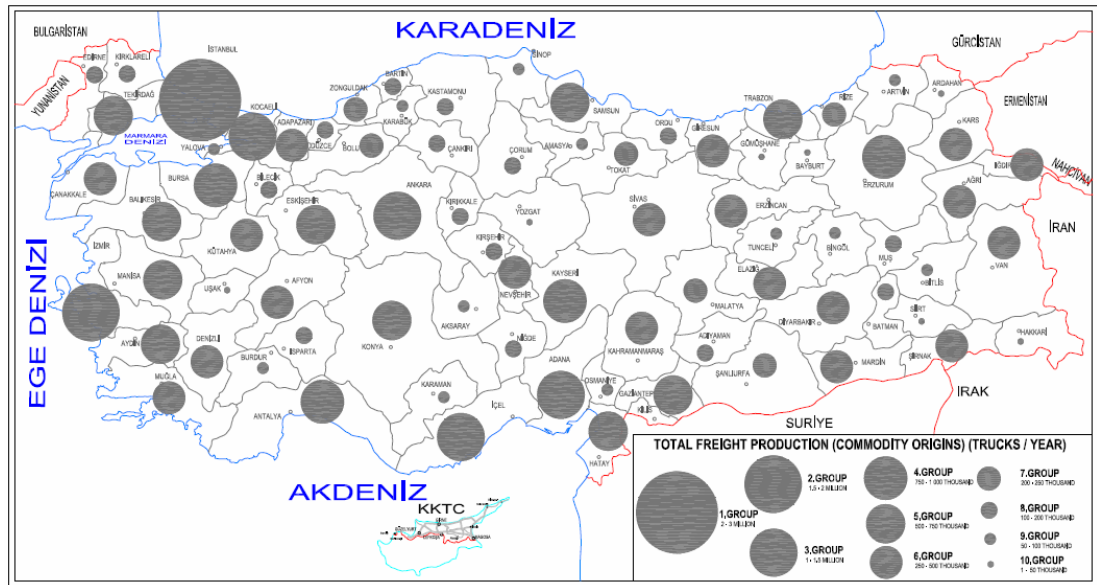


Figure 5.7 Total Freight Productions of Provinces (Trucks/year)

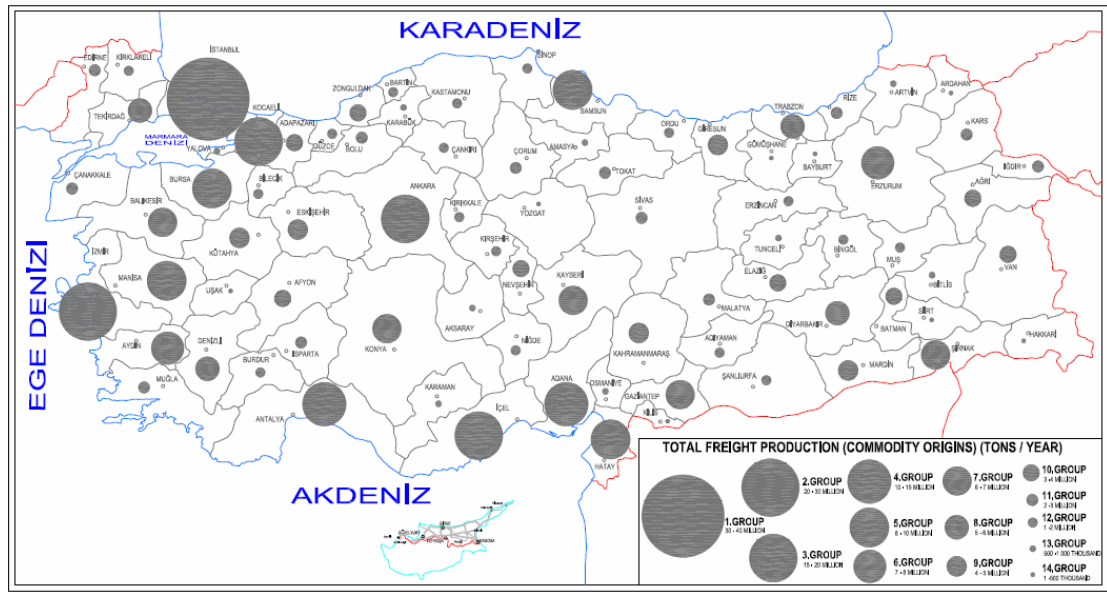


Figure 5.8 Total Freight Productions of Provinces (Ton/year)

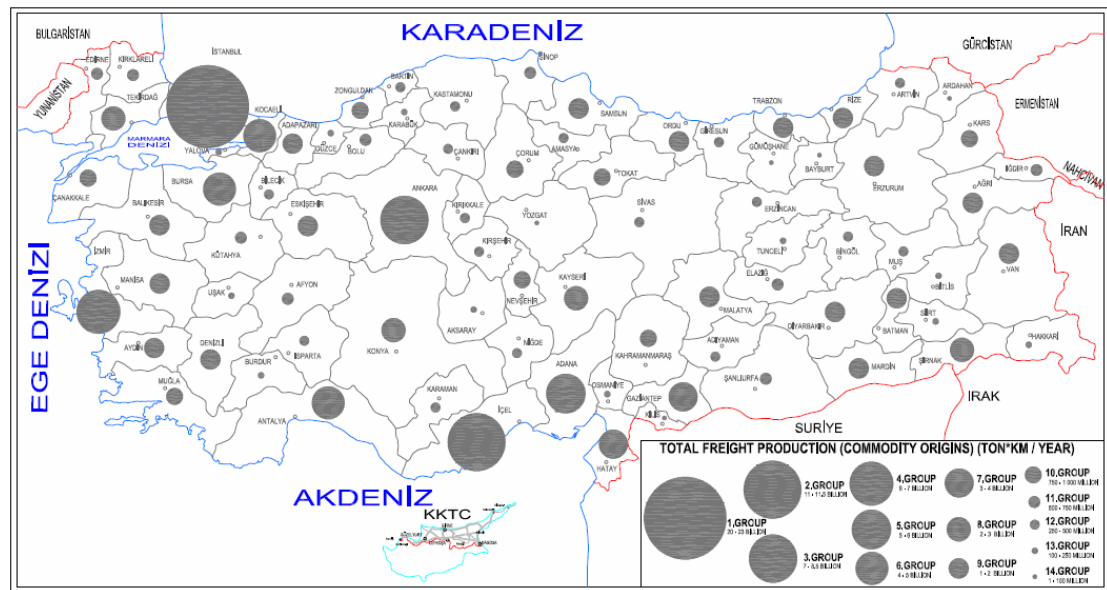


Figure 5.9 Total Freight Productions of Provinces (Tonxkm/year)

In addition there are some unexpected freight flows in magnitudes as tonnage of moved goods within top 50 inter-provincial freight flows and need to be explained (Table 4.15).

These are the flows between Diyarbakır and Mardin (#8 in the list), Şırnak and Gaziantep (#24), Kahramanmaraş and Gaziantep (#30), Mardin and Gaziantep (#35), and Sinop and İstanbul (#38). When these flows are examined the following outcomes are obtained. The flow between Diyarbakır and Mardin is transportation of sand, and aggregates from Dicle River and the transportation of construction materials such as brick and marble to Mardin. The flow between Şırnak and Gaziantep is explained as that in reality the flow is from Habur to Gaziantep regarding that Şırnak is the province where truck ownership is higher than expected. There are many truck drivers from Şırnak and they carry freight from Habur (Türkiye-Iraq Border) to other provinces of Türkiye. Hence it is thought that truck drivers from Şırnak stay over night in their homes while carrying the freight. The flow from Kahramanmaraş to Gaziantep is thought as the flow of raw materials of textile considering that Gaziantep is one of the most famous provinces of Türkiye in the production of textile. The flow from Sinop to İstanbul is transportation of brick and tile from Boyabat (one of the towns of Sinop) to İstanbul.

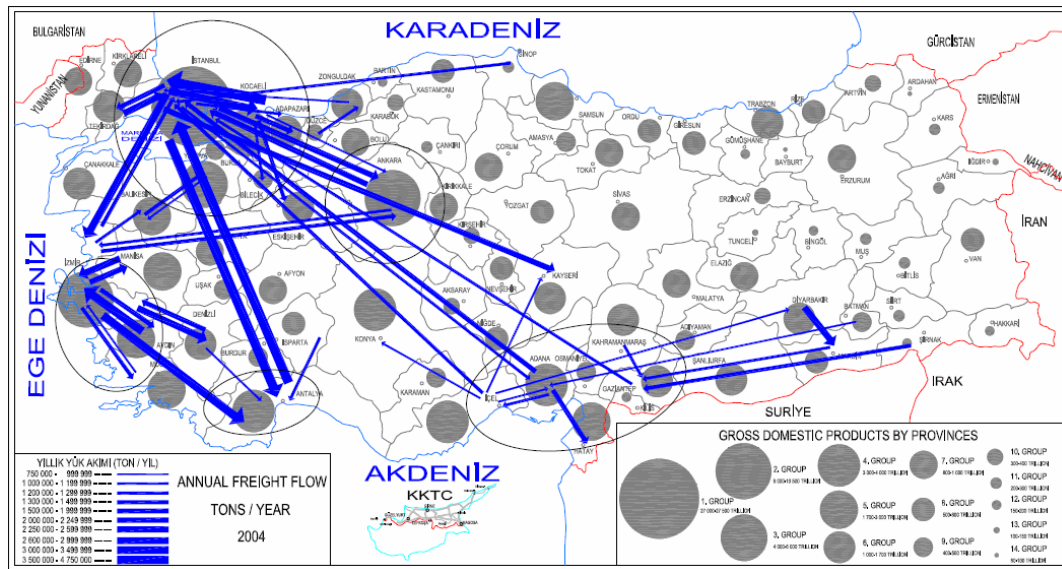
Moreover in Figure 5.10 layered approach is used and top 50 freight flows in point of tonnage per year is illustrated with Gross Domestic Product values (GDP) of provinces. From this figure it is seen that provinces with higher GDP generate and attract more freight flow. In addition the distances between provinces affect the freight flows between provinces.

Furthermore Figure 5.10 through Figure 5.13 shows the reliability of O-D matrices. Calibration is carried on the specified layers. Each layer services by aims. By this representation it is desired to reveal linkages visually between freight flows and socioeconomic factors presented on the same map with different layers. In short, layered approach is also used to validate the observed matrices.

In Figure 5.12 and Figure 5.13 the study named as “Prioritizing the Provinces by their Socioeconomic Developments” performed by State Planning Organization (SPO) is used to show the linkages between freight flow and economic development (Dinçer, Özasan and Kavasoglu, 2003). In this research SPO scaled the provinces in five levels according to their socioeconomic development regarding social, economic and demographic indicators and grouped the provinces according to these levels. Grouping of the provinces is given in Table 5.3.

One of the layers used in Figure 5.12 and Figure 5.13 is the level of socioeconomic developments of provinces. It is seen from these figures that even majority of provinces level of development coincides with the freight movement capacity; however there are some provinces which do not coincide and needs to be identified by discriminant analysis. These figures also reveal spatial inequalities in cities in terms of regional development.

Discriminant analysis is performed in order to identify the discriminating provinces from the provinces grouped by SPO. Discriminant analysis is employed regarding socioeconomic indicators including freight originating and ending capacities of provinces. The result is given in Table 5.4. It is read from this table that 15 Provinces (Artvin, Bilecik, Elazığ, Gaziantep, Isparta, Kırklareli, Malatya, Rize, Samsun, Trabzon, Tunceli, Zonguldak, Kırıkkale, Yalova and Karabük) have lower freight capacity compared to their economic levels and 13 provinces (Bingöl, Çankırı, Hatay, Kars, Kastamonu, Kütahya, Nevşehir, Niğde, Sinop, Aksaray, Bartın, Kilis and Osmaniye) have higher freight capacity with respect to their economic levels out of 81 provinces.



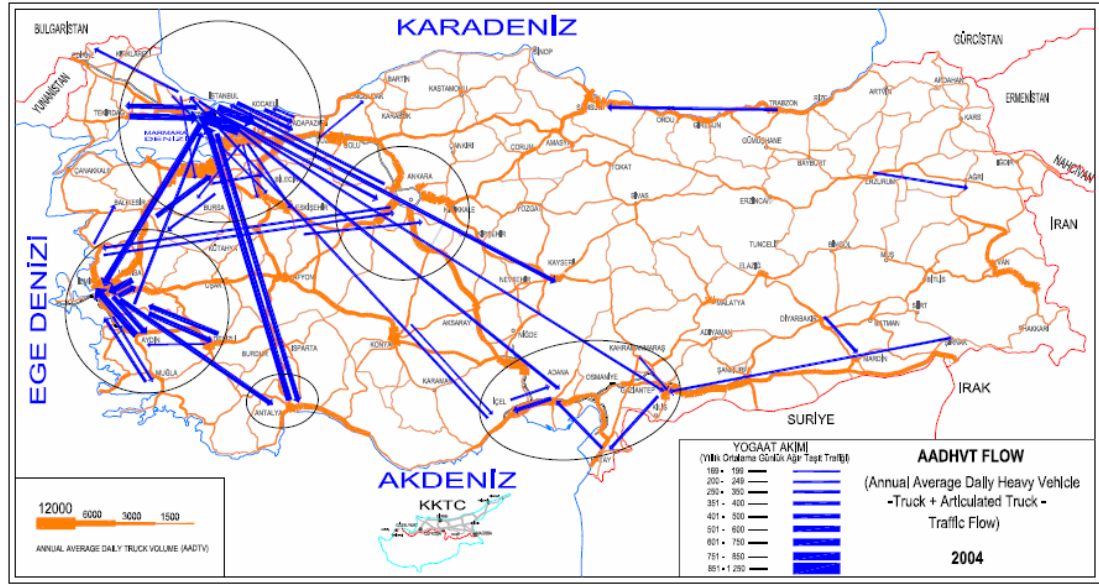


Figure 5.11 Layered Representation of Annual Average Daily Truck Volume with Top 50 Freight Flows as Trucks/day

Table 5.3 Groups of Provinces by Their Socioeconomic Development Index

First Level Developed Provinces	Second Level Developed Provinces	Third Level Developed Provinces	Fourth Level Developed Provinces	Fifth Level Developed Provinces
İstanbul Ankara İzmir Kocaeli Bursa	Eskişehir Tekirdağ Adana Yalova Antalya Kırklareli Denizli Muğla Bolu Balıkesir Edirne Mersin Bilecik Kayseri Gaziantep Zonguldak Aydın Sakarya Çanakkale Manisa	Konya Karabük Isparta Hatay Uşak Burdur Samsun Kırıkkale Nevşehir Karaman Elazığ Rize Trabzon Amasya Kütahya Malatya Kırşehir Artvin Afyon Düzce Çorum	Osmaniye Kahramanmaraş Niğde Giresun Kastamonu Tunceli Sivas Kilis Bartın Aksaray Sinop Erzincan Çankırı Erzurum Tokat Ordu Diyarbakır Yozgat Adıyaman	Bayburt Kars Şanlıurfa İğdır Batman Gümüşhane Mardin Siirt Ardahan Van Bingöl Hakkari Şırnak Bitlis Ağrı Muş

Source: Dinçer, Özaslan and Kavasoglu, 2003 (SPO)

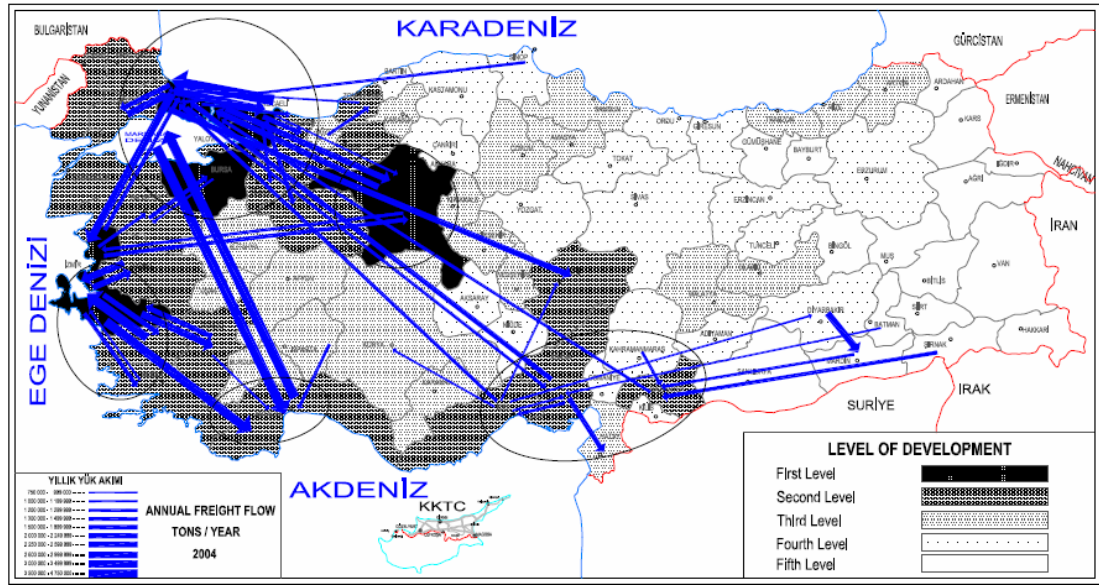


Figure 5.12 Layered Representation of Provinces Development Level with Top 50 Inter-Provincial Freight Flows as Tons/year

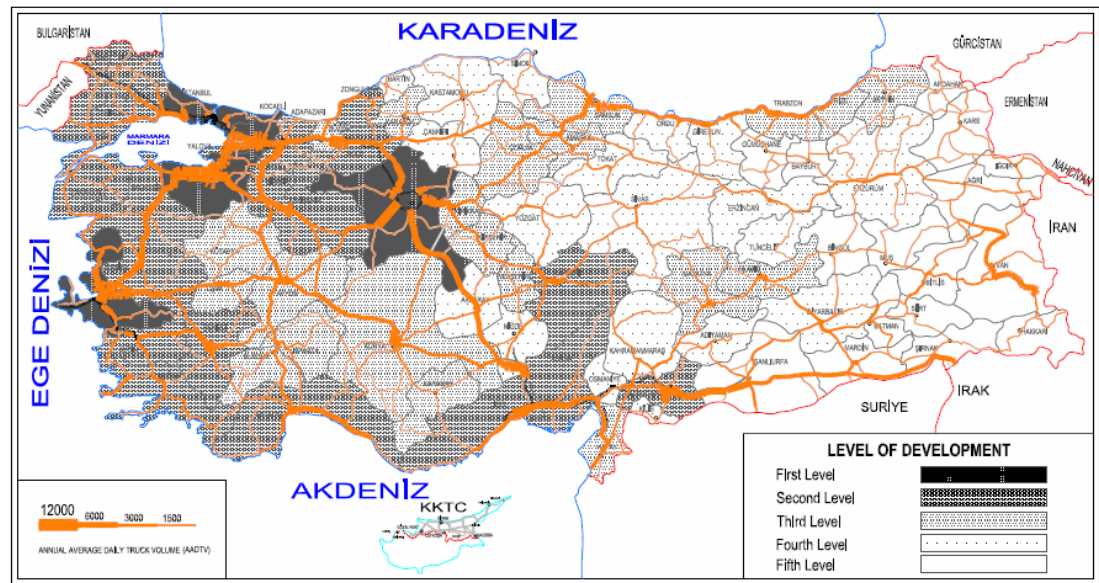


Figure 5.13 Layered Representation of Provinces Development Level with Annual Average Daily Truck Volume

Table 5.4 Discriminant Analysis Result

Discriminant Analysis (DA) Result				Discriminant Analysis (DA) Result			
Province		Grouped by SPO	Predicted Group by DA	Province		Grouped by SPO	Predicted Group by DA
1	Adana	2	2	42	Konya	3	3
2	Adiyaman	4	4	43	Kütahya	3	2
3	Afyon	3	3	44	Malatya	3	4
4	Ağrı	5	5	45	Manisa	2	2
5	Amasya	3	3	46	Kahramanmaraş	4	4
6	Ankara	1	1	47	Mardin	5	5
7	Antalya	2	2	48	Muğla	2	2
8	Artvin	3	5	49	Muş	5	5
9	Aydın	2	2	50	Nevşehir	3	2
10	Balıkesir	2	2	51	Niğde	4	3
11	Bilecik	2	3	52	Ordu	4	4
12	Bingöl	5	4	53	Rize	3	5
13	Bitlis	5	5	54	Sakarya	2	2
14	Bolu	2	2	55	Samsun	3	4
15	Burdur	3	3	56	Siirt	5	5
16	Bursa	1	1	57	Sinop	4	3
17	Çanakkale	2	2	58	Sivas	4	4
18	Çankiri	4	3	59	Tekirdağ	2	2
19	Çorum	3	3	60	Tokat	4	4
20	Denizli	2	2	61	Trabzon	3	4
21	Diyarbakir	4	4	62	Tunceli	4	5
22	Edirne	2	2	63	Şanlı Urfa	5	5
23	Elazığ	3	4	64	Uşak	3	3
24	Erzincan	4	4	65	Van	5	5
25	Erzurum	4	4	66	Yozgat	4	4
26	Eskişehir	2	2	67	Zonguldak	2	3
27	Gaziantep	2	3	68	Aksaray	4	3
28	Giresun	4	4	69	Bayburt	5	5
29	Gümüşhane	5	5	70	Karaman	3	3
30	Hakkari	5	5	71	Kirikkale	3	4
31	Hatay	3	2	72	Batman	5	5
32	Isparta	3	4	73	Şırnak	5	5
33	Içel	2	2	74	Bartın	4	3
34	Istanbul	1	1	75	Ardahan	5	5
35	Izmir	1	1	76	Iğdir	5	5
36	Kars	5	3	77	Yalova	2	3
37	Kastamonu	4	3	78	Karabük	3	5
38	Kayseri	2	2	79	Kilis	4	3
39	Kirklareli	2	3	80	Osmaniye	4	3
40	Kirşehir	3	3	81	Düzce	3	3
41	Kocaeli	1	1				

Number of Level by SPO : 5 3
Number of Level by DA : 5 3

Grouped Upper Level by DA
Grouped Lower Level by DA

The second part of research outcomes is on modeling freight trip generation. The trip generation equations in this research are developed locally using existing roadside surveys in two dimensions, i.e. the number of truck trips and tonnage of moved goods by means of regression analysis. Among regarded socioeconomic and demographic independent variables Number of Employees and Gross Domestic Product give the best GOF (Goodness-of-fit) results for the production model in point of Number of Originated Trucks and Tons of Originated Moved Goods; and Population and Passenger Car Ownership per 1000 Inhabitants give the best GOF result for the attraction model in point of Number of Destined Trucks and Tons of Destined Moved Goods. The following trip generation equations are obtained at the end of multiple regression analysis. Moreover to include the effects of ports, dummy argument which represents the existence of international import-export port in the province is included in regression analysis. This dummy is obtained significant only for production equations. In addition there are a few provinces which have international border. Border existence is therefore tried as dummy but the effect is not found statistically significant.

The GOF (Goodness-of-fit) results of trip generation equations are given in the following:

Freight Production Equations

***Freight Trip Production = f (Number of Employees,
(Number of Trucks per year) DUMMY (INTERNATIONAL PORT EXISTENCE))***

Number of Trucks as Origin = 70,498.06 + 0.981 *Number of Employees*
(NOTor) + DUMMY (INTPORT) (If exist add 302,163.4)

***Freight Trip Production = f (Gross Domestic Products +
(Tons of Moved Goods per year) DUMMY (INTERNATIONAL PORT EXISTENCE))***

Tons of Moved Goods as Origin 1,542,173 + 1.294 (*Gross Domestic Product*
(TOMGor) Million TL) + DUMMY (INTPORT) (If exit and
3,928,667)

Freight Attraction Equations

Freight Trip Attraction = f (Population, Passenger Car Ownership
(Number of Truck Trips per year) per 1000Households)

Number of Trucks as Destination = -25,454 + 0.287Population +
(NOTdes) 672.976 Passenger Car Ownership per
1000 Households

Freight Trip Attraction = f (Population, Passenger Car Ownership
(Tons of Moved Goods per year) per 1000 Households)

Tons of Moved Goods as Destination = -333,701 +
(TOMGdes) 3.556 Population + 6317.94 Passenger Car
Ownership per 1000 Households

Briefly, freight flow productions and attractions are explained by socioeconomic and demographic variables via the regression equations given above and expressed as Number of Trucks as Origin (NOTor), Tons of Moved Goods as Origin (TOMGor), Number of Trucks as Destination (NOTdes), and Tons of Moved Goods as Destination (TOMGdes). Additional to GOF test results, the ratios of estimated values divided by observed values of production and attraction variables (NOTor, NOTdes, TOMGor, and TOMGdes) are found and given in Table 5.5 as a summary of the reliability of the trip generation models.

In this study the ratio of predicted value divided by observed value in the base year bigger than 2.0 or less than 0.5 is assumed outlier. The outlier provinces are the ones where internal freight flows are not captured because of missing surveys within the border of provinces keeping in mind that intra-provincial freight movements are covered in the trip generation model. Furthermore some of the outlier provinces are the ones designated as province after 1989. Kilis is an outlier that none of the trip production equations are acceptable. Kilis is one of the provinces in Türkiye that its land area is the smallest one.

In addition, as given in Table 5.6 the ratios of predicted freight flows divided by observed freight flows are found for groups of provinces. The first group covers all of the provinces, second one covers all of the provinces excluding the one resulting the highest ratio, and following five different groups according to their level of socioeconomic development (Dinçer, Özaslan and Kavasoglu, 2003), the eighth one covers the provinces (Adana, Ankara, Antalya, Aydın, Balıkesir, Bursa, Denizli, Eskişehir, Gaziantep, İçel, İstanbul, İzmir, Kayseri, Kocaeli, Konya and Sakarya) dominating the nation's economy, and the last one covers the provinces including Ankara, İstanbul and İzmir, the biggest metropolitans of Türkiye.

These outcomes also show that attraction models give better estimates. Moreover the predictions are better for developed provinces and group of developed provinces as seen in Table 5.6. On the other hand for less developed provinces and group of less developed provinces the predictions are not closer to the observed values and production models give better result. It is inferred that for undeveloped provinces it is hard to forecast truck trips demand or freight flow demand.

As it is seen from Table 5.7 all trip generation models are statistically significant and give very good results in point of GOF tests and regression assumptions are provided, however, commodity based attraction models give the best result as widely mentioned in literature.

As a result the model used in this study (multiple regression analysis) explains the nationwide trip generation of freight in Türkiye significantly.

In order to use these models it is necessary to have forecast of zonal employment, GDP, population, number of households and passenger car ownership. Employing future forecasts of these mentioned variables into trip generation equations, future zonal freight productions and attractions are obtained. After finding future year provincial trip productions and attraction by trip generation models it is needed to distribute freight flows between provinces. Therefore the third part of research outcomes is on trip distribution model.

Table 5.5 Ratios Between Predicted to Observed Values of Freight Flows

Province	NOTdes	NOTor	TOMGor	TOMGdes
adana	0.71	0.82	0.77	0.87 ✓
adiyaman	2.09	1.76	1.67	2.19
afyon	1.26 ✓	0.96 ✓	0.90 ✓	1.51
ağrı	0.61	0.68	0.59	0.75
amasya	2.42	2.51	2.42	2.21
ankara	1.21 ✓	0.90 ✓	0.87 ✓	1.17 ✓
antalya	0.72	1.19 ✓	0.89 ✓	0.60
artvin	2.81	0.76	3.42	2.37
aydin	0.74	0.59	0.59	0.94 ✓
balıkesir	0.92 ✓	1.32 ✓	1.38 ✓	0.84
bilecik	0.66	0.72	2.15	0.62
bingöl	1.09 ✓	2.31	1.58	0.70
bitlis	1.55	3.01	2.01	1.43 ✓
bolu	1.15 ✓	0.59	1.13 ✓	1.12 ✓
burdur	1.90	1.77	1.96	1.34 ✓
bursa	1.06 ✓	1.44 ✓	1.55	1.25 ✓
çanakkale	0.91 ✓	1.73	2.50	1.09 ✓
çankiri	1.46 ✓	1.63	1.52	1.55
çorum	1.92	1.46 ✓	1.07 ✓	1.42 ✓
denizli	0.99 ✓	0.76	0.80	0.78
diyarbakir	0.88 ✓	1.00 ✓	0.62	0.77
edirne	1.50 ✓	0.93 ✓	1.24 ✓	1.72
elazığ	0.99 ✓	0.89 ✓	0.80	0.78
erzincan	0.77	0.54	1.02 ✓	0.87 ✓
erzurum	0.40	0.45	0.36	0.44
eskişehir	0.79	0.58	0.73	0.92 ✓
gaziantep	1.06 ✓	0.76	0.64	0.77
giresun	0.68	0.86 ✓	0.60	0.52
gümüşhane	2.54	2.09	13.52	3.20
hakkari	3.42	9.32	10.48	2.76
hatay	0.68	0.98 ✓	1.00 ✓	0.79
isparta	1.97	1.66	1.18 ✓	1.30 ✓
içel	0.51	0.69	0.53	0.75
istanbul	1.12 ✓	1.08 ✓	1.12 ✓	1.08 ✓
izmir	0.61	0.75	0.77	0.65
kars	0.49	0.60	0.71	0.50
kastamonu	1.45 ✓	1.46 ✓	1.32 ✓	1.26 ✓
kayseri	0.63	0.47	0.52	0.61
kırklareli	2.12	1.12 ✓	2.16	2.29
kırşehir	2.03	1.24 ✓	1.80	2.33
Missing Internal Freight Flow	outlier	Numbers which are < 0.5 and >2		

✓ within the range 1.15 and 0.85

NOTdes : Number of Trucks as Origin
 NOTor : Number of Trucks as Destination
 TOMGdes : Tons of Moved Goods as Origin
 TOMGor : Tons of Moved Goods as Destination

Table 5.5 (continued)

Province	NOTdes	NOTor	TOMGor	TOMGdes
kocaeli	0.58	0.51	0.72	0.74
konya	1.28 ✓	1.05 ✓	0.81	1.42 ✓
kütahya	0.71	0.68	0.72	0.99 ✓
malatya	1.93	1.64	1.40 ✓	1.60
manisa	0.85 ✓	0.69	0.82 ✓	1.12 ✓
kahramanmaraş	1.40 ✓	0.96 ✓	0.80	0.98 ✓
mardin	0.95 ✓	0.89 ✓	0.57	0.67
muğla	1.51	1.29 ✓	1.53	1.42 ✓
muş	1.59	2.17	1.53	1.23 ✓
nevşehir	0.80	0.50	0.78	1.20 ✓
niğde	1.02 ✓	1.05 ✓	1.64	1.40 ✓
ordu	4.21	3.87	2.00	4.30
rize	1.53	0.79	1.17 ✓	1.22 ✓
sakarya	0.96 ✓	1.09 ✓	0.95 ✓	1.00 ✓
samsun	0.64	1.31 ✓	0.98 ✓	0.59
sırt	1.93	7.36	5.51	1.37 ✓
sinop	6.20	1.69	1.13 ✓	6.62
sivas	0.85 ✓	0.96 ✓	1.39 ✓	0.84
tekirdağ	0.67	1.11 ✓	1.47 ✓	0.70
tokat	1.41 ✓	1.71	0.97 ✓	1.62
trabzon	0.59	0.76	0.53	0.59
tunceli	0.62	0.86 ✓	3.09	0.62
şanlı urfa	2.95	1.93	2.12	2.42
uşak	4.10	3.76	4.72	3.22
van	0.74	0.76	0.71	0.71
yozgat	3.22	8.72	6.42	3.06
zonguldak	1.51	1.12 ✓	0.92 ✓	1.23 ✓
aksaray	2.56	2.25	2.52	2.55
bayburt	5.48	1.16 ✓	9.66	5.53
karaman	3.99	2.53	2.97	3.95
kırıkkale	1.06 ✓	1.94	1.48 ✓	1.28 ✓
batman	1.60	1.24 ✓	0.58	2.10
şırnak	1.21 ✓	0.59	0.27	1.21 ✓
bartın	1.71	0.85 ✓	1.39 ✓	1.27 ✓
ardahan	4.42	5.66	33.64	3.61
iğdir	0.39	0.55	0.57	0.33
yalova	3.46	8.33	12.83	3.02
karabük	3.69	2.29	3.28	3.00
kilis	50.43	35.64	67.72	46.00
osmaniye	3.34	2.66	2.90	3.38
düzce	2.67	1.42 ✓	1.35 ✓	1.87
Missing Internal Freight Flow	outlier	Numbers which are < 0.5 and >2		

✓ within the range 1.15 and 0.85

NOTdes : Number of Trucks as Origin
 NOTor : Number of Trucks as Destination
 TOMGdes : Tons of Moved Goods as Origin
 TOMGor : Tons of Moved Goods as Destination

Table 5.6 Ratios Between Predicted to Observed Values of Freight Flows

Province	NOTdes	NOTor	TOMGor	TOMGdes
Average (all values)	2.24	2.11	3.18	2.11
Average (ecl. Max value)	1.64	1.69	2.37	1.56
1.Level Provinces	0.92	0.94	1.01	0.98
2.Level Provinces	1.12	1.30	1.73	1.12
3.Level Provinces	1.86	1.47	1.65	1.67
4.Level Provinces	1.90	1.87	1.70	1.95
5.Level Provinces	1.94	2.52	5.25	1.78
Kilis which is in fourt level is excluded in average values				
National Economy Dominating Provinces*	0.87	0.88	0.85	0.90
Ankara, İstanbul, İzmir	0.98	0.91	0.92	0.97
National Economy Dominating Provinces*	Adana, Ankara, Antalya, Aydın, Balıkesir, Bursa, Denizli, Eskişehir, Gaziantep, İçel, İstanbul, İzmir, Kayseri, Kocaeli, Konya and Sakarya			

NOTdes : Number of Trucks as Origin
 NOTor : Number of Trucks as Destination
 TOMGdes : Tons of Moved Goods as Origin
 TOMGor : Tons of Moved Goods as Destination

Table 5.7 Summary of GOF Results of Trip Generation Equations

GOF Indicator	Dependent Variables			
	NOTdes	NOTor	TOMGor	TOMGdes
Independent Variables	Population and Passenger Car Ownership per 1000 Households	Number of Employees and International Port Existence	Gross Domestic Product and International Port Existence	Population and Passenger Car Ownership per 1000 Households
R ²	0.826	0.854	0.848	0.874
Adjusted R ²	0.821	0.850	0.844	0.871
Standard Error of the Estimate	204,011	193,302	2,317,105	2,032,380
significance (p)	0.000	0.000	0.000	0.000
F	184	227	217	270

Gravity Model which is the most widely used in practice and referred in the literature as the most appropriate model for freight flow distribution is also applied in this research, not only because of these properties but also because of data availability.

TRANPLAN which is one of the modeling packages on demand analysis is used to find the simulated O-D matrix and to calibrate gravity model as freight distribution model for nationwide freight demand modeling in Türkiye. Doubly constrained gravity model is applied by TRANPLAN. Deterrence function ($e^{-\beta d_{ij}}$) is employed and the coefficient β in this equation is found as 0.0216 at the end of fourteen iterations. In addition trip length frequency distribution and average trip lengths are found from simulated and observed O-D matrices. Average trip distances obtained from observed matrix is 450 km and from simulated matrix is 499 km. Comparison of observed and simulated truck trip distance frequency distribution is given in Figure 5.14. The Gravity Model is calibrated by comparing the trip length frequency distribution and average trip lengths.

According to observed truck trips length distribution (Figure 5.14) the majority of trucks (23%) travel around 200 km. On the other hand according to simulated truck trips length distribution there are five descending peaks which are around 200 km, 300 km, 400 km, 500 km and 600 km. The coincidence ratio is found 0.71 and R-square is equal to 0.673 between observed and simulated O-D pairs. These results reveal that around 30% of truck trips in the model do not fit the actual situation. Even the gravity model is statistically significant it does not give very good results at moderate truck travel distances (400-600 km).

Trip generation model is suggested to be developed based on large scale in literature, however, trip distribution might be developed based on annual data and aggregation of different year data may not be necessary. In this research trip generation model is therefore developed based on aggregated surveys which represent the majority of the main arterial of road network of Türkiye and the results are found statistically significant.

The gravity model is, however, first calibrated based on aggregated surveys, all regression assumptions are provided and the results are found statistically significant. And later annual data is used to check the validity of gravity model and to check the

impedance function parameter depend on limited scale data. In this case the coefficient β is found 0.0239 and coincidence ratio is found as 0.70. The results of gravity model calibration are found very similar based on large scale data and limited scale data.

Furthermore gravity model and friction related to the efficiency of the transport system between zones are calibrated via regression analysis applied to logarithmic transformation of gravity equation (equation 3.3 presented in Chapter 3). Three parameters explaining the level of interaction and the relationship between freight demand between two zones and the level of interaction are found. All results are significant and R-square is found 0.527. In this research the obtained parameters and their interpretation is given in the following paragraph.

If the value of beta is higher than 0.5 the friction of distance is much more important than with a low value of *beta* (such as 0.25) (Rodrigue, Comtois and Slack, 2006). In this research beta is 0.894 which means friction of distance is important. In this equation beta reveals the influence of friction instead of its value. In addition *alpha* and *lambda* components have the same effect on the interaction level and if their value is less than one than there is a linear relationship between T_{ij} and level of interactions. In this research these parameters (*alpha* and *lambda*) close to each other and less than one which means the relation is linear.

In this research two steps, trip generation and trip distribution, of four-step model are employed to be used for predicting future nationwide truck trips and freight flows in Türkiye and both of them found reliable and significant.

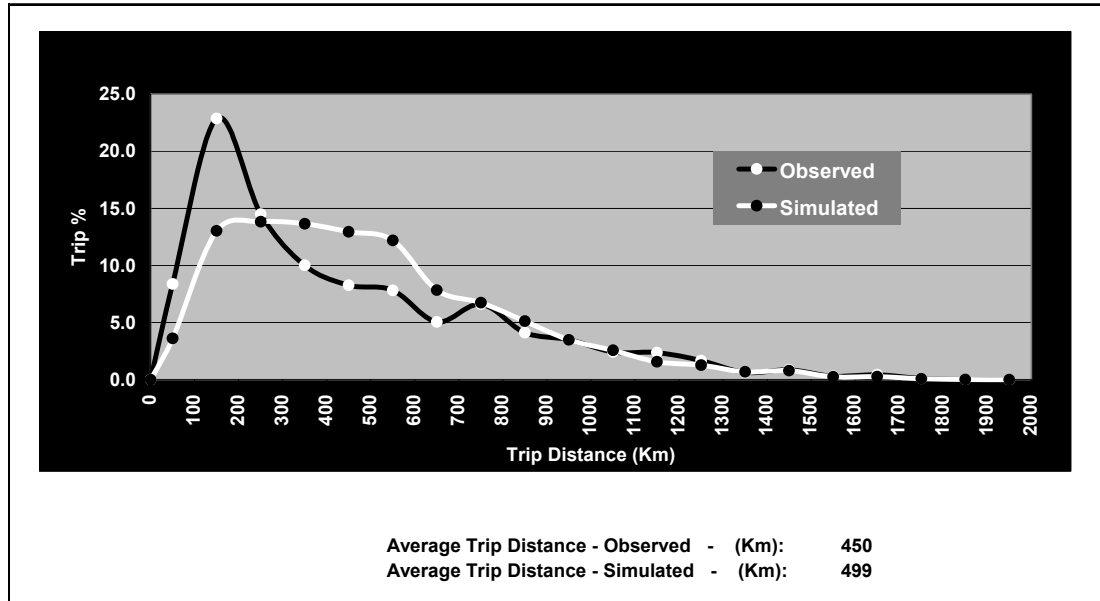


Figure 5.14 Comparison of Observed and Simulated Truck Trip Distance Distribution as a Result of Aggregated Surveys

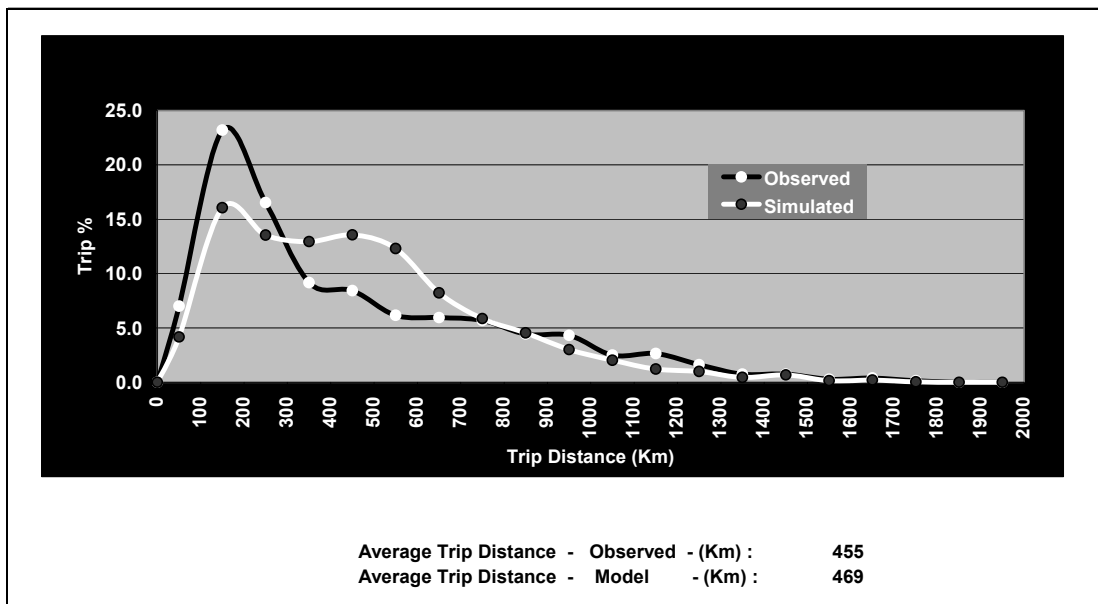


Figure 5.15 Comparison of Observed and Simulated Truck Trip Distance Distribution as a Result of Limited Scale Data (2004 Data)

CHAPTER 6

CONCLUSIONS

Freight transportation plays an important role in nations' economy therefore modeling freight is increasingly becoming important in national transportation planning. Even freight traffic accounts for approximately 20-25% of average daily traffic on the Turkish Highway Network, its size, low maneuverability, noisiness, and high pollution characteristics require that it's planning should be made carefully. At the same time freight flows by trucks is vital for the economy and the well being of the society. Since commerce is assisted by truck flows, the movements of commodities on the highway network is the reflection of economic activities over space.

This research focuses on two steps of traditional four step analysis to forecast freight demand between provinces of Türkiye. The applied steps are Trip Generation and Trip Distribution (Modal Split and Traffic Assignment steps are not applied). As it is mentioned earlier Four-Step Model is used as modeling methodology of this research, but the third (modal split) and the fourth steps (traffic assignment) are not covered in the model. Even the applied model is very old and traditional; it has been widely used since 1960's.

Formation of nationwide O-D matrix and trip generation stage are based on both commodity flows and truck trips; however trip distribution stage is only based on truck trips. Since the research is also based on truck trips, modal split step is not needed. Provinces are regarded as Traffic Analysis Zones (TAZ) and the developed model is nationwide, single commodity and single-mode model. Moreover this research is the first study conducted on nationwide freight demand modeling in Türkiye.

In the first stage of this research, by employing roadside surveys O-D matrices are obtained in terms of truck trips and tonnage of commodities. Travel matrices are produced in two dimensions on annual and annual average day basis. Using roadside

surveys and observed matrices, national freight flow characteristics are identified and detailed findings are submitted in Chapter 4 and 5.

The second step which is trip generation is the stage where freight flow production and attraction models are specified for Türkiye's provinces by means of regression analyses regarding the relationships between freight flows and socioeconomic and demographic structures. Since regression models for trip generation are generally developed when O-D surveys are conducted for relatively large sample sizes, roadside surveys of sequential years are aggregated. The coefficients for each explanatory variable are estimated by regression analyses and the strength of the models is determined based on a range of statistics. In this stage, trip generation are formulated both as production and attraction models in two dimensions. In the literature the trip distribution model that is most often used is the gravity model.

Therefore at the third stage of the research, Gravity Model is applied for the distribution of freight flows between provinces (81 administrative regions). In general the gravity model uses the zonal productions and attractions which are obtained in the trip generation step. In addition, the separation on deterrence between zones is explained by the distance. Conventional gravity equation specified by Wilson (1970) is applied in order to find deterrence function. Exponential form of deterrence function is employed and the function coefficient (beta) is determined by travel demand modeling package TRANPLAN. An iterative procedure is applied for all rows and columns, which constitute an 81 by 81 matrix.

TRANPLAN which tends to rely on traditional gravity model is used to distribute freight flows between provinces employing the observed zonal freight flow attractions and productions on average day basis and observed trip distance distribution frequency to calibrate the gravity model. Fourteen iterations for number of truck productions and attractions of provinces are performed to obtain simulated Origin-Destination matrix. Observed and simulated O-D pairs are compared to calibrate the gravity model. Moreover simulated and observed trip length distribution frequency and average trip distance values are also compared in order to perform calibration. At this stage exponential form of impedance function is applied and the related coefficients are found. In addition Gravity Model applicability is also tested by using limited scale annual of

data. By this way Gravity Model is calibrated using both aggregated sequential data and one year limited data to test the reasonableness. Moreover logarithmic transformation of gravity function extended form is used via regression analysis to calibrate the model and to explain related parameters.

Since transportation models are developed based on observations of actual travel behavior, the most important problem of this research is the availability and quality of truck travel data. In this research the existing data collected annually through axle load surveys by KGM are used as truck travel data. Although these data are not specifically collected in order to develop a freight demand model, there are a lot of valuable information such as origin and destination of the truck trips, the tonnage of moved freight, commodity types, and similar ones to develop a model. Even though the idea is very comprehensive to get data about truck travels during axle load surveys, they are not sensitively collected and uniformity is not ensured as commodity types between regional directorates at archiving stage. Therefore commodity type is not included at the trip distribution stage even it is one of the important inputs.

Another problem of data is about quantity of truck surveys and collection procedures. Since annual data is not representing the highway network completely sequential years' data are aggregated and used in modeling procedures to overcome representation problem of the highway network and to increase sample size.

Socioeconomic and demographic data availability to structure the model is also faced as problem. These data are collected and released periodically by Turkish Statistics Institute (TÜİK). Although many national demographic and socioeconomic data are published annually, some of them are not disseminated at province level. In this research some forecasting techniques are applied to overcome that problem even it is suggested to use exact values of independent variables for regression analysis applied at trip generation stage.

The road transport is widely preferred (more than 90%) for freight transportation as well as passenger transportation in Türkiye. The average trip distance of trucks is found 400 km for all movements including intra-provincial, inter-provincial and international. On the other hand, it is 450-500 km for inter-provincial truck trips. The majority of truck

trips on main arterials in Türkiye are inter-provincial, 76%. These figures reveal why road transport is widely chosen by freight transport in Türkiye regarding that road transport is the most efficient and economic when the distance is less than 500 km. In addition freight transportation is very sensitive to available physical and transport structures. In Türkiye road transportation is highly accessible and in better condition compared to other modes and this situation also reveals high preference of road transportation.

On the other hand around 30% of trucks are empty in both 2004 and 2007 surveys. This figure reveals some inefficiency in the freight transportation via highways in Türkiye. In addition the results are analyzed in terms of truck operators and it is obtained that 49% of shipping is conducted by for-hire trucking operators according to the 2007 survey. This high ratio may be the primary cause of the problems in logistic issues in Türkiye. Furthermore logistic firms may not be organized in an efficient manner. In addition even trucks reported empty carry small amount of load, which is 2.53 tons per truck in 2004, 2.56 tons per truck in 2007, and 3.41 tons per truck in 2008 on the average, whereas this figure is 5.4 tons per truck in the USA.

The freight flows are densely observed among the largest and the most developed provinces which are İstanbul, Ankara, and İzmir regardless of the distance among them. They are also the provinces that have interaction not only with each other but also with the nearby moderate sized provinces. Therefore it is noticed that freight flows densely occur between these provinces and their closest neighbors.

In addition it is observed that provinces have the advantage of being close to the most developed provinces of the country. Kocaeli, Adapazarı, Bilecik, and Tekirdag have the advantage of being close to İstanbul. Aydın, Denizli, and Manisa have the advantage of being close to İzmir. In addition Bursa and Eskisehir have the advantage of being close to İstanbul and Ankara. It is observed that adjacency of provinces significantly affect freight flows and hence the trade between them.

Furthermore the major metropolitan cities of Türkiye which are İstanbul, Ankara and İzmir dominate the national freight flows and therefore country's trade. The freight movements between İstanbul-Kocaeli, İstanbul-Tekirdağ, İzmir-Manisa, İzmir-Aydın,

Balıkesir-Bursa, Kocaeli-Sakarya, Kocaeli-Bilecik, Adana-Mersin, Adana-Hatay, Diyarbakır-Mardin, Erzurum-Ağrı, Nevşehir-Niğde, Bursa-Bilecik and/or the reverse movements represent a high share of all freight movements. These movements occur not only as a result of the reflection of economic interaction on highway network but also as a result of the reflection of adjacency.

All these results show that provinces are not only connected with each other in economic manner but they are also connected geographically. In other words neighboring provinces trade with one another more than non-neighboring ones. Shortly the most developed provinces trade with each other and also they trade with the nearby provinces more densely.

Trip generation equations for freight flows are developed using socioeconomic, demographic and land use variables at the province level. It is inferred that freight demand model equations are responsive to socioeconomic and demographic characteristics as it is given in the following functions. Number of employees and Gross Domestic Product are the most explanatory variables for freight trip production equations on the other hand population and passenger car ownership per 1000 households are the most descriptive variables for freight trip attractions as mentioned in the majority of the literature. Increasing population naturally results in increased freight attraction and therefore increases the transportation demand. Moreover increased employment generates more freight flows and as a result increases the freight demand.

Freight Production Equations

$$\text{Freight Trip Production} = f(\text{Number of Employees,} \\ \text{(Number of Trucks per year) DUMMY (INTERNATIONAL PORT EXISTENCE)})$$

$$\text{Freight Trip Production} = f(\text{Gross Domestic Products} + \\ \text{(Tons of Moved Goods per year) DUMMY (INTERNATIONAL PORT EXISTENCE)})$$

Freight Attraction Equations

*Freight Trip Attraction = f (Population, Passenger Car Ownership
(Number of Truck Trips per year) per 1000Households)*

*Freight Trip Attraction = f (Population, Passenger Car Ownership
(Tons of Moved Goods per year) per 1000 Households)*

In this research all regression assumptions are provided at the stage of structuring trip generation equations and additionally GOF (goodness-of-fit) results are very explanatory and statistically significant for freight trip production and freight trip attraction equations. Even all production and attraction equations give very significant results, the best and the most significant one as a result of statistical tests is the attraction model based on commodity flows (tonnage of moved goods as destination). The results are very similar to application and model development researches in the literature in terms of explanatory socioeconomic variables, population for freight attraction model and employment and Gross Domestic Product for freight production models gives more significant and better results. In addition as it is mentioned in the literature that attraction model based on commodity flow superior to production model is achieved.

It is a general inference that there is a direct relation between freight flow and economic growth. As mentioned earlier freight flows are the spatial reflection of socioeconomic development. More developed provinces generate and attract more freight flows. According to the research “Prioritizing the Provinces by their Socioeconomic Developments” performed by State Planning Organization (SPO), provinces are scaled in five levels. The developed provinces at the first level are İstanbul, Ankara, İzmir and Kocaeli, which dominate the freight flows of Türkiye. On the other hand provinces at fifth level (least one) such as Bayburt, Gümüşhane, Siirt, Ardahan, Bingöl, Hakkari, Muş, etc. are the provinces attracting and/or generating the least amount of freight flows. In these provinces level of freight traffic is low due to limited economic activity. This research also shows that freight productions and attractions for less developed provinces are not easily predictable.

Moreover for the provinces, in terms of freight flow attraction or production, existence of international port in the province is an important parameter and therefore this feature

is included in trip generation models as a dummy variable. This dummy is found significant only for production models. However actual foreign export and import values in terms of tonnage give better results and actual values may be used in the next step of this research depending on availability of data. In addition predicted production and attraction values for the provinces which have an international border do not fit very well to the observed values. As a result existence of an international border in a province is also included in regression analysis as a dummy variable but this variable is not found statistically significant and explanatory both in production and attraction models. Results also show that predicted values are not reliable for many of the provinces announced as province after 1989. It has been contemplated that this is because these provinces are not in similar size units to others in economic, demographic and geographic features. The residuals (errors) of these provinces at freight trip generation stage are high because of their dimensions.

Visual representations of freight flows between important provinces are also visual confirmation of the gravity model which states that the attraction between two TAZs is proportional to the magnitudes of the freight flows and inversely proportional to the distance between two TAZs. The results of this research confirm this and are very compatible with the theory of the gravity. Highest freight flows occur between competing provinces. Regarding all these results it is inferred that gravity model gives statistically significant results in freight flow distribution and can be used in transportation planning to predict freight movements between provinces in Türkiye. Research outcomes on trip length show that the frequency of moderate freight trip length is more than that of shorter and longer trip lengths for inter-provincial truck trips.

This research is focused on inter-provincial freight movement. The average inter-provincial truck distance is approximately 450 – 500 km. Therefore the developed model is long-distance model. The applied gravity model is doubly constrained and it is employed both for aggregated sequential year data and for limited annual data. The coefficient of deterrence function (beta) is found as 0.0216 for aggregated surveys and found as 0.0239 for limited annual data. In addition coincidence ratio is found 0.71 and R-square is equal to 0.673 between observed and simulated O-D pairs for aggregated surveys. On the other hand coincidence ratio is found 0.70 for limited annual surveys. Briefly gravity model is calibrated by comparing observed and simulated O-D pairs and

trip length distribution frequency. The obtained R-square of observed and simulated O-D pairs and coincidence ratio of observed and simulated trip length distributions frequency are found statistically significant. These results show that annual data is also successfully used to calibrate the gravity model and the gravity model is a good tool to be used to forecast freight demand between provinces of Türkiye. In addition logarithmic transformation of gravity equation confirms that the friction of distance between provinces is important and the relationship between O-D pairs (between provinces) and level of interactions is linear. Observations and results show that gravity model explains the distance effect between trading provinces. Therefore it is inferred that gravity model serves directional distribution of freight quantity between provinces and could be used for future estimates.

Data is very critical for this kind of empirical research. In this research axle load surveys performed by KGM are used to obtain observed origin-destination matrix and therefore to develop freight demand model. These data are open to researchers in order to be used in similar studies. However annual surveys are insufficient to represent all links of the highway network of Türkiye to develop nationwide freight demand model. In this research aggregated surveys of different years were used. However annual surveys also give very good results for the calibration of gravity model used in trip distribution stage. In addition, during the process of this research, in the light of the suggestions made by the researcher, KGM changed commodity groups and has started to use the European Union Commodity Groups given in Appendix E and also altered the way of collecting and archiving data to increase the reliability.

In this research, two steps of traditional Four-Step Model is applied for nationwide freight flow modeling and all GOF tests and results are found significant and reliable hence the results may be used by related authorities in planning studies. On the other hand similar research is recommended to further researchers for passenger movements.

The freight trip generation and distribution models are applied for total truck flows, however it could give better results if truck trips were subdivided by their axle types. Therefore the next step of this research should be to develop and calibrate the models for trucks according to their axle types.

Impedance between two zones is represented by the distance between these zones in this research. In further studies monetary and/or time parameters may be applied to find out the coefficient of friction.

Since the average distances for trucks change by commodity types, the models depending on commodity types may give better results. Modeling procedure including commodity types to develop nationwide freight demand model depending on commodity types is therefore the next step of this research. However in this research it was not applied because of the insufficiency of data on commodity types but KGM has improved the way of collecting and archiving the freight flow data starting from 2007.

Depending upon the availability of new explanatory socioeconomic variables, the model can be improved and more accurate results may be obtained by including these new variables such as employment break downed by economic sectors.

The last suggestion is applying these models on more complex road network which is a GIS based road network and using more complex computational processes regarding all truck types, commodity groups and network characteristics. One of the undergoing projects of KGM is developing GIS based road network and the further researcher may use this advantage. By this way truck flows obtained from models can be easily assigned to road network and the results can be calibrated by counted traffic data.

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APPENDIX A

DATA RELATED TO CHAPTER 4

Table A.1 Statistical Regions According to NUTS

CODE	LEVEL 1	LEVEL 2	LEVEL 3
TR			TÜRKİYE
TR1 <i>TR10</i> TR100	İstanbul	<i>İstanbul</i>	İstanbul
TR2 <i>TR21</i> TR211 TR212 TR213 <i>TR22</i> TR221 TR222	Batı Marmara	<i>Tekirdağ</i> <i>Balıkesir</i>	Tekirdağ Edirne Kırklareli Balıkesir Çanakkale
TR3 <i>TR31</i> TR310 <i>TR32</i> TR321 TR322 TR323 <i>TR33</i> TR331 TR332 TR333 TR334	Ege	<i>İzmir</i> <i>Aydın</i> <i>Manisa</i>	İzmir Aydın Denizli Muğla Manisa Afyon Kütahya Uşak
TR4 <i>TR41</i> TR411 TR412 TR413 <i>TR42</i> TR421 TR422 TR423 TR424 TR425	Doğu Marmara	<i>Bursa</i> <i>Kocaeli</i>	Bursa Eskişehir Bilecik Kocaeli Sakarya Düzce Bolu Yalova
TR5 <i>TR51</i> TR510 <i>TR52</i> TR521 TR522	Batı Anadolu	<i>Ankara</i> <i>Konya</i>	Ankara Konya Karaman
TR6 <i>TR61</i> TR611 TR612 TR613 <i>TR62</i> TR621 TR622 <i>TR63</i> TR631 TR632 TR633	Akdeniz	<i>Antalya</i> <i>Adana</i> <i>Hatay</i>	Antalya Isparta Burdur Adana Mersin Hatay Kahramanmaraş Osmaniye
TR7 <i>TR71</i> TR711 TR712 TR713 TR714 TR715 <i>TR72</i> TR721 TR722 TR723	Orta Anadolu	<i>Kırıkkale</i> <i>Kayseri</i>	Kırıkkale Aksaray Niğde Nevşehir Kırşehir Kayseri Sivas Yozgat
TR8 <i>TR81</i> TR811 TR812 TR813 <i>TR82</i> TR821 TR822 TR823 <i>TR83</i> TR831 TR832 TR833 TR834	Batı Karadeniz	<i>Zonguldak</i> <i>Kastamonu</i> <i>Samsun</i>	Zonguldak Karabük Bartın Kastamonu Çankırı Sinop Samsun Tokat Çorum Amasya
TR9 <i>TR90</i> TR901 TR902 TR903 TR904 TR905 TR906	Doğu Karadeniz	<i>Trabzon</i> <i>Erzurum</i>	Trabzon Ordu Giresun Rize Artvin Gümüşhane
TRA <i>TRA1</i> TRA11 TRA12 TRA13 <i>TRA2</i> TRA21 TRA22 TRA23 TRA24	Kuzeydoğu Anadolu	<i>Erzurum</i> <i>Ağrı</i>	Erzurum Erzincan Bayburt Ağrı Kars Iğdır Ardahan
TRB <i>TRB1</i> TRB11 TRB12 TRB13 TRB14 <i>TRB2</i> TRB21 TRB22 TRB23 TRB24	Ortadoğu Anadolu	<i>Malatya</i> <i>Van</i>	Malatya Elazığ Bingöl Tunceli Van Muş Bitlis Hakkari
TRC <i>TRC1</i> TRC11 TRC12 TRC13 <i>TRC2</i> TRC21 TRC22 <i>TRC3</i> TRC31 TRC32 TRC33 TRC34	Güneydoğu Anadolu	<i>Gaziantep</i> <i>Şanlıurfa</i> <i>Mardin</i>	Gaziantep Adıyaman Kilis Şanlıurfa Diyarbakır Mardin Batman Şırnak Siirt

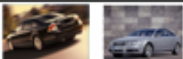
Source: Türkiye's Statistical Yearbook (2004), T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2005.

Table A-2 Areas of Provinces (km²)

Licence Plate No	Province	Region Landsquare (km2) (inc. lakesl)	Region Landsquare (km2) (ecl. lakesl)	Licence Plate No	Province	Region Landsquare (km2) (inc. lakesl)	Region Landsquare (km2) (ecl. lakesl)
	Türkiye	783523	769564				
1	Adana	14045	13914	42	Konya	40813	38872
2	Adıyaman	7606	7033	43	Kütahya	12013	11977
3	Afyon	14718	14313	44	Malatya	12102	11776
4	Ağrı	11498	11470	45	Manisa	13228	13096
5	Amasya	5703	5690	46	Kahramanmaraş	14456	14345
6	Ankara	25401	24520	47	Mardin	8806	8806
7	Antalya	20790	20723	48	Muğla	12949	12851
8	Artvin	7367	7367	49	Muş	8067	8058
9	Aydın	7904	7851	50	Nevşehir	5391	5379
10	Balıkesir	14472	14299	51	Niğde	7365	7352
11	Bilecik	4306	4301	52	Ordu	5952	5952
12	Bingöl	8253	8253	53	Rize	3921	3921
13	Bitlis	7094	7021	54	Samsun	9364	9083
14	Bolu	8323	8319	55	Şanlıurfa	19336	18764
15	Burdur	7134	6839	56	Siirt	5473	5473
16	Bursa	10886	10421	57	Sinop	5816	5791
17	Çanakkale	9950	9933	58	Sivas	28567	28549
18	Çankırı	7491	7490	59	Tekirdağ	6342	6312
19	Çorum	12796	12792	60	Tokat	10072	9957
20	Denizli	11804	11691	61	Trabzon	4664	4664
21	Diyarbakır	15204	15057	62	Tunceli	7685	7432
22	Edirne	6097	6074	63	Sakarya	4880	4838
23	Elazığ	9281	8454	64	Uşak	5363	5340
24	Erzincan	11727	11619	65	Van	22983	19299
25	Erzurum	25330	25322	66	Yozgat	14074	14072
26	Eskişehir	13902	13841	67	Zonguldak	3309	3303
27	Gaziantep	6844	6819	68	Aksaray	7965	7570
28	Giresun	6831	6831	69	Bayburt	3739	3739
29	Gümüşhane	6437	6437	70	Karaman	8868	8844
30	Hakkari	7178	7178	71	Kırkkale	4569	4533
31	Hatay	5831	5827	72	Batman	4659	4659
32	Isparta	8871	8276	73	Şırnak	7151	7151
33	Mersin	15512	15484	74	Bartın	2080	2080
34	İstanbul	5315	5196	75	Ardahan	4967	4841
35	İzmir	12015	12012	76	Iğdır	3587	3587
36	Kars	10139	10126	77	Yalova	850	847
37	Kastamonu	13157	13152	78	Karabük	4108	4108
38	Kayseri	17109	17042	79	Kilis	1427	1427
39	Kırklareli	6299	6277	80	Osmaniye	3195	3123
40	Kırşehir	6530	6351	81	Düzce	2592	2566
41	Kocaeli	3625	3612				

Source: Türkiye's Statistical Yearbook (2003), T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2004

Table A.3 Continuous Counts Classification Scheme (Inductive Loops)

Category		
1	Motorcycle	
2	Passenger Car	
3	Passenger Car+Caravan	 
4	Light Commercial Vehicle	
5	Medium Commercial Vehicle	
6	Bus	 
7	Truck	    
8	Truck+Remork	    
9	Trailer+ SemiRemork	    

Source: KGM, Transportation and Cost Analysis Division

Table A.4 Short Term Mobile Counts Classification Scheme (Pneumatic Tubes)

Class	Vehicle Type	No. of Axles	Axle spacing in cm					
			Axle 1 to 2	Axle 2 to 3	Axle 3 to 4	Axle 4 to 5	Axle 5 to 6	Axle 6 to 7
1	motorcycle	2	< 183					
2	passenger car	2	183 - 300					
	car + 1 axle trailer	3	183 - 300	183 - 424				
3	pickup	2	301 - 349					
	pickup + 1 axle trailer	3	301 - 349	183 - 424				
4	Bus	2	540 - 1200					
		3	540 - 1200	< 183				
5	single unit truck dual rear axle	2	350 - 530					
6	3 axle truck	3	280 - 530	< 183				
		3	< 183	280 - 530				
7	Truck	4	< 183	200 - 705	< 183			
		4	200 - 705	< 183	< 183			
		4	< 183	< 183	200 - 705			
		5	< 183	200 - 705	< 183	< 183		
8	Trailer	3	183 - 610	425 - 1200				
		4	183 - 610	< 183	183 - 1200			
		4	183 - 610	183 - 1200	< 183			
		4	183 - 610	183 - 700	183 - 1200			
9	5 axle combination	5	183 - 670	183 - 1200	< 183	< 183		
		5	183 - 670	< 183	183 - 1200	< 183		
		5	183 - 670	< 183	183-765	183 - 1200		
		5	183 - 670	183 - 1200	183-765	183 - 1200		
10	6 axle combination	6	183 - 670	< 183	183 - 1200	< 183	< 183	
		6	183 - 670	< 183	183 - 1200	183 - 765	183 - 765	
		6	183 - 670	< 183	183-765	183 - 1200	< 183	
11	7 axle and more	7	<1000	<1000	<1000	<1000	<1000	<1000
Ungrouped Classes								
12		unclassifiable vehicle						
0		unclassifiable axle event						

Source: KGM, Transportation and Cost Analysis Division

Table A.5 Vehicle Classification of Weigh in Motion (WIM) (Continuous Counts)
Stations

VEHICLE CATEGORY	
1	 1
2	 2  3
3	 4
4	 5
5	 22  32
6	 9  23  18  33  16
7	 12  13  19  20  17
8	 14  21
9	 6
10	 7  8
11	 10  11
12	 15
13	 24  25  26  27
	 28  29  30  31  34
14	> 6 AXLES

Source: KGM, Transportation and Cost Analysis Division



Source: KGM, Transportation and Cost Analysis Division

Figure A.1 Total Traffic Volume Map (2005)



Source: KGM, Transportation and Cost Analysis Division

Figure A.2 Total Truck Volume Map (2005)



Data Source: KGM, Transportation and Cost Analysis Division

Figure A.3 Truck Intercept Survey Stations Between 1996 and 2004

Table A.6 Annual Highway Statistics

Year	Mobility Values					
	Vehicle-Km. (Million)	Vehicle-Km. Growth Rate	Ton-Km. (Million)	Ton-Km Growth Rate	Passenger-Km (Million)	Passenger-Km Growth Rate
1950	558		957		2,597	
1960	1,563		3,678		10,880	
1970	6,477		17,447		41,311	
1972	8,113		18,777		50,207	
1974	11,515		25,874		61,341	
1975	13,432	17	29,424	13.7	68,395	11
1976	15,127	13	33,812	14.9	74,100	8
1977	17,610	16	38,013	12.4	85,678	16
1978	18,416	5	41,404	8.9	88,560	3
1979	15,878	-14	37,119	-10.3	75,770	-14
1980	15,343	-3	37,507	1.0	73,127	-3
1981	15,957	4	39,007	4.0	76,491	5
1982	16,595	4	40,567	4.0	80,010	5
1983	17,260	4	42,189	4.0	83,690	5
1984	17,949	4	43,878	4.0	87,539	5
1985	18,667	4	45,634	4.0	91,566	5
1986	20,849	12	54,018	18.4	93,587	2
1987	23,016	10	58,832	8.9	112,034	20
1988	24,553	7	65,459	11.3	128,202	14
1989	26,613	8	68,239	4.2	133,833	4
1990	27,041	2	65,710	-3.7	134,991	1
1991	26,056	-4	61,969	-5.7	131,029	-3
1992	28,514	9	67,704	9.3	142,173	9
1993	30,807	8	97,843	44.5	146,029	3
1994	31,251	1	95,020	-2.9	140,743	-4
1995	34,833	11	112,515	18.4	155,202	10
1996	41,015	18	135,781	20.7	167,871	8
1997	46,384	13	139,789	3.0	180,967	8
1998	49,947	8	152,210	8.9	186,159	3
1999	49,866	0	150,974	-0.8	175,236	-6
2000	56,151	13	161,552	7.0	185,681	6
2001	52,631	-6	151,421	-6.3	168,211	-9
2002	51,664	-2	150,912	-0.3	163,327	-3
2003	52,349	1	152,163	0.8	164,311	1
2004	57,767	10	156,853	3.1	174,312	6

Data Source: Karayolu Ulaşım İstatistikleri 2006, KGM, 2007

Table A.7 Annual Population and Growth Rates

Year	Population		Year	Population	
	Population	Population Growth Rate (%)		Population	Population Growth Rate (%)
1950	20,947,000		1991	57,024,000	1
1960	27,755,000		1992	57,914,000	2
1970	35,605,000		1993	58,808,000	2
1972	37,132,000		1994	59,709,000	2
1974	39,037,000		1995	60,611,000	2
1975	40,348,000	3	1996	61,528,000	2
1976	40,916,000	1	1997	62,866,000	2
1977	41,769,000	2	1998	63,391,000	1
1978	42,641,000	2	1999	64,337,000	1
1979	43,531,000	2	2000	67,853,000	5
1980	44,737,000	3	2001	68,618,000	1
1981	45,540,000	2	2002	69,626,000	1
1982	46,688,000	3	2003	70,712,000	2
1983	47,684,000	2	2004	71,789,000	2
1984	49,070,000	3			
1985	50,664,000	3			
1986	51,433,000	2			
1987	52,561,000	2			
1988	53,715,000	2			
1989	54,893,000	2			
1990	56,473,000	3			

Data Source: Karayolu Ulaşım İstatistikleri 2006, KGM, 2007;
İstatistiklerle Türkiye 2000, T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2001
Türkiye's Statistical Yearbook 2000, T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2001

Table A.8 Annual Employment and Growth Rates

Year	Employment		Year	Employment	
	Employment	Employment Growth Rate (%)		Employment	Employment Growth Rate (%)
1950	8,790,000		1990	18,539,000	2
1960	8,342,000		1991	19,288,000	4
1970	13,768,000		1992	19,459,000	1
1972	14,405,000		1993	18,500,000	-5
1974	14,985,000		1994	20,006,000	8
1975	15,169,000	1	1995	20,586,000	3
1976	15,380,000	1	1996	21,194,000	3
1977	15,873,000	3	1997	21,204,000	0
1978	16,085,000	1	1998	21,779,000	3
1979	16,320,000	1	1999	22,048,000	1
1980	16,523,000	1	2000	21,580,000	-2
1981	16,664,000	1	2001	21,524,000	0
1982	16,837,000	1	2002	21,354,000	-1
1983	17,004,000	1	2003	21,147,000	-1
1984	17,260,000	2	2004	21,791,000	3
1985	17,547,000	2			
1986	17,865,000	2			
1987	18,268,000	2			
1988	17,755,000	-3			
1989	18,222,000	3			

Data Source: Karayolu Ulaşım İstatistikleri 2006, KGM, 2007;
İstatistiklerle Türkiye 2000, T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2001;
Türkiye's Statistical Yearbook 2004, T.C. Başbakanlık, Türkiye İstatistik Kurumu, 2005

Table A.9 Annual National Accounts

Year	National Accounts					
	Gross National Product (with 1987 prices) (YTL.)	Gross National Product Per Capita (with 1987 prices YTL.)	GNP Growth Rates	Gross Domestic Product (with 1987 prices) (YTL.)	Gross Domestic Product Per Capita (with 1987 prices YTL.)	GDP Growth Rates
1950	19,732,074,000	942	9			
1960	26,589,290,000	958	3			
1970	34,468,624,000	976	4			
1972	40,279,247,000	1,085	9			
1974	43,633,171,000	1,118	3			
1975	46,275,413,000	1,155	6			
1976	50,437,967,000	1,233	9			
1977	51,944,339,000	1,244	3			
1978	52,582,170,000	1,233	1			
1979	52,324,175,000	1,202	-1			
1980	50,869,915,000	1,145	-3	50,295,991,000	2,288	
1981	53,316,849,000	1,171	5	52,738,671,000	2,564	5
1982	54,963,215,000	1,177	3	54,617,937,000	2,750	4
1983	57,279,000,000	1,197	4	57,332,996,000	2,934	5
1984	61,349,829,000	1,250	7	61,181,163,000	3,168	7
1985	63,989,098,000	1,272	4	63,776,133,000	3,320	4
1986	68,314,878,000	1,328	7	68,248,100,000	3,552	7
1987	75,019,388,000	1,427	10	74,416,097,000	3,911	9
1988	76,108,142,000	1,417	2	76,143,294,000	4,042	2
1989	77,347,305,000	1,409	2	76,364,109,000	4,116	1
1990	84,591,716,000	1,505	9	83,370,708,000	4,566	9
1991	84,887,074,000	1,481	1	84,271,019,000	4,677	1
1992	90,322,517,000	1,547	6	88,892,781,000	4,975	5
1993	97,676,585,000	1,642	8	96,390,529,000	5,395	8
1994	91,733,010,000	1,514	-6	91,599,730,000	5,112	-5
1995	99,028,241,000	1,606	8	97,728,752,000	5,489	7
1996	106,079,778,000	1,692	7	104,939,938,000	5,921	7
1997	114,874,197,000	1,839	8	112,892,073,000	6,303	8
1998	119,303,117,000	1,880	4	116,541,203,000	6,456	3
1999	112,043,830,000	1,741	-6	111,082,911,000	6,089	-5
2000	119,144,472,000	1,766	6	119,146,716,000	6,820	7
2001	107,783,063,000	1,573	-10	110,266,804,000	6,151	-7
2002	116,337,624,000	1,668	8	118,922,803,000	6,542	8
2003	123,164,990,000	1,742	6	125,778,039,000	6,980	6
2004	135,308,023,000	1,885	10	137,109,791,000	7,736	9

Data Source: Ekonomik ve Sosyal Göstergeler (1950-1995), T.C. Başbakanlık, DPT, 1996;
Ekonomik ve Sosyal Göstergeler (1950-2004), T.C. Başbakanlık, DPT, 2005;
İstatistiklerle Türkiye 2000, T.C. Başbakanlık, Devlet İstatistik Enstitüsü, 2001;
Türkiye's Statistical Yearbook 2004, T.C. Başbakanlık, Türkiye İstatistik Kurumu,
2005

Table A.10 Annual Vehicle Ownership

Yıl	Vehicle Ownership Values										Number of Vehicles Growth Rate (%)
	Number of Passenger Cars	Number of Trucks	Number of Small Trucks	Number of Buses	Number of Minibuses	Number of Motorcycles	Special Purpose Vehicles	Road Construction and Work Machinery	Total Number of Motor Vehicles		
1950	13,405	15,404		3,755		2,661			35,225		
1960	45,767	57,460		10,981		9,380			123,588		
1970	137,771	70,730	52,152	15,980	20,916	60,994	5,070	6,195	369,808		
1972	187,272	78,920	62,796	18,504	25,559	74,402	5,747	6,887	460,087		
1974	313,160	95,309	81,025	21,404	34,122	86,028	7,338	9,561	647,947		
1975	403,546	108,381	98,579	23,763	40,623	91,421	8,450	11,157	785,920	21	
1976	488,894	122,176	116,861	25,388	46,066	96,984	9,224	14,548	920,141	17	
1977	560,424	138,093	134,213	27,096	51,999	102,127	10,137	18,150	1,042,239	13	
1978	624,438	146,551	144,695	28,559	56,836	109,890	10,698	20,894	1,142,561	10	
1979	688,687	157,095	155,278	30,634	61,596	120,378	11,291	22,875	1,247,834	9	
1980	742,252	164,893	165,821	32,783	64,707	137,931	11,777	24,090	1,344,254	8	
1981	776,432	172,372	172,269	33,839	66,514	160,557	12,459	26,246	1,420,688	6	
1982	811,465	180,772	178,762	35,432	69,598	182,795	13,386	30,160	1,502,370	6	
1983	856,350	190,277	186,427	38,478	73,585	217,327	14,705	33,532	1,610,681	7	
1984	919,577	197,721	198,106	43,638	80,697	256,338	16,312	39,445	1,751,834	9	
1985	983,444	205,496	212,505	47,119	87,951	289,052	17,639	45,561	1,888,767	8	
1986	1,087,234	217,111	224,755	50,798	97,917	327,326	19,448	50,819	2,075,408	10	
1987	1,193,021	225,872	233,480	53,554	106,314	369,894	21,236	55,129	2,258,500	9	
1988	1,310,257	234,166	240,718	56,172	112,885	420,889	23,301	58,300	2,456,688	9	
1989	1,434,830	241,392	248,567	58,859	118,026	472,853	25,060	60,191	2,659,778	8	
1990	1,649,879	257,353	263,407	63,700	125,399	531,941	26,519	63,024	2,981,222	12	
1991	1,864,344	273,409	280,891	68,973	133,632	590,488	28,606	66,981	3,307,324	11	
1992	2,181,388	287,160	308,180	75,592	145,312	655,347	31,158	72,000	3,756,137	14	
1993	2,619,852	305,511	354,290	84,254	159,900	743,320	33,703	79,233	4,380,063	17	
1994	2,861,640	313,771	374,473	87,545	166,424	788,786	35,495	83,072	4,711,206	8	
1995	3,058,511	321,421	397,743	90,197	173,051	819,922	37,274	87,214	4,985,333	6	
1996	3,274,156	333,269	442,788	94,978	182,694	854,150	40,212	95,318	5,317,565	7	
1997	3,570,105	353,586	529,838	101,896	197,057	905,121	45,327	107,151	5,810,081	9	
1998	3,838,288	371,163	626,004	108,361	211,495	940,935	49,925	117,913	6,264,084	8	
1999	4,072,326	378,967	692,935	112,186	221,683	975,746	52,105	120,937	6,626,885	6	
2000	4,422,180	394,283	794,459	118,454	235,885	1,011,284	55,677	129,157	7,161,379	8	
2001	4,534,803	396,493	833,175	119,306	239,381	1,031,221	57,490	131,019	7,342,888	3	
2002	4,600,140	399,025	875,381	120,097	241,700	1,046,907	58,790	133,003	7,475,043	2	
2003	4,700,343	405,034	973,457	123,500	245,394	1,073,415	60,511	137,933	7,719,587	3	
2004	5,400,714	647,295	1,260,009	152,380	318,957	1,218,710	27,979		9,026,044	17	

Data Source: Motorlu Kara Taşıtları İstatistikleri (2005), T.C. Başbakanlık, Türkiye İstatistik Kurumu, 2006

Table A.1.1 List of Regarded Roadside Surveys on State Roads

YEAR	NO.	DIRECTION 1	DIRECTION 2	KGM Regional Division	Control Section Number & Traffic Segment	PROVINCE	Annual Average Daily Total Traffic (AADT)	Annual Average Daily Passenger Car	Annual Average Daily Medium Gross Vehicle	Annual Average Daily Bus	Annual Average Daily Truck	Annual Average Daily Articulated Truck	Date When Survey Began	Season When Survey Done	Annual Average daily Total Truck	Number of Sample (Suggested)	SAMPLE (Realized) (%)	Realized / Suggested
2005	1	ÇUMRA AYR.	KONYA	3	715-04	KONYA	3886	2636	407	143	611	99	23.05.05	spring	710	201	28.31	2.38
2005	2	ÇANKIRI	KALEÇİK	4	765-06	ANKARA	2728	1952	200	107	433	35	24.05.05	spring	468	114	24.36	1.43
2005	3	AVANOS	KAYSERİ	6	300-16(4)	NEVŞEHİR	3427	2113	219	239	756	100	10.05.05	spring	856	21	2.45	10.09
2005	4	ERZURUM	CAT	12	950-04(1)	ERZURUM	1170	736	132	14	271	16	07.09.05	fall	287	182	56.45	2.25
2005	5	TASLIÇAY	AGRI	12	100-32(1)	AGRI	1757	850	255	58	369	225	09.08.05	summer	594	303	51.01	3.67
2005	6	ERZINCAN	UZUNLU	16	100-25(2)	ERZINCAN	3525	1761	340	224	911	289	07.06.05	summer	1200	348	29.00	3.91
2005	7	GÜMÜŞOVA	DÜZCE	4	100-11(2)	DÜZCE	7478	4435	514	115	1890	524	20.09.05	summer	2414	475	19.68	5.15
2005	8	MERSİN	TARSUS	5	400-18(2)	MERSİN	24116	15790	2221	601	4547	957	29.11.05	fall	5504	517	9.39	1.71
2005	9	SERİK	MANAVGAT	13	400-11(1)	ANTALYA	15227	11192	971	772	2021	271	22.11.05	fall	2292	392	17.10	4.02
2005	10	YALOVA	ORHANGAZI	14	575-01(3)	YALOVA	21598	13353	1755	989	4092	1410	18.10.05	fall	5502	218	3.96	1.72
2004	1	AYDIN	CİNE	2	550-13(1)	AYDIN	6047	3877	568	167	1189	246	08.07.04	summer	1435	270	18.82	3.00
2004	2	YARMA	KARAPINAR	3	330-14(2)	KONYA	4331	2005	285	216	1453	372	24.05.04	spring	1825	425	23.29	5.00
2004	3	BOLU	GEREDE	4	100-12(3)	BOLU	5881	2266	273	103	2419	620	25.05.04	spring	3039	497	16.35	3.06
2004	4	CEYHAN	ADANA	5	400-19(2)	ADANA	12502	8544	1250	176	2255	277	25.05.04	spring	2532	446	17.61	5.82
2004	5	KAYSERİ	SARIOĞLAN	6	260-11(2)	KAYSERİ	3774	2175	341	163	982	112	11.05.04	spring	1094	352	32.18	8.07
2004	6	SUNGÜRLÜ	ÇORUM	7	795-04(4)	ÇORUM	6236	3515	390	355	1636	340	11.05.04	spring	1976	134	6.78	4.64
2004	7	KÜREÇİK	MALATYA	8	300-22(2)	MALATYA	1658	1109	179	221	318	31	11.05.04	spring	349	120	34.38	1.59
2004	8	DIYARBAKIR AYR.	BATMAN	9	370-01(2)	DIYARBAKIR	3397	2086	246	79	859	127	25.05.04	spring	986	359	36.41	4.10
2004	9	MAÇKA	TORUL	10	885-01(2)	TRABZON	1415	888	164	38	282	43	24.08.04	summer	325	212	65.23	2.86
2004	10	ELEŞKİRT	AGRI	12	100-31(2)	AGRI	2281	1356	212	73	422	219	08.06.04	summer	641	349	54.45	4.18
2004	11	AKSU	İSPARTA	13	685-05(0)	ANTALYA	3667	2823	192	138	563	151	25.05.04	spring	714	288	40.34	3.40
2004	12	KARAC	KASTAMONU	15	830-03(0)	KASTAMONU	1605	1056	118	72	313	46	25.05.04	spring	359	250	69.64	3.30
2004	13	(SIVAS-ŞARKIŞLA)AYR ULUŞ	ULUŞ	16	850-06(2)	SIVAS	2155	1373	202	64	462	54	11.05.04	spring	516	234	45.35	2.89
2004	14	İZMİT	SAKARYA	1	550-08(2)	KOCAELİ	13084	8186	593	74	3371	860	01.07.04	summer	4231	316	7.47	3.36
2004	15	AYDIN	GERMENÇİK	2	550-12(3)	AYDIN	10300	7517	1370	94	1092	262	25.08.04	summer	1319	190	14.40	2.12
2004	16	AYFON	İSCEHİŞAR	3	260-01(1)	AYFON	6012	3686	385	409	1270	282	08.06.04	summer	1532	307	20.04	3.40
2004	17	SİLİFKE	ERDEMLİ	5	400-17(1)	İÇEL	11589	9290	1124	168	887	120	27.07.04	summer	1007	199	19.76	2.27
2004	18	KIRŞEHİR	KAYSERİ	6	260-08(5)	KIRŞEHİR	6103	3683	381	432	1345	262	01.06.04	summer	1607	503	31.30	5.64
2004	19	SAMSUN	ÇARŞAMBA	7	010-16(2)	SAMSUN	13478	8493	946	531	3092	416	17.08.04	summer	3508	111	3.16	5.55
2004	20	ÇINAR	MARDİN	9	950-10(0)	MARDİN	3280	2165	338	15	708	53	08.06.04	summer	761	588	77.27	1.19
2004	21	ERZURUM	PASINLER	12	100-29(1)	ERZURUM	5194	2747	631	265	1213	337	25.08.04	summer	1550	445	28.71	6.90
2004	22	DINAR	DAZKIRI	13	320-05(2)	AFYON	4938	3115	285	262	1048	228	13.07.04	summer	1276	313	24.53	4.92
2004	23	ILGAZ	ÇANKIRI	15	765-04(1)	ÇANKIRI	2540	1724	182	95	505	34	10.08.04	summer	539	153	28.39	3.50
2004	24	AKDAĞMADENİ	YILDIZELİ	16	200-19(0)	SIVAS	1989	1299	142	166	333	49	06.07.04	summer	382	229	23.59	1.88
2004	25	CATALCA AYR.	KÜMBURGAZ	1	100-05(1)	İSTANBUL	53303	40996	4555	1012	6265	475	30.09.04	fall	6740	410	59.95	2.98
2004	26	KONYA	ÖBRÜK	3	300-13(1)	KONYA	3134	1947	278	175	636	98	13.09.04	fall	734	270	6.08	4.33
2004	27	SIVRHIŞAR	POLATLI	4	200-11(0)	ANKARA	8609	5347	567	786	1434	675	28.06.04	summer	2109	303	36.78	3.30
2004	28	GOLBAŞI	KÜLLÜ	4	750-08(2)	ANKARA	9311	5231	394	719	2136	830	12.10.04	fall	2966	449	14.37	3.30
2004	29	NEVŞEHİR	AKSARAY	6	300-15(2)	AKSARAY	3583	2022	379	225	832	124	12.10.04	fall	956	364	15.14	4.83
2004	30	YILDIZELİ	TOKAT	7	850-03(2)	TOKAT	2092	1360	190	48	443	51	28.09.04	fall	494	68	38.08	4.17
2004	31	MALATYA	ELAZIĞ	8	300-24(1)	ELAZIĞ	3397	1959	279	209	851	100	03.08.04	summer	951	215	13.77	0.85
2004	32	TUNCELİ	KOVANCILAR	8	885-09(0)	ELAZIĞ	351	57	17	142	17	17	21.09.04	summer	2261	87	22.61	2.46
2004	33	VİRANŞEHİR	KIZILTEPE	9	400-28(2)	MARDİN	3641	1502	217	12	1474	436	05.10.04	fall	1910	484	94.97	2.52
2004	34	ADILCEVAZ	AHLAT	11	965-11(3)	BITLİS	1136	562	89	44	375	66	22.06.04	summer	441	132	25.34	5.29
2004	35	TATVAN	GEVAŞ	11	300-33(1)	VAN	2479	1275	157	75	919	53	28.09.04	summer	972	321	29.93	1.67
2004	36	KOTEK AYR.	KARS	12	965-03(2)	KARS	2431	1478	283	56	581	53	04.10.04	fall	614	322	33.02	3.67
2004	37	ANTALYA	KORKUTELİ	13	350-05(0)	ANTALYA	5833	4349	409	136	826	615	12.10.04	fall	938	232	52.44	3.88
2004	38	OSMANELİ	BİLEÇİK	14	650-03(2)	BİLEÇİK	8263	4227	790	461	2170	706	07.09.04	fall	2785	305	24.73	9.29
2004	39	REFAHİYE	ERZINCAN	16	100-24(3)	ERZINCAN	3049	1575	203	236	766	289	14.09.04	fall	1035	466	10.95	2.66

Table A.11 (continued)

YEAR	NO.	DIRECTION 1	DIRECTION 2	KGM Regional Division	Control Section Number & Traffic Segment	PROVINCE	Annual Average Daily Total Traffic (AADT)	Annual Average Passenger Car	Annual Average Medium Cross Vehicle	Annual Average Daily Bus	Annual Average Daily Truck	Annual Average Daily Articulated Truck	Date When Survey Began	Season When Survey Done	Annual Average daily Total Truck	Number of Trucks	SAMPLE (Suggested) %	Realized / Suggested
2003	1	ALIAGA	BERGAMA	2	550-09(1)	IZMIR	8049	5546	590	237	1343	332	26.05.03	null	1675	387	91	5.42
2003	2	AKSEHIR	ILGIN	3	300-11	KONYA	5974	3015	347	297	1932	384	27.05.03	spring	2316	98	86	4.23
2003	3	BAHCE	OSMANIYE	5	400-21(4)	OSMANIYE	4004	2989	233	15	710	148	27.05.03	spring	868	250	82	10.07
2003	4	MERZIFON	OSMANCIK	7	100-17(2)	AMASYA	4904	2900	242	469	979	414	01.07.03	summer	1393	140	90	6.45
2003	5	BESNI AYR.	S.UREFA AYR.	8	360-04(3)	ADIVAMAN	2977	1900	261	64	712	612	27.05.03	spring	752	199	85	11.32
2003	6	SANLIURFA	BIRECIK	9	400-25(0)	S.UREFA	5948	5948	693	265	3182	682	13.05.03	spring	3844	612	94	2.44
2003	7	ÇARŞIBAŞI	AQÇAMBAT	10	010-21(2)	TRABZON	8239	5145	723	274	1791	304	13.05.03	spring	2095	550	92	4.38
2003	8	MUŞ	BITLIS	11	300-31(2)	BITLIS	2177	1177	269	58	632	41	20.05.03	spring	673	169	84	12.49
2003	9	ERZURUM	ASKALE	12	600-27(2)	ERZURUM	3906	2045	515	253	665	428	17.06.03	summer	1093	379	88	8.08
2003	10	BURDUR	ISPARTA AYR.	13	650-12(1)	BURDUR	3064	2072	269	302	1374	346	28.05.03	spring	1720	316	88	4.29
2003	11	ALAPLI	AQÇAKOCA	15	010-06(1)	ZONGULDAK	4639	2928	339	152	859	187	27.05.2003	spring	1220	277	89	5.29
2003	12	SULUFLU	OF	10	010-22(4)	TRABZON	9647	6577	1108	214	1561	187	01.07.03	summer	1748	380	91	7.30
2003	13	VAN	ERCIŞ AYR.	11	975-05(2)	VAN	1934	942	177	60	718	371	07.07.03	summer	755	267	85	11.29
2003	14	ANTALYA	DAĞ	13	650-14(1)	ANTALYA	5861	3465	345	271	1497	293	26.08.03	summer	1790	257	91	5.09
2003	15	TAVŞANLI	KUTAHYA	14	200-06(4)	KUTAHYA	5055	3340	559	58	908	190	19.08.2003	summer	1098	480	88	8.04
2003	16	KIZILÇAHAMAM	ANKARA	4	750-06(4)	ANKARA	5608	1713	251	43	2626	973	07.10.03	fall	3599	339	94	2.60
2003	17	NARLI	KAHRAMANMARAŞ	5	835-01(11)	K.İMARŞ	4917	3415	401	67	969	66	21.10.03	fall	1035	257	88	8.49
2003	18	AKSARAY	ULUKIŞLA	6	750-15(2)	KONTA	5720	2373	448	472	1751	677	16.09.03	fall	2428	476	92	3.15
2003	19	ELAZIG	KOVANÇILAR	8	300-25(2)	ELAZIG	2808	1499	302	136	796	76	07.10.03	fall	872	248	87	9.92
2003	20	SIVEREK	HILVAN	9	885-12(1)	S.UREFA	3493	2003	285	143	907	154	30.09.03	fall	1061	286	88	8.30
2003	21	ERZURUM	TORTUM	12	950-03(2)	ERZURUM	1781	1161	182	26	398	14	23.09.03	fall	412	209	78	18.90
2003	22	SUSURLUK	BANDIRMA AYR.	14	565-06(2)	BALIKESIR	11907	6290	0	605	4732	280	13.08.03	summer	5012	661	94	1.88
2003	23	ILGAZ	TOSYA	15	100-15(1)	KASTAMONU	4170	2083	216	495	960	416	02.09.03	fall	1376	265	90	6.52
2002	1	AKHISAR	MANISA	2	565-09(1)	MANISA	17901	13078	1094	744	2066	619	29.05.02	spring	2885	387	93	3.45
2002	2	KONYA	SEYDİŞEHİR	3	696-01(1)	KONYA	1812	1812	182	110	414	414	29.05.02	spring	503	87	81	16.03
2002	3	DOĞUYOL	ISKENDERUN	5	817-04(1)	HATAY	6967	877	877	300	1675	356	21.05.02	spring	2031	455	92	4.52
2002	4	NARLI	ULUKIŞLA	6	805-07(0)	NİĞDE	3392	1951	224	94	923	200	28.05.02	spring	1123	227	88	7.88
2002	5	TURKOĞLU	KAHRAMANMARAŞ	5	825-04(3)	K.İMARŞ	3421	1797	409	76	913	226	27.07.02	summer	1139	276	89	7.78
2002	6	IZMIR	KAHRAMANMARAŞ	2	200-01(1)	IZMIR	5909	4083	0	332	1261	133	21.08.02	summer	1394	345	90	6.45
2002	7	TURHAL	TOKAT	7	180-06(2)	TOKAT	2092	1360	190	48	443	51	20.08.02	summer	494	223	80	16.28
2002	8	ÇAYCUMA	DEVRİK	15	010-07(1)	ZONGULDAK	4907	3829	332	123	568	55	03.09.02	fall	623	268	83	13.36
2002	9	ANKARA	DEMREĞAZ	4	200-13(1)	ANKARA	19702	12735	1272	1274	3538	883	01.10.02	fall	4421	472	94	2.13
2001	1	TURGUTLU	SALIHLI	2	300-03(3)	MANISA	12282	6863	798	735	3204	682	08.08.01	summer	3886	366	94	2.41
2001	2	SAKARYA	KAVAK	7	795-01(1)	SAKARYA	6970	542	542	2253	495	414	21.08.01	summer	2748	295	93	3.38
2001	3	KUTAHYA	ERGANI	9	885-11(2)	DIYARBAKIR	3524	1961	499	83	940	41	23.10.01	fall	981	285	87	8.92
2001	4	YARPAZLI	KUTAHYA	14	650-06(1)	KUTAHYA	3688	372	372	333	1723	41	07.08.01	summer	2154	371	92	4.27
2001	5	DERINKUYU	NİĞDE	6	765-13(0)	NİĞDE	1713	1063	117	18	459	56	07.08.01	null	515	212	81	15.72
2001	6	ÇORUM	ALACA	7	795-05(0)	ÇORUM	1848	1002	151	36	574	85	25.09.01	fall	659	123	84	12.72
2000	1	ERBAĞ	AMASTA	7	100-18(2)	AMASTA	1237	1237	155	207	578	223	23.05.00	spring	801	135	86	10.71
2000	2	TIREBOLU	GİRESUN	10	010-19(5)	GİRESUN	4698	4698	424	288	1356	307	09.05.00	spring	1663	677	91	5.46
2000	3	DINAR AYR.	SANDIKLI	13	650-10(1)	AFYON	3854	371	463	163	1356	436	23.05.00	spring	2071	541	92	4.43
2000	4	KIRKHAN	HASSA	5	825-07(3)	HATAY	3328	2065	411	7	778	67	27.08.00	summer	845	240	86	10.21
2000	5	NUYUN	ÇİZRE	9	400-30(2)	MARJIN	1705	1705	277	66	1769	562	17.10.00	fall	2331	444	92	3.96

Table A.11 (continued)

YEAR	NO.	DIRECTION 1	DIRECTION 2	KGM Regional Division	Control Section Number & Traffic Segment	PROVINCE	Annual Average Daily Total Traffic (AADT)	Annual Average Daily Passenger Car	Annual Average Daily Medium Gross Vehicle	Annual Average Daily Bus	Annual Average Daily Truck	Annual Average Daily Articulated Truck	Date When Survey Began	Season When Survey Done	Annual Average daily Total Truck	Number of Surveyed Trucks	SAMPLE Number of Sample (Suggested)	SAMPLE (Suggested) %	Realized / Suggested
93	1999	1	TEKIRDAG	1	110-04(2)	TEKIRDAG	14850	12028	1188	148	1336	150	27.05.99	spring	1486	226	15.21	6.07	2.51
94	1999	2	AFYON	3	665-02(1)	AFYON	2608	1812	182	110	414	89	13.07.99	summer	503	167	33.20	16.03	2.07
95	1999	3	EZINE	14	550-04(2)	ÇANAKKALE	3979	2684	300	156	643	196	06.07.99	summer	839	413	49.23	10.27	4.79
96	1999	4	SALİHLI	2	300-04(2)	MANİSA	6338	3377	674	373	1456	458	24.08.99	summer	1914	648	33.86	4.78	7.09
97	1999	5	PINARBAŞI	6	815-01(1)	KAYSERİ	1633	901	138	68	449	77	08.06.99	summer	526	107	20.34	15.44	1.32
98	1999	6	İĞDIR	12	080-05(2)	İĞDIR	1027	402	186	41	345	53	24.08.99	summer	398	340	85.43	19.44	4.39
99	1999	7	KAMAN AYR.	6	765-05(2)	KIRŞEHİR	5359	3067	302	511	1196	283	30.09.99	fall	1479	258	17.44	6.10	2.86
100	1998	1	LOLEBURGAZ	1	100-02(3)	KIRKLARELİ	4145	3094	327	123	510	118	21.05.98	spring	628	354	56.41	13.27	4.25
101	1998	2	SALİHLİ	2	585-04(0)	MANİSA	4738	3123	406	47	968	194	26.05.98	spring	1162	629	54.13	7.63	7.09
102	1998	3	ESKİŞEHİR	4	200-09(2)	ESKİŞEHİR	5040	2906	271	373	1098	392	26.05.98	spring	1490	304	20.40	6.06	3.37
103	1998	4	FETHİYE	13	400-04(0)	MUĞLA	3616	2654	349	80	482	51	26.05.98	spring	533	181	33.96	15.27	2.22
104	1998	5	KARAMÜRSEL	1	130-01(2)	KOCAELİ	14138	8480	1032	512	2767	1348	27.08.98	summer	4115	323	7.85	2.28	3.44
105	1998	6	BANDIRMA	14	200-04(1)	BURSA	7914	5666	494	205	1283	266	21.07.98	summer	1549	448	28.92	5.84	4.95
106	1998	7	KARTAL	1	100-06	İSTANBUL	49896	34862	1628	178	951	788	29.09.98	fall	13406	785	5.86	0.71	8.23
107	1998	8	YESİLHISAR	6	805-05(4)	KAYSERİ	3286	1566	341	178	951	230	20.10.98	fall	1181	305	25.83	89	7.52
108	1998	9	BOZÜYÜK	14	200-07(1)	BİLECİK	5947	2866	399	399	2416	266	06.10.98	fall	2682	745	27.78	3.46	8.03
109	1998	10	NAZILLI	2	320-02(2)	AYDIN	7258	4510	0	541	2054	153	08.08.98	summer	2207	630	26.55	92	4.17
110	1998	11	SUSEHİRİ	16	100-23(2)	SIVAS	2303	1293	144	135	525	205	01.09.98	fall	730	452	61.92	11.63	5.33
111	1996	1	SAMSUN	7	070-15(3)	SAMSUN	5143	3655	0	142	1295	51	23.07.96	summer	1346	348	25.85	6.66	3.88

Data Source: KGM, Transportation and Cost Analysis Division

APPENDIX B

OBSERVED TRUCK MATRIX (Vehicle per Day)

The following table (TableB.1) includes only inter-provincial O-D pairs.

Table B.1 Observed Truck Matrix (Vehicle per Day)

	adana	adiyaman	afyon	ağrı	amasya	ankara	antalya	artvin	aydın	balıkesir	bilecik	bingöl	bitlis	bolu	burdur	bursa	çanakkale
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
adana	1	0	21	0	29	8	87	19	8	19	19	0	19	25	15	10	69
adiyaman	2	44	0	0	0	0	4	2	0	0	0	0	0	0	0	0	12
afyon	3	2	0	0	0	0	58	75	0	23	2	0	0	0	4	27	33
ağrı	4	2	2	0	0	40	35	4	0	2	4	0	0	6	27	2	10
amasya	5	2	0	2	6	0	2	0	0	6	0	0	0	0	0	0	6
ankara	6	40	8	29	46	8	0	121	8	31	37	0	8	2	31	4	175
antalya	7	35	0	31	0	6	52	0	0	17	21	6	2	0	4	81	44
artvin	8	0	0	0	2	2	12	0	0	2	0	0	0	0	0	0	4
aydın	9	4	2	25	2	0	21	40	0	0	12	8	0	0	2	6	8
balıkesir	10	31	0	29	6	2	44	27	0	4	0	4	0	0	0	10	405
bilecik	11	2	0	0	2	0	8	23	0	0	2	0	0	0	0	0	164
bingöl	12	2	0	0	0	0	23	2	0	0	2	4	0	0	2	2	4
bitlis	13	42	0	0	4	0	2	0	0	0	0	0	15	0	0	0	0
bolu	14	8	0	4	4	0	44	4	0	0	4	2	0	4	0	2	12
burdur	15	0	0	2	0	0	2	73	0	4	2	0	0	0	0	0	8
bursa	16	85	12	33	8	2	110	91	0	15	200	214	2	2	10	2	0
çanakkale	17	2	0	0	0	0	12	23	0	0	106	0	2	0	4	2	54
çankırı	18	8	0	0	0	0	75	4	0	4	6	6	0	0	0	0	4
çorum	19	4	0	2	8	4	46	6	0	12	4	0	0	2	4	10	12
denizli	20	17	0	21	0	0	23	91	0	195	19	0	0	0	0	10	25
diyarbakır	21	58	2	0	0	0	33	4	0	2	4	0	0	8	0	0	6
edime	22	8	0	2	2	0	21	21	0	6	2	2	0	0	6	0	17
elazığ	23	23	0	0	0	0	29	0	0	4	2	4	50	6	4	0	4
erzincan	24	6	2	0	0	10	6	2	0	0	0	0	0	0	4	0	2
erzurum	25	10	2	2	214	31	56	2	50	0	0	0	6	0	2	2	17
eskişehir	26	33	2	148	4	2	206	31	0	6	77	2	0	0	4	2	125
gaziantep	27	121	29	2	4	2	29	6	0	8	0	0	6	2	0	2	58
giresun	28	0	0	0	2	4	4	4	0	0	0	0	0	0	2	0	0
gümüşhane	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
hakkari	30	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
hataş	31	333	10	0	6	10	23	15	0	8	2	0	8	6	2	0	25
isparta	32	2	0	10	0	0	8	154	0	10	0	0	0	0	0	42	17
içel	33	241	23	4	10	4	94	46	2	4	6	0	21	25	8	4	48
istanbul	34	272	8	21	46	10	339	672	17	48	89	179	4	6	46	37	177
izmir	35	98	4	33	6	0	222	443	2	482	233	25	0	0	10	46	67
kars	36	8	0	6	17	6	29	0	0	0	2	4	0	0	0	0	10
kastamonu	37	0	0	0	0	0	46	4	0	0	0	0	0	0	8	0	4
kayseri	38	54	12	4	10	4	96	23	2	2	12	2	15	2	10	0	50

Table B.1 (continued)

	adana	adiyaman	afyon	ağrı	amasya	ankara	antalya	artvin	aydın	balıkesir	bilecik	bingöl	bitlis	bolu	burdur	bursa	çanakkale
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
kırklareli	39	2	0	4	0	0	15	0	0	0	0	0	0	0	6	15	4
kirsehir	40	4	0	0	0	0	50	2	0	0	4	0	0	0	2	2	0
kocaeli	41	44	4	25	10	4	135	102	6	6	40	187	6	0	69	6	183
konya	42	98	0	15	12	0	54	50	0	37	12	0	0	2	6	0	33
kütahya	43	4	0	25	0	0	58	17	0	2	19	12	4	0	4	8	67
malatya	44	6	8	0	0	0	25	0	2	10	0	0	8	8	0	0	8
manisa	45	17	0	6	0	0	31	71	2	35	52	10	4	0	4	2	50
kmaraş	46	171	35	0	0	2	0	2	0	2	2	2	10	2	8	2	10
mardin	47	37	8	0	2	0	15	0	0	0	0	0	12	23	0	0	8
muğla	48	0	0	4	0	0	12	35	0	37	4	10	0	0	0	0	2
muş	49	2	2	0	2	2	2	2	0	0	0	0	0	52	0	0	0
nevşehir	50	17	0	0	0	0	29	8	0	8	6	0	0	0	4	0	6
niğde	51	23	0	0	0	0	4	0	0	4	4	0	2	0	0	0	6
ordu	52	10	0	0	12	0	10	8	0	0	0	0	0	0	6	0	6
rize	53	4	0	2	4	2	42	12	0	0	0	2	0	0	4	0	8
sakarya	54	23	2	2	12	0	44	29	0	4	25	17	2	0	58	2	17
samsun	55	23	0	2	2	21	31	6	8	2	8	0	0	0	6	2	8
siirt	56	19	0	0	2	0	0	0	0	0	0	0	4	0	0	0	0
sinop	57	4	0	0	0	0	4	0	2	0	0	0	0	0	2	0	0
sivas	58	2	0	0	0	10	25	4	0	2	2	0	4	0	2	0	2
tekirdağ	59	19	0	8	0	0	48	23	2	0	4	0	0	0	8	0	15
tokat	60	6	4	0	10	21	4	10	6	6	0	0	2	0	4	0	10
trabzon	61	15	0	0	33	19	42	21	6	2	4	2	6	4	2	2	12
tunceli	62	8	4	0	0	0	17	0	0	0	0	0	0	0	2	2	0
şanlı urfa	63	64	8	2	6	0	2	4	0	0	12	0	4	2	8	0	6
uşak	64	2	0	0	0	0	4	6	0	0	0	0	0	0	0	0	4
van	65	25	0	2	44	4	44	2	2	2	0	0	0	67	0	6	6
yozgat	66	0	0	0	0	0	8	2	0	0	2	0	0	0	0	0	0
zonguldak	67	2	2	2	0	2	2	6	2	6	0	6	0	0	17	4	27
aksaray	68	15	0	0	0	0	10	4	0	2	0	0	0	0	0	0	0
bayburt	69	0	0	0	0	4	0	2	2	0	0	0	0	0	0	0	2
karaman	70	2	0	0	0	2	4	6	0	0	2	0	0	0	2	0	2
kirikkale	71	2	0	0	2	4	67	2	0	0	0	0	0	0	0	0	2
batman	72	31	2	0	0	2	6	4	0	0	0	0	0	0	0	0	0
şimnak	73	114	25	0	0	0	4	6	0	0	0	0	0	0	0	27	2
bartın	74	0	0	0	2	0	17	8	0	0	2	0	0	0	12	0	10
ardahan	75	0	0	0	0	0	4	0	0	2	0	0	0	0	0	0	0
iğdir	76	0	0	0	12	8	15	0	0	0	2	0	0	0	0	0	2
yalova	77	4	0	0	0	0	15	2	0	2	4	2	0	0	0	0	6
karabük	78	0	0	0	2	0	6	0	0	0	0	2	0	0	4	0	10
kilis	79	2	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
osmaniye	80	46	6	0	0	0	6	2	0	0	0	0	0	0	0	2	2
düzce	81	6	0	0	0	0	8	2	0	0	0	8	0	0	4	0	4
Total	2470	249	509	607	262	2813	2509	129	1085	1079	722	226	256	445	376	2231	406

Table B.1 (continued)

		çankiri	çorum	denizli	diyarbakir	edirne	elazığ	erzincan	erzurum	eskişehir	gaziantep	giresun	gümüşhane	hakkari	hatay	isparta
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
adana	1	4	29	29	62	10	25	8	31	4	29	6		0	2	250
adiyaman	2	0	2	0	6	2	6	0	0	2	27	0	0	0	0	50
afyon	3	0	0	40	0	4	0	0	0	173	0	0	0	0	0	8
ağrı	4	2	8	0	6	0	0	8	164	8	10	0	0	0	6	2
amasya	5	2	10	0	0	0	0	2	6	2	2	8	2	0	2	0
ankara	6	46	19	25	31	10	10	31	121	175	15	10	0	2	21	4
antalya	7	2	6	25	12	12	2	2	25	17	4	4	0	0	12	146
artvin	8	0	2	0	0	0	0	0	50	0	0	6	0	0	0	0
aydın	9	0	0	146	2	6	0	0	0	23	8	0	0	4	2	15
balıkesir	10	0	0	2	6	6	6	2	8	58	8	0	0	0	4	6
bilecik	11	0	0	4	0	2	2	0	0	4	0	0	0	0	0	2
bingöl	12	0	0	0	0	0	50	0	19	0	17	0	0	0	6	0
bitlis	13	0	0	0	10	0	8	0	2	2	2	0	0	4	2	0
bolu	14	0	0	2	2	0	0	4	4	8	0	2	0	0	6	0
burdur	15	0	2	12	0	0	0	0	0	0	0	2	0	0	0	12
bursa	16	0	2	17	2	17	15	2	27	162	31	0	0	2	8	4
çanakkale	17	0	2	2	4	0	0	2	4	12	2	0	0	0	6	4
çankiri	18	0	2	0	0	2	2	6	0	2	0	0	0	0	0	0
çorum	19	6	0	8	4	0	0	2	8	0	15	2	0	0	2	4
denizli	20	0	0	0	0	6	0	0	0	4	8	0	0	0	15	31
diyarbakir	21	0	0	2	0	0	25	4	0	0	40	0	0	2	10	2
edirne	22	0	0	6	0	0	0	2	4	4	0	0	0	0	2	2
elazığ	23	0	2	0	71	0	0	8	6	4	6	0	0	0	8	0
erzincan	24	2	8	0	0	0	0	0	58	0	0	2	31	0	0	0
erzurum	25	2	12	2	25	0	17	44	0	2	10	2	8	0	31	0
eskişehir	26	4	4	4	15	6	23	0	21	0	0	2	0	6	8	2
gaziantep	27	2	4	37	46	2	6	2	19	0	0	0	0	6	214	0
giresun	28	0	4	0	0	0	2	0	4	0	0	0	0	0	0	0
gümüşhane	29	0	2	0	0	0	0	17	0	0	0	0	0	0	0	0
hakkari	30	0	0	0	19	0	2	0	4	0	10	0	0	0	2	0
hatay	31	0	2	10	75	0	15	2	8	2	116	2	0	2	0	0
isparta	32	2	2	2	2	0	0	2	2	2	0	2	0	2	4	0
içel	33	0	31	15	131	10	25	2	40	8	48	4	0	2	81	2
istanbul	34	12	27	171	44	212	64	46	171	160	112	23	0	4	69	35
izmir	35	4	2	410	12	17	19	0	15	89	50	4	2	2	35	56
kars	36	0	4	0	4	0	0	4	83	2	2	2	0	0	10	0
kastamonu	37	19	0	2	2	0	0	2	0	2	4	0	0	0	0	2
kayseri	38	4	4	25	6	2	19	12	87	8	23	0	0	0	44	0
kırklareli	39	0	0	0	0	12	0	0	0	10	0	0	0	0	0	0
kişehir	40	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0
kocaeli	41	6	8	40	12	21	6	2	46	218	29	2	0	2	19	17
konya	42	4	15	25	10	2	4	6	23	2	4	2	0	0	23	0
kütahya	43	4	2	8	2	0	0	2	4	85	2	0	0	0	2	17
malatya	44	0	2	2	23	0	46	0	10	0	2	0	2	2	19	0
manisa	45	4	0	123	2	0	6	0	8	17	2	0	0	0	2	10
kmaras	46	0	2	19	0	0	6	0	10	6	179	0	0	0	141	0
mardin	47	0	0	0	171	0	40	0	4	0	158	0	0	0	73	0
muğla	48	0	0	17	0	0	0	0	0	6	0	2	0	0	2	4
muş	49	0	0	0	19	0	2	0	2	2	40	0	0	4	4	0
nevşehir	50	0	0	6	12	2	2	0	0	2	4	0	0	0	10	2
niğde	51	0	2	0	2	0	12	0	0	2	4	0	0	0	6	0
ordu	52	0	2	2	0	2	0	4	12	0	8	8	0	0	0	0
rize	53	4	4	0	2	0	0	2	0	4	0	15	0	2	2	2
sakarya	54	0	2	4	2	6	2	4	6	2	15	4	0	0	6	4
samsun	55	10	96	6	4	0	4	8	15	2	17	21	0	0	6	0
siirt	56	0	0	0	4	0	0	0	0	6	4	0	0	4	2	0
sinop	57	0	0	0	2	0	2	2	0	2	0	0	0	0	2	0
sivas	58	2	10	0	2	0	2	19	8	10	0	0	2	0	12	2
tekirdağ	59	0	0	21	2	79	2	4	4	4	4	0	0	0	2	4
tokat	60	0	6	0	0	0	2	21	27	0	4	6	6	2	25	2
trabzon	61	6	10	0	0	0	10	31	71	12	4	108	48	4	8	2
tunceli	62	0	0	0	0	0	48	6	0	0	10	0	2	0	4	0
şanlı urfa	63	0	0	4	75	2	6	0	0	0	21	0	0	0	48	0
uşak	64	0	0	0	0	2	0	0	0	0	4	0	0	0	6	0
van	65	2	0	2	81	0	23	4	27	2	54	4	0	4	21	2
yozgat	66	0	4	0	0	0	0	0	4	0	2	0	0	0	8	0
zonguldak	67	0	0	6	0	0	2	0	4	2	2	0	0	2	0	0
aksaray	68	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
bayburt	69	0	2	0	0	0	0	0	4	0	0	2	0	0	0	0
karaman	70	0	0	0	8	0	0	0	0	0	0	0	0	0	6	2
kırıkkale	71	12	0	0	0	0	0	4	15	2	6	4	0	0	4	0
batman	72	0	0	0	52	0	37	0	12	2	48	0	0	4	12	10
şirnak	73	0	0	0	125	0	44	0	0	4	208	0	6	0	17	19
bartın	74	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2
ardahan	75	0	0	0	0	0	0	4	15	0	0	0	0	0	0	0
iğdir	76	0	6	4	0	2	2	0	73	2	0	4	0	0	0	0
yalova	77	0	0	2	0	2	0	0	2	4	15	0	0	0	2	0
karabük	78	0	0	4	0	0	2	0	0	0	0	2	0	0	12	0
kilis	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
osmaniye	80	0	2	0	0	0	0	0	2	0	4	0	0	0	62	0
düzce	81	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0
Total		167	367	1295	1211	460	659	339	1399	1351	1455	267	109	70	1482	444

Table B.1 (continued)

		ıçel	istanbul	izmir	kars	kastamonu	kayseri	kırklareli	kiřehir	kocaeli	konya	kütahya	malatya	manisa	kahramanmarař
		33	34	35	36	37	38	39	40	41	42	43	44	45	46
adana	1	351	272	110	6	8	73	0	4	37	85	4	8	12	42
adiyaman	2	29	15	12	0	0	17	0	0	0	6	0	25	0	33
afyon	3	8	40	79	0	0	2	4	0	27	15	46	0	17	0
ađri	4	8	75	27	15	4	60	2	2	19	8	0	0	0	2
amasya	5	0	10	8	2	8	2	0	2	4	0	0	0	0	0
ankara	6	48	299	243	31	62	129	0	19	110	96	44	15	23	27
antalya	7	54	553	160	2	0	2	2	2	31	75	12	0	10	4
artvin	8	0	15	8	2	0	0	0	0	6	0	0	0	0	0
aydin	9	8	69	657	0	0	10	0	0	2	35	8	2	35	0
balıkesir	10	17	89	135	0	0	25	0	8	19	10	10	0	21	4
bilecik	11	6	21	6	0	0	0	0	0	50	2	17	0	2	0
bingöl	12	12	12	2	2	0	0	0	0	2	2	0	6	0	4
bitlis	13	0	6	0	0	0	0	0	0	0	2	0	4	0	2
bolu	14	4	121	4	0	25	2	0	0	77	4	10	6	2	0
burdur	15	2	21	25	0	0	0	0	0	6	0	2	0	0	0
bursa	16	40	154	87	4	4	46	2	0	102	25	137	17	31	10
çanakkale	17	6	33	54	0	0	0	0	2	10	2	2	2	10	2
çankiri	18	0	31	0	0	46	0	0	0	2	2	0	2	2	2
çorum	19	12	42	6	4	4	15	0	6	15	6	4	0	0	0
denizli	20	10	75	441	0	2	12	2	0	17	8	2	6	152	19
diyarbakir	21	52	42	25	4	0	4	0	0	0	4	0	10	0	4
edirne	22	2	135	33	0	2	6	8	0	25	2	4	0	2	4
elazığ	23	31	25	17	0	0	27	0	0	4	4	2	50	0	8
erzincan	24	6	35	4	0	0	19	0	0	17	6	0	0	0	2
erzurum	25	25	85	10	69	2	52	0	2	17	27	0	8	4	2
eskiřehir	26	27	85	67	0	2	6	6	0	52	2	156	6	12	4
gaziantep	27	114	214	64	0	0	27	0	0	12	21	4	0	4	114
giresun	28	6	25	2	2	0	0	0	0	0	0	0	0	0	0
gümüşhane	29	2	2	2	0	0	0	0	0	2	0	0	0	0	0
hakkari	30	2	2	0	0	0	6	0	0	4	0	0	0	0	0
hataı	31	102	52	29	2	4	44	0	2	0	73	2	37	4	44
isparta	32	2	35	52	0	0	0	0	0	6	2	12	0	8	0
ıçel	33	0	206	100	10	2	154	6	6	10	158	4	23	15	44
istanbul	34	129	0	503	35	67	366	77	12	836	64	67	89	62	64
izmir	35	48	316	0	6	12	60	2	2	87	48	33	17	460	25
kars	36	2	29	12	0	2	8	2	0	12	4	0	0	0	0
kastamonu	37	2	100	8	2	0	17	0	0	31	4	0	0	0	0
kayseri	38	168	195	119	6	2	0	0	44	21	46	10	6	6	37
kırklareli	39	0	100	0	0	0	2	0	0	2	0	0	0	0	0
kiřehir	40	10	12	0	0	6	50	2	0	6	0	2	2	0	4
kocaeli	41	35	1227	83	8	37	44	10	4	0	37	98	10	4	4
konya	42	185	91	106	10	2	75	2	15	27	0	25	4	12	6
kütahya	43	0	25	12	0	0	8	0	8	27	15	0	4	4	2
malatya	44	29	114	54	0	2	25	0	0	4	6	0	0	0	21
manisa	45	21	123	503	4	0	17	2	0	27	4	15	0	0	6
kmaraş	46	40	104	8	2	0	44	2	0	2	4	2	2	0	0
mardin	47	62	6	2	2	0	8	0	0	0	15	0	29	2	2
muğla	48	8	83	252	0	0	2	0	0	4	2	0	0	12	0
muř	49	10	12	2	2	0	33	0	0	0	0	0	4	0	2
nevřehir	50	60	46	10	0	0	12	0	8	4	46	8	6	2	2
niğde	51	29	44	0	0	0	67	0	6	8	19	2	6	0	4
ordu	52	8	33	17	0	0	2	0	0	6	0	0	0	0	0
rize	53	6	106	52	2	0	8	0	0	4	6	0	2	0	4
sakarya	54	8	96	15	4	2	19	0	2	208	4	6	4	4	8
samsun	55	12	69	23	0	8	12	0	2	12	8	6	4	0	0
siirt	56	4	2	0	0	0	0	0	0	0	0	0	0	0	0
sinop	57	2	135	0	0	2	0	0	0	2	0	0	0	0	2
sivas	58	52	23	2	2	0	83	0	0	4	0	0	15	0	4
tekirdağ	59	12	547	60	0	2	17	162	2	37	6	10	0	2	8
tokat	60	4	37	19	15	2	19	0	0	6	0	0	2	0	0
trabzon	61	10	85	31	23	0	12	0	0	29	0	2	6	2	0
tunceli	62	8	8	2	0	0	15	0	0	0	0	0	40	2	6
řanlı urfa	63	52	29	15	0	0	8	0	0	0	8	0	0	0	12
uřak	64	2	8	44	0	0	0	0	0	0	0	4	0	12	0
van	65	56	31	15	6	0	29	0	0	15	6	0	2	0	2
yozgat	66	8	6	0	0	0	0	0	0	2	4	2	0	0	4
zonguldak	67	12	135	25	0	4	2	0	2	33	12	2	2	4	0
aksaray	68	21	10	15	0	0	25	0	0	6	64	2	0	0	0
bayburt	69	0	10	0	0	0	0	0	2	0	0	0	0	0	0
karaman	70	8	10	8	0	0	8	0	0	12	50	0	0	0	2
kirikkale	71	6	19	0	0	29	67	0	10	4	0	4	0	0	0
batman	72	21	2	4	0	0	2	0	0	2	15	0	17	2	37
řirnak	73	98	0	2	4	0	17	0	0	4	50	0	25	0	25
bartın	74	2	52	4	0	8	0	0	0	15	2	0	0	0	0
ardahan	75	0	2	4	2	0	2	0	0	0	0	0	0	0	0
iğdir	76	25	21	12	89	2	6	0	0	0	6	0	0	0	2
yalova	77	0	17	0	0	0	2	2	0	35	0	2	0	0	2
karabük	78	0	12	2	0	94	2	0	0	19	0	0	0	0	0
kilis	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0
osmaniye	80	17	17	2	0	0	2	0	0	0	2	0	2	0	12
düzce	81	4	17	2	2	19	0	0	0	19	0	0	0	0	0
Total		2282	7062	4518	381	477	1937	295	174	2257	1239	784	527	958	686

Table B.1 (continued)

		mardin	muğla	muş	nevşehir	niğde	ordu	rize	sakarya	samsun	siirt	sinop	sivas	tekirdağ	tokat	trabzon	tunceli	şanlı urfa
		47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
adana	1	0	6	25	19	42	0	15	6	12	27	2	10	8	2	35	10	10
adiyaman	2	0	0	2	2	0	0	2	0	2	0	0	2	2	0	6	0	10
afyon	3	0	8	0	4	0	0	0	2	0	0	0	0	6	0	8	2	0
ağrı	4	2	2	2	0	0	10	2	6	12	6	0	6	8	33	31	0	2
amasya	5	0	0	8	2	2	2	4	0	12	0	0	2	0	4	17	0	0
ankara	6	6	58	4	62	15	15	37	46	37	0	4	35	10	19	98	8	10
antalya	7	0	69	2	2	2	8	2	10	31	0	0	4	10	4	94	4	2
artvin	8	0	0	0	0	0	0	0	0	15	0	0	0	2	0	33	2	0
aydin	9	0	54	2	6	0	2	4	8	4	0	0	4	6	0	2	2	0
balıkesir	10	2	6	0	10	0	8	6	12	12	2	0	2	6	2	17	0	4
bilecik	11	0	0	0	0	0	0	10	0	0	0	0	0	0	0	2	2	0
bingöl	12	8	0	2	0	2	0	0	0	0	0	0	0	0	2	0	4	4
bitlis	13	0	0	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bolu	14	0	2	0	0	0	0	8	129	2	0	2	6	0	2	6	0	0
burdur	15	0	0	2	0	0	0	0	8	0	0	0	0	0	2	0	0	0
bursa	16	2	6	4	10	2	4	6	25	42	2	2	6	17	12	31	4	2
çanakkale	17	0	6	0	0	0	0	4	6	4	0	0	0	6	0	2	0	6
çankiri	18	0	0	0	0	0	0	0	2	6	0	0	0	4	4	2	0	0
çorum	19	0	4	0	2	4	2	12	2	40	0	0	4	6	6	19	0	4
denizli	20	0	25	0	4	0	0	0	10	4	0	0	0	27	0	8	2	6
diyarbakir	21	343	2	2	8	0	0	0	0	2	2	0	2	4	2	6	10	27
edirne	22	6	0	0	0	0	0	0	4	2	0	0	2	148	2	0	2	4
elazığ	23	46	4	10	0	6	0	0	4	2	0	0	6	6	4	4	62	0
erzincan	24	0	0	0	0	2	4	2	0	10	0	0	71	0	46	40	8	0
erzurum	25	2	0	4	0	4	0	6	4	19	0	0	12	0	91	133	0	4
eskişehir	26	8	4	0	2	0	0	6	8	17	0	0	10	4	4	12	0	0
gaziantep	27	21	0	27	0	2	0	4	4	15	2	0	6	12	10	8	8	27
giresun	28	0	0	0	0	0	2	4	2	12	0	0	4	0	2	46	0	0
gümüşhane	29	0	0	0	0	0	0	0	0	8	0	0	0	0	4	48	0	0
hakkari	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
hatay	31	15	10	8	6	8	2	2	10	33	8	0	10	8	27	10	0	50
isparta	32	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
içel	33	25	6	27	62	58	2	17	10	21	44	2	46	10	6	17	4	37
istanbul	34	12	50	15	21	8	23	42	362	171	4	8	67	420	54	139	2	35
izmir	35	6	231	0	8	8	8	17	17	52	2	0	8	71	12	31	2	8
kars	36	0	0	2	0	0	2	2	2	2	0	0	4	0	8	10	0	4
kastamonu	37	0	0	0	0	0	0	0	12	2	0	0	0	0	0	2	0	0
kayseri	38	0	6	10	12	116	6	4	6	15	6	0	87	6	15	21	8	8
kırklareli	39	0	0	0	0	0	0	0	0	2	0	2	0	173	0	0	0	0
kişehir	40	0	0	0	19	4	0	0	2	4	0	2	2	0	0	0	0	0
kocaeli	41	2	4	0	6	2	6	17	366	31	2	2	23	48	6	46	0	2
konya	42	15	12	4	42	6	6	6	4	8	6	0	4	0	4	10	0	8
kütahya	43	0	0	0	12	2	0	0	6	8	2	0	2	2	0	6	0	0
malatya	44	12	0	6	4	0	0	0	0	2	0	0	29	0	6	0	10	0
manisa	45	0	25	0	2	0	0	0	10	6	0	0	0	0	2	10	2	0
kmaraş	46	0	0	2	0	4	0	2	4	0	0	0	0	2	0	2	8	6
mardin	47	0	0	8	0	0	0	0	0	0	4	0	19	0	0	0	0	44
muğla	48	0	0	0	0	0	0	4	2	0	0	0	10	2	0	4	0	2
muş	49	17	0	0	2	0	0	0	0	0	15	0	4	0	2	0	2	8
nevşehir	50	4	0	0	0	193	0	4	0	2	0	0	8	4	0	6	0	0
niğde	51	4	0	0	139	0	0	0	0	4	0	2	4	0	2	0	0	0
ordu	52	2	0	4	0	2	0	17	0	6	0	0	0	0	0	19	0	2
rize	53	0	0	0	2	0	2	0	8	64	0	0	2	0	6	152	0	0
sakarya	54	0	4	0	4	2	2	6	0	15	0	2	2	6	0	21	2	6
samsun	55	0	2	0	0	0	17	35	4	0	0	37	15	0	23	50	0	0
siirt	56	0	0	8	0	0	0	0	2	0	0	0	0	0	0	0	0	0
sinop	57	0	2	0	0	0	2	4	0	15	0	0	0	0	0	44	0	0
sivas	58	0	2	2	4	0	0	0	4	10	0	0	0	0	46	6	4	0
tekirdağ	59	0	0	0	6	0	2	2	15	2	0	0	0	0	2	15	0	2
tokat	60	0	12	2	0	0	0	2	0	17	0	0	33	2	0	15	0	0
trabzon	61	0	2	0	0	2	58	25	2	262	0	8	0	4	25	0	0	2
tunceli	62	2	0	2	2	0	0	0	0	0	0	0	0	0	2	2	0	2
şanlı urfa	63	19	0	0	0	2	0	0	0	2	4	0	2	2	0	2	4	0
uşak	64	0	4	0	0	0	0	0	0	4	0	0	0	0	0	2	0	2
van	65	10	0	25	0	2	2	0	2	15	21	0	4	0	15	17	0	4
yozgat	66	0	2	0	0	2	0	0	0	2	0	0	19	0	8	0	0	0
zonguldak	67	0	2	0	2	0	0	0	52	4	0	0	2	4	0	15	0	0
aksaray	68	0	0	2	52	2	0	0	0	0	0	0	0	0	0	0	0	2
bayburt	69	0	0	0	0	0	0	0	0	4	0	0	0	0	6	40	0	0
karaman	70	4	0	0	0	0	0	4	0	8	0	0	4	2	0	0	0	0
kirikkale	71	0	0	0	4	0	0	2	0	2	0	0	12	0	0	4	0	0
batman	72	50	0	6	4	0	0	2	0	0	0	0	21	0	2	2	0	60
şirnak	73	35	0	0	8	8	0	0	0	0	0	0	40	0	0	0	0	67
bartın	74	0	0	0	0	0	0	0	2	6	0	0	0	2	0	2	0	0
ardahan	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
iğdir	76	0	0	0	0	2	2	0	2	2	0	0	4	0	6	0	0	0
yalova	77	0	4	0	0	0	0	4	4	0	0	0	0	4	0	0	0	0
karabük	78	0	4	0	0	0	0	0	2	2	0	2	0	0	0	2	0	0
kilis	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
osmaniye	80	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
düzce	81	0	2	0	0	0	4	0	15	4	0	0	0	0	0	0	0	0
Total		682	644	281	556	516	203	356	1225	1131	159	77	681	1064	542	1436	178	483

Table B.1 (continued)

		uşak	van	yozgat	zonguldak	aksaray	bayburt	karaman	kirikkale	batman	şirnak	bartın	ardahan	ığdır	yalova	karabük	kilis
		64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
adana	1	2	44	23	2	23	0	15	21	10	25	0	0	6	4	2	0
adiyaman	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
afyon	3	2	8	0	0	0	0	2	0	0	0	0	0	0	0	0	0
ağrı	4	0	12	4	0	0	0	2	0	4	2	0	0	27	0	0	0
amasya	5	0	6	0	0	0	0	0	0	0	0	0	4	6	0	0	0
ankara	6	4	37	21	10	4	0	0	42	4	10	31	2	33	6	17	0
antalya	7	6	2	0	2	2	0	0	0	0	0	2	0	2	0	0	0
artvin	8	0	10	0	0	0	2	0	0	0	0	0	0	0	0	2	0
aydin	9	10	8	0	4	0	0	2	4	0	2	2	0	2	0	0	0
balıkesir	10	0	4	6	6	0	0	0	2	0	0	2	0	4	0	2	0
bilecik	11	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	0
bingöl	12	0	2	0	0	0	0	0	0	0	4	0	0	0	0	0	0
bitlis	13	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bolu	14	0	6	0	6	0	0	0	0	0	0	17	0	0	0	2	0
burdur	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bursa	16	8	23	4	8	2	0	4	4	4	2	19	0	6	27	0	0
çanakkale	17	0	0	0	2	0	0	0	0	0	0	0	0	2	2	0	0
çankiri	18	0	0	0	0	0	0	0	37	2	0	2	0	0	0	4	0
çorum	19	0	4	10	4	0	0	4	6	0	0	2	0	2	0	0	0
denizli	20	0	0	0	12	0	0	2	0	0	0	0	0	2	2	2	0
diyarbakir	21	0	12	4	0	0	2	0	2	12	123	0	0	0	0	0	0
edirne	22	0	4	0	0	0	0	0	0	0	0	2	0	2	0	0	0
elazığ	23	0	23	0	0	0	0	0	4	42	4	0	0	2	0	0	0
erzincan	24	0	2	0	0	2	8	0	10	0	0	0	0	2	0	0	0
erzurum	25	0	40	2	0	0	10	0	15	4	0	6	8	25	0	0	0
eskişehir	26	2	12	4	8	2	0	2	0	0	4	0	0	2	15	0	0
gaziantep	27	2	46	0	2	0	0	6	8	4	29	0	0	0	0	0	0
giresun	28	0	2	0	4	0	0	0	0	0	4	0	0	6	0	0	0
gümüşhane	29	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
hakkari	30	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
hatay	31	0	48	4	0	4	0	0	19	6	4	0	0	2	0	23	2
isparta	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
içel	33	4	56	19	17	25	0	10	8	37	15	0	0	2	0	0	2
istanbul	34	25	121	10	64	10	2	12	27	4	2	46	6	37	10	17	0
izmir	35	83	12	2	4	10	0	2	4	2	4	4	0	4	2	0	0
kars	36	0	23	4	0	0	0	2	2	4	0	4	0	48	0	0	0
kastamonu	37	0	0	0	17	0	0	0	4	0	0	4	0	0	0	46	0
kayseri	38	0	15	0	6	12	0	2	52	12	0	4	0	15	4	0	0
kırklareli	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
kişşehir	40	0	0	0	0	4	0	0	37	4	0	0	0	0	0	0	0
kocaeli	41	2	15	0	52	6	0	0	25	0	4	40	2	0	56	10	0
konya	42	0	8	19	4	91	0	64	2	12	6	0	0	4	2	0	0
kütahya	43	8	2	0	6	6	0	0	2	0	0	2	0	0	2	0	0
malatya	44	0	4	0	0	2	0	0	4	21	12	0	0	0	0	0	0
manisa	45	17	0	0	6	2	0	0	0	0	0	4	0	0	4	0	0
kmaraş	46	0	0	4	0	2	0	0	4	4	2	0	0	0	0	0	0
mardin	47	0	8	2	0	0	0	0	2	37	27	0	0	0	0	0	0
muğla	48	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
muş	49	0	35	2	0	0	0	0	0	12	2	0	0	0	0	0	0
nevşehir	50	0	0	0	0	60	0	0	17	0	2	2	0	2	0	0	0
niğde	51	0	2	2	0	2	0	0	8	0	0	0	0	0	0	0	0
ordu	52	0	4	2	0	0	0	0	0	0	0	0	0	2	0	0	0
rize	53	0	6	0	0	2	0	2	4	2	0	0	0	0	0	0	0
sakarya	54	0	2	0	52	2	0	0	0	0	0	8	0	2	6	4	0
samsun	55	2	6	15	10	2	2	0	0	0	0	2	0	10	0	6	0
siirt	56	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sinop	57	0	0	0	8	0	0	0	0	0	0	0	0	0	2	0	0
sivas	58	0	2	48	2	2	0	2	37	4	0	0	0	2	0	0	2
tekirdağ	59	2	0	0	2	0	0	0	0	2	0	0	0	0	2	2	0
tokat	60	0	6	2	0	0	0	0	0	0	0	4	0	23	0	0	0
trabzon	61	0	33	2	2	0	23	2	10	0	0	0	2	6	0	2	0
tunceli	62	0	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0
şanlı urfa	63	0	2	0	0	0	0	0	0	29	23	0	0	0	0	0	0
uşak	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
van	65	0	0	2	0	2	0	2	0	40	0	0	2	0	0	0	0
yozgat	66	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
zonguldak	67	2	6	0	0	2	0	0	0	0	0	91	0	0	0	0	0
aksaray	68	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
bayburt	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
karaman	70	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
kirikkale	71	0	2	0	4	0	0	0	0	0	0	0	0	0	0	4	0
batman	72	0	25	6	0	0	0	0	0	0	0	0	0	0	0	0	0
şirnak	73	0	17	0	0	6	0	6	2	0	0	0	0	0	0	0	0
bartın	74	0	0	2	143	0	0	0	0	0	0	0	0	0	0	17	0
ardahan	75	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
ığdır	76	0	29	2	0	0	0	0	0	0	2	0	4	0	0	0	0
yalova	77	0	0	0	4	0	0	0	0	0	0	2	0	0	0	0	0
karabük	78	0	0	0	6	0	0	0	0	0	0	4	0	0	2	0	0
kilis	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
osmaniye	80	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
düzce	81	0	0	0	191	0	0	0	0	0	0	4	0	0	0	4	0
Total		181	852	229	674	291	49	145	435	322	316	314	30	294	148	170	6

Table B.1 (continued)

		osmaniye	düzce	adana
		80	81	Total
adana	1	33	6	2306
adiyaman	2	4	0	328
afyon	3	2	0	733
ağrı	4	0	0	743
amasya	5	0	0	165
ankara	6	4	15	2960
antalya	7	0	0	1737
artvin	8	0	0	177
aydin	9	0	0	1296
balıkesir	10	0	0	1175
bilecik	11	0	0	341
bingöl	12	0	0	203
bitlis	13	0	0	209
bolu	14	0	8	569
burdur	15	0	0	187
bursa	16	0	2	2064
çanakkale	17	0	0	406
çankiri	18	0	4	275
çorum	19	0	0	416
denizli	20	4	0	1323
diyarbakir	21	0	0	914
edirne	22	0	0	508
elazığ	23	0	2	630
erzincan	24	2	0	431
erzurum	25	0	2	1245
eskişehir	26	0	4	1304
gaziantep	27	21	0	1449
giresun	28	0	0	149
gümüşhane	29	0	0	89
hakkari	30	0	0	57
hatay	31	17	0	1417
isparta	32	0	0	386
içel	33	12	2	2284
istanbul	34	2	8	7368
izmir	35	4	2	4215
kars	36	0	0	387
kastamonu	37	0	8	354
kayseri	38	2	4	1658
kırklareli	39	0	0	349
kişşehir	40	0	0	240
kocaeli	41	2	25	3662
konya	42	0	6	1360
kütahya	43	0	0	527
malatya	44	2	2	554
manisa	45	0	0	1299
kmaraş	46	17	0	884
mardin	47	12	0	842
muğla	48	2	0	528
muş	49	0	0	303
nevşehir	50	2	4	632
niğde	51	0	0	427
ordu	52	0	0	216
rize	53	0	0	559
sakarya	54	6	21	853
samsun	55	2	4	710
siirt	56	0	0	65
sinop	57	0	4	246
sivas	58	0	0	486
tekirdağ	59	0	2	1178
tokat	60	0	0	412
trabzon	61	0	0	1156
tunceli	62	0	0	204
şanlı urfa	63	15	0	504
uşak	64	0	0	110
van	65	2	0	759
yoğat	66	0	2	93
zonguldak	67	0	73	588
aksaray	68	0	0	244
bayburt	69	0	0	80
karaman	70	0	0	158
kirikkale	71	0	0	299
batman	72	17	0	519
şirnak	73	17	0	1032
bartin	74	0	4	318
ardahan	75	0	0	39
iğdir	76	0	0	352
yalova	77	0	0	146
karabük	78	0	0	197
kilis	79	0	0	8
osmaniye	80	0	0	194
düzce	81	0	0	323
Total		203	214	66113

APPENDIX C

SOCIO-ECONOMIC AND DEMOGRAPHIC DATA BY PROVINCES

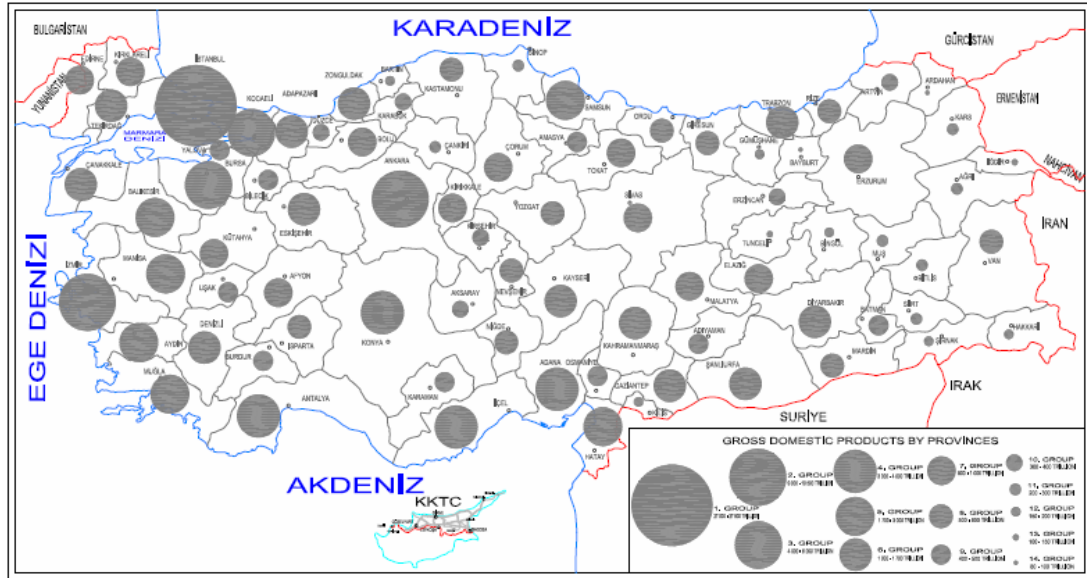


Figure C.1 Gross Domestic Products by Provinces (in current prices 2000)

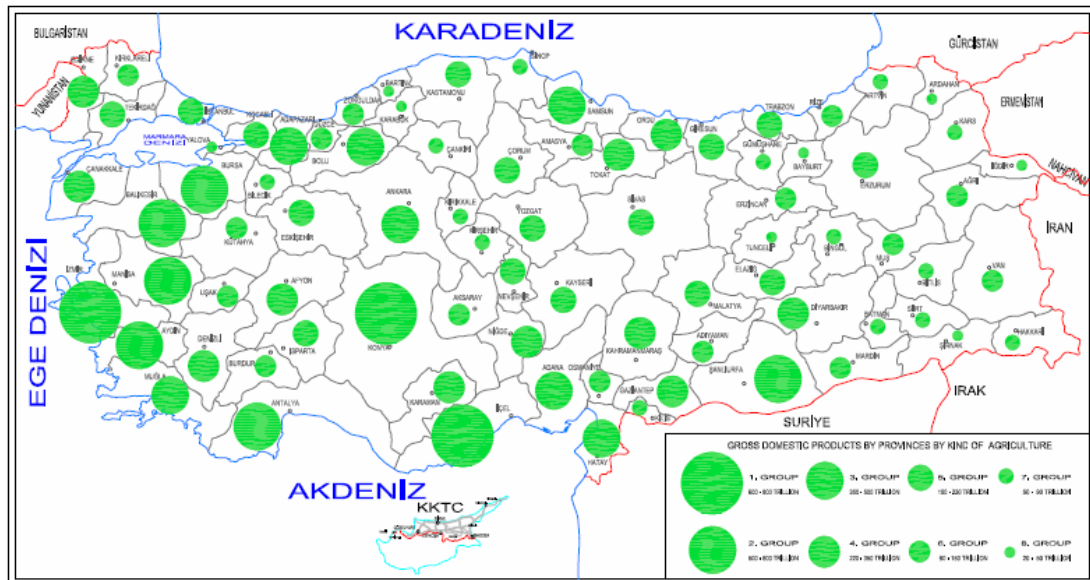


Figure C.2 Gross Domestic Products by Provinces by Kind of Agriculture
(in current prices 2000)

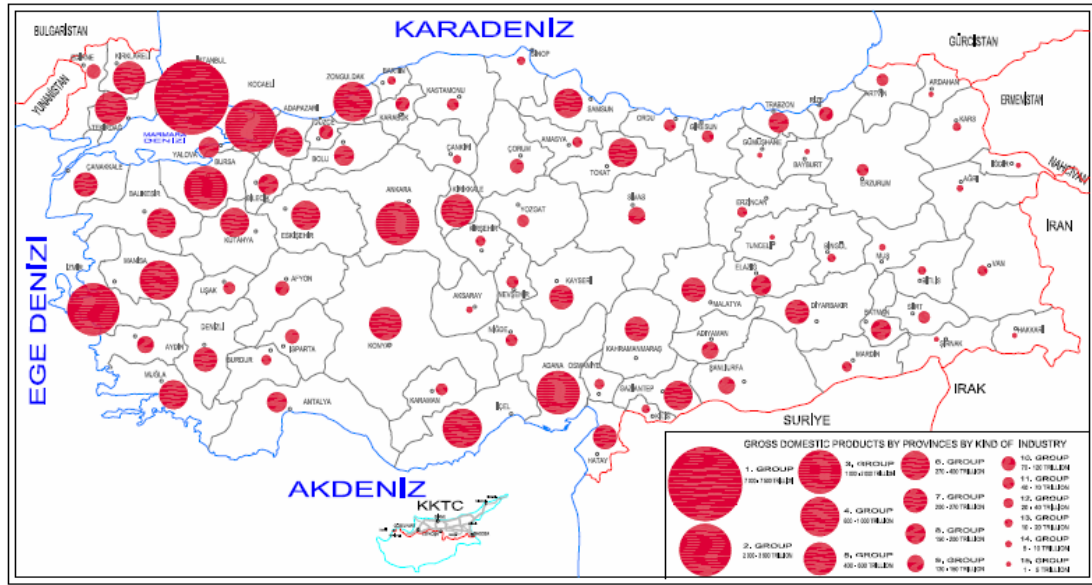


Figure C.3 Gross Domestic Products by Provinces by Kind of Industry
(in current prices 2000)

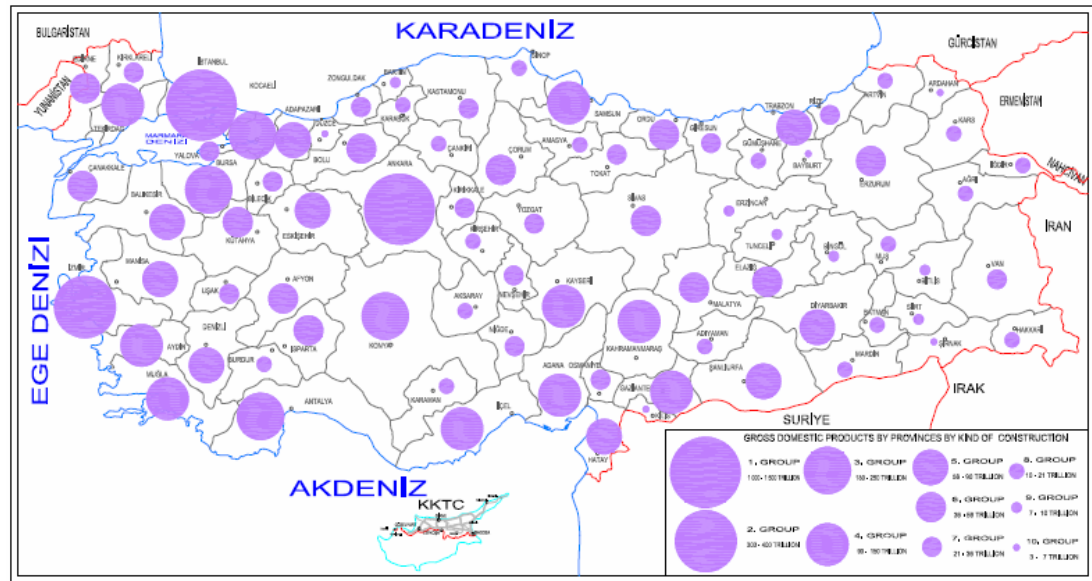


Figure C.4 Gross Domestic Products by Provinces by Kind of Construction
(in current prices 2000)

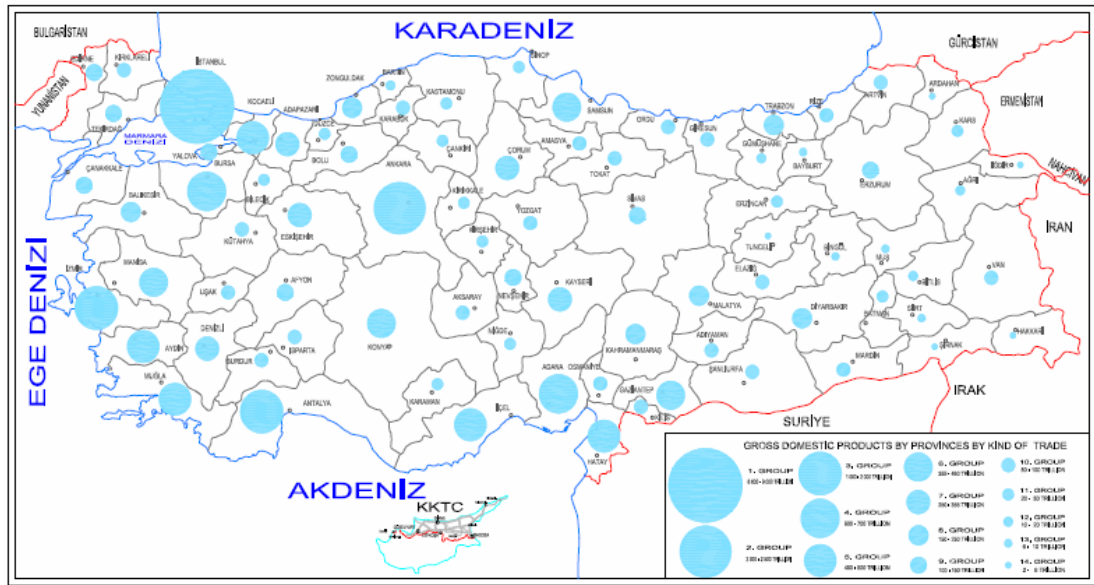


Figure C.5 Gross Domestic Products by Kind of Trade (in current prices 2000)

Table C.1 Population by Provinces

Population		1980	1985	1990	2000	2004	1980	1985	1990	2000	2004
Türkiye		44 736 957	50 664 458	56 473 035	67 803 927	71 789 000					
Adana		1 485 743	1 725 940	1 934 907	1 849 478	1 953 599	Kocaeli	742 245	936 163	1 206 085	1 316 201
Adıyaman		367 595	430 728	513 131	623 811	664 423	Konya	1 562 139	1 750 303	2 192 166	2 354 794
Afyon		597 516	666 978	739 223	812 416	830 746	Kütahya	497 089	543 384	578 020	656 903
Ağrı		368 009	421 131	437 093	528 744	561 237	Malatya	606 996	702 055	853 658	906 742
Amasya		341 287	358 289	357 191	365 231	360 789	Manisa	941 941	1 050 130	1 260 169	1 284 775
Ankara		2 854 689	3 306 327	3 236 626	4 007 860	4 290 157	K.Maraş	738 032	840 472	892 952	1 033 211
Antalya		748 706	891 149	1 132 211	1 719 751	1 961 155	Mardin	564 967	652 069	557 727	705 098
Artvin		228 997	226 338	212 833	191 934	178 330	Muğla	438 145	486 290	562 809	715 328
Aydın		652 488	743 419	824 816	950 757	990 963	Muş	302 406	339 492	376 543	453 654
Balıkesir		853 177	910 282	973 314	1 076 347	1 102 872	Nevşehir	256 933	278 129	289 509	309 914
Bilecik		147 001	160 909	175 526	194 326	199 162	Niğde	512 071	560 386	305 861	348 081
Bingöl		228 702	241 548	250 966	253 739	250 897	Ordu	713 535	763 857	830 105	887 765
Bitlis		257 908	300 843	330 115	388 678	408 433	Rize	361 258	374 206	348 776	365 938
Bolu		471 751	504 778	536 869	270 654	268 916	Sakarya	548 747	610 500	683 061	756 168
Burdur		235 009	248 002	254 899	256 803	252 605	Samsun	1 008 113	1 108 710	1 158 400	1 207 643
Bursa		1 148 492	1 324 015	1 603 137	2 125 140	2 331 049	Siirt	445 483	524 741	243 435	263 676
Çanakkale		391 568	417 121	432 263	464 975	471 096	Sinop	276 242	280 140	265 153	225 574
Çankırı		258 436	263 964	279 129	270 355	274 848	Sivas	750 144	772 209	767 481	755 091
Çorum		571 831	599 204	609 863	597 065	579 793	Tekirdağ	360 742	402 721	468 842	623 591
Denizli		603 338	667 478	750 882	850 029	879 669	Tokat	624 508	679 071	719 251	828 027
Diyarbakır		778 150	934 505	1 094 996	1 362 708	1 460 544	Trabzon	731 045	786 194	795 849	975 137
Edirne		363 286	389 638	404 599	402 606	393 691	Tunceli	157 974	151 906	133 143	93 584
Elazığ		440 808	483 715	498 225	569 616	591 799	Ş.Urfa	602 736	795 034	1 001 455	1 443 422
Erzincan		282 022	299 985	299 251	316 841	318 808	Uşak	247 224	271 261	290 283	322 313
Erzurum		801 809	856 175	848 201	937 389	960 627	Van	468 646	547 216	637 433	872 706
Eskişehir		543 802	597 397	641 057	706 009	722 355	Yozgat	504 433	545 301	579 150	682 919
Gaziantep		808 697	966 490	1 140 594	1 285 249	1 388 649	Zonguldak	954 512	1 044 945	1 073 560	615 599
Giresun		480 083	502 151	499 087	523 819	524 784	Aksaray			326 399	396 084
Gümüşhane		275 191	283 753	169 375	186 953	191 738	Bayburt			107 330	90 752
Hakkari		155 463	182 645	172 479	236 581	261 948	Karaman			217 536	243 210
Hatay		856 271	1 002 252	1 109 754	1 253 726	1 296 381	Kırıkkale			349 396	383 508
İsparta		350 116	382 844	434 771	513 681	540 499	Batman			344 669	500 484
Mersin		843 931	1 034 085	1 266 995	1 651 400	1 798 789	Siirt			262 006	388 955
İstanbul		4 741 890	5 842 985	7 309 190	10 018 735	11 143 807	Bartın			184 178	170 373
İzmir		1 976 763	2 317 829	2 694 770	3 370 866	3 621 064	Ardahan			133 756	124 113
Kars		700 238	722 431	662 155	325 016	304 128	Iğdır			168 634	177 498
Kastamonu		450 946	450 353	423 611	375 476	345 653	Yalova			168 593	180 946
Kayseri		778 383	864 060	943 484	1 060 432	1 093 963	Karabük			225 102	211 696
Kırklareli		283 408	297 098	309 512	328 461	330 835	Kilis			114 724	105 194
Kırşehir		240 497	260 156	256 862	253 239	246 604	Osmaniye			458 782	484 704
							Düzce			314 266	327 067

Source: T.C. Başbakanlık Devlet İstatistik Enstitüsü, İl Göstergeleri 1980-2003

Table C.2 Population Growth Rate (%) by Provinces

Population growth rate(%)		1980	1985	1990	2000	2004	1980	1985	1990	2000	2004
Türkiye		20.65	24.88	21.71	18.28	15.23					
Adana	36.08	29.97	22.86	17.71	14.47	14.47	Kocaeli	44.54	43.59	46.42	23.22
Adıyaman	11.59	31.70	35.01	19.53	16.72	16.72	Konya	18.73	24.88	22.97	19
Afyon	6.24	22.00	20.57	9.44	5.56	5.56	Kütahya	11.03	17.81	12.36	9.32
Ağrı	21.68	26.97	7.44	19.03	15.79	15.79	Malatya	10.98	18.50	10.80	15.98
Amasya	11.13	9.72	-0.61	2.23	-4.16	-4.16	Manisa	15.34	21.75	18.94	8.76
Ankara	19.82	29.38	21.28	21.37	18.06	18.06	K.Maraş	28.04	26.00	12.11	11.56
Antalya	22.41	34.83	47.88	41.79	34.68	34.68	Mardin	16.71	28.68	25.87	19.91
Artvin	0.85	-2.34	-12.30	-10.34	-22	-22	Muğla	17.82	20.85	29.23	20.48
Aydın	13.51	26.09	20.78	14.21	10.83	10.83	Muş	24.75	23.14	20.72	15.39
Balıkesir	15.58	12.96	13.39	10.06	6.12	6.12	Neveşehir	6.03	15.85	8.02	2.4
Bilecik	13.92	18.08	17.39	10.17	6.19	6.19	Niğde	20.09	18.03	12.04	10.93
Bingöl	16.30	10.93	7.65	1.10	-3.88	-3.88	Ordu	14.30	13.63	16.63	6.71
Bitlis	33.34	30.80	18.57	16.33	13.06	13.06	Rize	14.33	7.04	-14.08	4.80
Bolu	19.14	13.53	12.33	2.90	-2.51	-2.51	Sakarya	20.35	21.33	22.46	10.17
Burdur	10.58	10.76	5.49	0.74	-5.37	-5.37	Samsun	21.28	19.02	8.77	4.29
Bursa	35.51	28.44	38.26	28.62	24.57	24.57	Silivri	31.01	32.75	12.50	7.98
Çanakkale	11.60	12.64	7.13	7.29	2.99	2.99	Sinop	6.35	2.80	-11.00	3.81
Çankırı	-5.37	4.23	11.17	8.09	3.94	3.94	Sivas	2.26	5.80	-1.23	-1.63
Çorum	8.67	9.35	3.53	-2.12	-9.07	-9.07	Tekirdağ	23.98	22.02	30.40	28.52
Denizli	14.58	20.21	23.55	12.40	8.87	8.87	Tokat	8.29	16.75	11.50	14.08
Diyarbakır	35.61	36.62	31.70	21.87	18.4	18.4	Trabzon	3.32	14.55	2.44	20.31
Edirne	12.82	14.01	7.54	-0.49	-7.06	-7.06	Tunceli	-8.21	-7.83	-26.37	-35.65
Elazığ	10.66	18.58	5.91	13.39	9.95	9.95	Ş.Urfa	1.82	55.38	46.16	36.55
Erzincan	-1.17	12.35	-0.49	5.71	1.05	1.05	Uşak	14.72	18.56	13.55	10.46
Erzurum	14.25	13.12	-1.87	10.00	6.16	6.16	Van	38.64	31.00	30.52	31.96
Eskişehir	18.77	18.80	14.11	9.65	5.72	5.72	Yozgat	1.62	15.58	12.04	16.48
Gaziantep	24.37	35.65	33.13	24.05	20.56	20.56	Zonguldak	26.48	18.10	5.40	-6.01
Giresun	6.99	8.99	-1.22	4.84	-0.17	-0.17	Aksaray			19.35	14.84
Gümüşhane	-13.00	6.13	21.28	9.87	6.38	6.38	Bayburt			-9.75	-21.03
Hakkari	41.97	32.23	43.58	31.59	27.03	27.03	Karaman			11.15	-18.41
Hatay	28.08	31.48	20.38	12.19	8.64	8.64	Kırıkkale			9.31	-25.95
İsparta	16.32	17.87	25.44	16.67	13.42	13.42	Batman			28.14	24.3
Mersin	33.21	40.64	40.63	26.49	22.72	22.72	Şırnak			29.86	-32.29
İstanbul	38.86	41.76	44.78	33.09	28.23	28.23	Bartın			-11.11	-23.31
İzmir	33.25	31.83	30.14	22.38	19.01	19.01	Ardahan			-20.22	-20.28
Kars	-2.03	6.24	-17.42	-9.05	8.69	8.69	Iğdır			16.76	13.51
Kastamonu	5.71	-0.26	-12.24	-12.06	-19.9	-19.9	Yalova			22.13	18.77
Kayseri	27.97	20.88	17.59	11.68	-24.76	-24.76	Karabük			-8.13	7.77
Kırklareli	10.88	9.43	8.19	5.94	5.05	5.05	Kilis			-12.65	8
Kırşehir	6.46	15.71	-2.55	-1.42	1.34	1.34	Osmaniye			17.76	14.52
							Düzce			13.82	10.42

Source: T.C. Başbakanlık Devlet İstatistik Enstitüsü, İl Göstergeleri 1980-2003

Table C.3 Population Density by Provinces

Population density	(person/km ²)					(person/km ²)				
	1980	1985	1990	2000	2004*	1980	1985	1990	2000	2004*
Türkiye	58	65	73	88	91					
Adana	86	100	112	132	139	Kocaeli	165	205	258	333
Adıyaman	48	57	67	82	87	Konya	33	37	46	54
Afyon	42	47	52	55	56	Kütahya	42	46	49	55
Ağrı	32	37	38	46	49	Malatya	49	54	57	71
Anayasa	62	65	65	64	63	Manisa	68	76	84	95
Ankara	93	108	126	158	169	K.Mara:	52	59	62	69
Antalya	36	43	55	83	94	Mardin	44	51	63	80
Artvin	31	30	29	26	24	Muğla	33	36	42	55
Aydın	81	93	103	120	125	Muş	37	41	46	56
Balıkesir	60	64	68	74	76	Nevşehir	47	51	53	57
Bilecik	34	37	41	45	46	Niğde	36	39	42	47
Bingöl	28	30	31	31	30	Ordu	119	127	138	149
Bitlis	38	45	49	55	58	Rize	92	95	89	93
Bolu	43	46	49	33	32	Sakarya	114	127	142	155
Burdur	34	36	37	36	35	Samsun	105	116	121	129
Bursa	104	120	145	195	214	Siirt	40	48	45	48
Çanakkale	40	43	44	47	47	Sinop	47	48	45	39
Çankırı	31	31	33	36	37	Sivas	26	27	26	26
Çorum	45	47	48	47	45	Tekirda	58	65	75	98
Denizli	51	56	63	72	75	Tokat	63	68	72	82
Diyarbakır	51	61	71	90	96	Trabzon	156	168	170	209
Edirne	58	62	64	66	65	Tunceli	20	20	17	12
Elazığ	48	53	54	61	64	Ş.Urfa	32	43	54	75
Erzincan	24	25	25	27	27	Uşak	46	51	54	60
Erzurum	32	34	34	37	38	Van	25	29	33	38
Eskişehir	40	44	47	51	52	Yozgat	36	39	41	49
Gaziantep	106	126	149	188	203	Zonguld	111	121	124	186
Giresun	69	72	72	77	77	Aksaray			43	50
Gümüşhane	27	28	26	29	30	Bayburt			29	26
Hakkari	16	19	24	33	36	Karaman			24	27
Hatay	158	185	205	215	222	Kırıkkale			80	84
İsparta	39	43	49	58	61	Batman			73	98
Mersin	53	65	80	106	116	Şırnak			49	54
İstanbul	830	1,023	1,280	1,885	2,097	Bartın			37	82
İzmir	165	194	225	281	301	Ardahan			27	25
Kars	38	39	36	32	30	Iğdır			47	49
Kastamonu	34	34	32	29	26	Yalova			198	213
Kayseri	46	51	56	62	64	Karabük			55	52
Kırklareli	43	45	47	52	53	Kilis			80	74
Kırşehir	37	40	39	39	38	Osmaniye			144	152
						Düzce			121	126

Source: T.C. Başbakanlık Devlet İstatistik Enstitüsü, İl Göstergeleri 1980-2003

Table C.4 Number of Households by Provinces

Number of Households

	1980	1985	1990	2000	2004*		1980	1985	1990	2000	2004*
Türkiye	8 409 202	9 705 835	11 362 784	15 067 539	15 954 000						
Adana	260 657	309 864	365 767	396 034	417 929	Kocaeli	123 072	157 589	205 750	289 924	305 953
Adıyaman	57 258	65 163	78 102	99 650	105 160	Konya	295 300	331 904	325 307	441 080	465 466
Afyon	107 661	118 259	132 240	163 136	172 155	Kütahya	99 617	112 038	124 305	151 360	159 728
Ağrı	50 551	54 551	56 399	69 207	73 034	Malatya	97 431	107 389	120 628	158 085	166 825
Amasya	59 251	64 673	68 297	80 803	85 271	Manisa	210 255	240 304	274 209	327 317	345 413
Ankara	588 596	715 655	765 160	1 049 178	1 107 184	K.Maraş	116 409	132 567	145 195	179 961	189 911
Anıyaya	152 176	186 824	257 907	432 098	455 988	Mardin	81 998	89 570	75 267	91 334	96 384
Artvin	36 640	37 849	39 414	42 183	44 515	Muğla	102 370	118 607	144 681	206 146	217 544
Aydın	157 226	180 442	208 287	258 358	272 842	Miüs	37 473	41 001	45 041	55 391	58 454
Balıkesir	199 807	221 480	251 502	310 186	327 336	Neveşehir	45 881	52 280	57 786	69 177	73 002
Bilecik	33 639	37 161	42 194	52 098	54 978	Niğde	90 632	99 891	59 161	73 280	77 332
Bingöl	31 764	31 575	34 145	39 339	41 514	Ordu	110 626	121 633	138 582	169 421	178 788
Bitlis	31 919	36 823	41 110	49 894	52 653	Rize	51 830	57 218	57 840	70 918	74 839
Bolu	83 941	96 148	108 240	63 984	67 522	Sakarya	100 136	113 687	135 797	167 665	176 934
Burdur	50 978	57 012	62 629	70 550	74 451	Samsun	166 630	187 599	207 971	251 380	265 278
Bursa	253 530	296 864	371 958	543 514	573 563	Sirt	59 319	67 017	31 330	35 251	37 200
Canakkale	96 663	107 229	117 463	141 761	149 598	Sinop	44 991	46 768	48 921	51 267	54 101
Çankırı	42 022	43 630	48 376	52 496	55 398	Sivas	119 450	124 349	130 969	143 281	151 203
Çorum	96 921	104 209	112 729	127 851	134 920	Tekirdağ	76 106	88 510	110 837	164 536	173 633
Denizli	130 593	148 328	173 014	220 787	232 993	Tokat	102 044	111 141	120 276	143 010	150 916
Dişarbakır	115 281	135 044	158 236	201 584	212 729	Trabzon	109 274	123 810	135 810	186 451	196 759
Edirne	73 989	84 155	94 312	107 937	113 905	Tunceli	22 002	21 952	20 707	18 906	19 951
Elazığ	72 382	79 558	86 950	109 331	115 376	Ş.Urfa	91 462	117 089	147 490	208 286	219 802
Erzincan	47 399	50 333	54 409	62 865	66 341	Uşak	48 380	56 631	64 651	79 583	83 983
Erzurum	124 311	132 126	135 712	163 593	172 638	Van	60 237	67 308	79 283	116 537	122 980
Eskişehir	121 384	139 253	158 286	192 899	203 563	Yozgat	80 196	86 693	94 478	121 085	127 779
Gaziantep	136 835	164 369	198 710	245 746	259 332	Zonguldak	165 714	184 946	200 665	135 296	142 777
Giresun	76 936	84 112	90 414	108 676	114 685	Aksaray			55 042	75 158	79 314
Gümüşhane	41 382	43 857	28 324	34 366	36 266	Bayburt			16 640	17 354	18 314
Hakkari	18 355	20 732	19 780	29 909	31 563	Karaman			44 215	56 039	59 137
Halay	146 121	166 764	194 353	251 752	265 671	Kırıkkale			64 583	78 749	83 103
İsparta	70 023	79 264	93 701	115 694	122 090	Batman			44 820	60 097	63 419
Mersin	166 785	205 176	261 236	366 164	386 408	Sırnak			42 812	45 179	45 763
İstanbul	1 110 513	1 374 820	1 765 505	2 602 269	2 746 141	Bartın			39 291	41 463	41 463
İzmir	485 691	579 457	698 127	941 583	993 640	Ardahan			23 449	24 746	24 746
Kars	96 966	99 763	97 807	54 169	57 164	İğdir			27 369	28 882	28 882
Kastamonu	80 526	80 134	83 883	86 515	91 298	Yalova			44 442	46 899	46 899
Kayseri	143 879	161 809	183 915	228 541	241 177	Karabük			56 162	59 267	59 267
Kırklareli	59 539	66 764	74 761	89 743	94 705	Kilis			22 733	23 989	23 989
Kırşehir	38 790	43 724	46 702	53 766	56 739	Osmaniye			89 482	94 430	94 430
						Düzce			68 883	72 691	72 691

*Forecasted

Source: T.C. Başbakanlık Devlet İstatistik Enstitüsü, İl Göstergeleri 1980-2003

Table C.5 Average Household Sizes by Provinces

Average household size		1980	1985	1990	2000	2004*	1980	1985	1990	2000	2004*
Türkiye		5.3	5.2	5.0	4.5	4.5					
Adana		5.7	5.6	5.3	4.7	4.7	Kocaeli	4.9	4.7	4.6	4.3
Adıyaman		6.4	6.6	6.6	6.3	6.3	Konya	5.3	5.3	5.2	5.1
Afyon		5.6	5.6	5.6	5.0	4.8	Kütahya	5.0	4.9	4.7	4.3
Ağrı		7.3	7.7	7.8	7.6	7.7	Malatya	6.2	6.2	5.8	5.4
Amasya		5.8	5.5	5.2	4.5	4.2	Manisa	4.5	4.4	4.2	3.9
Ankara		4.9	4.6	4.2	3.8	3.9	K.Maraş	6.3	6.3	6.2	5.6
Antalya		4.9	4.8	4.4	4.0	4.3	Mardin	6.9	7.3	7.4	7.7
Artvin		6.3	6.0	5.4	4.6	4.0	Muğla	4.3	4.1	3.9	3.6
Aydın		4.2	4.1	4.0	3.7	3.6	Muş	8.1	8.3	8.4	8.2
Balıkesir		4.3	4.1	3.9	3.5	3.4	Nevşehir	5.6	5.3	5.0	4.5
Bilecik		4.4	4.3	4.2	3.7	3.6	Niğde	5.7	5.6	5.2	4.7
Bingöl		7.2	7.7	7.4	6.5	6.0	Ordu	6.5	6.3	6.0	5.2
Bitlis		8.1	8.2	8.0	7.8	7.8	Rize	7.0	6.5	6.0	5.2
Bolu		5.6	5.3	5.0	4.2	4.0	Sakarya	5.5	5.4	5.0	4.5
Burdur		4.6	4.4	4.1	3.6	3.4	Samsun	6.1	5.9	5.6	4.8
Bursa		4.5	4.5	4.3	3.9	4.1	Sart	7.5	7.8	7.5	7.2
Çanakkale		4.1	3.9	3.7	3.3	3.1	Sinop	6.1	6.0	5.4	4.4
Çankırı		6.2	6.1	5.8	5.2	5.0	Sivas	6.3	6.2	5.9	5.3
Çorum		5.9	5.8	5.4	4.7	4.3	Tekirdağ	4.7	4.6	4.2	3.8
Denizli		4.6	4.5	4.3	3.9	3.8	Tokat	6.1	6.1	6.0	5.8
Diğarbakır		6.8	6.9	6.9	6.8	6.9	Trabzon	6.7	6.4	5.9	5.2
Edirne		4.9	4.6	4.3	3.7	3.5	Tunceli	7.2	6.9	6.4	5.0
Elazığ		6.1	6.1	5.7	5.2	5.1	Ş.Urfa	6.6	6.8	6.8	6.9
Erzincan		6.0	6.0	5.5	5.0	4.8	Uşak	5.1	4.8	4.5	4.1
Erzurum		6.5	6.5	6.3	5.7	5.6	Van	7.8	8.1	8.0	7.5
Eskişehir		4.5	4.3	4.1	3.7	3.5	Yozgat	6.3	6.3	6.1	5.6
Gaziantep		5.9	5.9	5.7	5.2	5.4	Zonguldak	5.8	5.7	5.4	4.6
Giresun		6.2	6.0	5.5	4.8	4.6	Aksaray			5.9	5.3
Gümüşhane		6.7	6.5	6.0	5.4	5.3	Bayburt			6.5	5.6
Hakkari		8.5	8.8	8.7	7.9	8.3	Karaman			4.9	4.3
Hatay		5.9	6.0	5.7	5.0	4.9	Kırıkkale			5.4	4.9
İsparta		5.0	4.8	4.6	4.4	4.4	Batman			7.7	7.6
Mersin		5.1	5.0	4.9	4.5	4.7	Şırnak			8.1	8.3
İstanbul		4.3	4.3	4.1	3.9	4.1	Bartın				4.7
İzmir		4.1	4.0	3.9	3.6	3.6	Ardeşan				5.7
Kars		7.2	7.2	6.8	6.0	5.3	Iğdır				6.2
Kastamonu		5.6	5.6	5.1	4.3	3.8	Yalova				3.8
Kayseri		5.4	5.3	5.1	4.6	4.5	Karabük				4.0
Kırklareli		4.8	4.5	4.1	3.7	3.5	Kilis				5.0
Kırşehir		6.2	6.0	5.5	4.7	4.3	Osmaniye				5.1
							Düzce				4.6

* Forecasted

Source: T. C. Başbakanlık Devlet İstatistik Enstitüsü, İl Göstergeleri 1980-2003

Table C.6 Gross Domestic Products (at 1987 prices Million TL) by Provinces

Gross domestic product [At 1987 prices Million TL]		Million TL					Million TL					
		1990	1995	2000	2001	2004*	1990		1995	2000	2001	2004*
Türkiye	83,578,464	97,887,800	118,789,113	109,885,336	136,692,579		Kocaeli	3,643,984	4,525,655	5,223,778	5,035,541	5,843,945
Adana	3,016,540	3,248,253	3,565,131	3,190,488	3,785,530		Konya	1,957,269	2,051,111	2,639,553	2,272,249	3,091,117
Adıyaman	526,741	464,230	491,854	473,001	643,461		Kütahya	671,259	884,147	963,686	831,895	1,131,691
Afyon	620,310	671,990	829,715	767,987	1,044,752		Malatya	707,042	858,442	942,046	907,019	1,233,888
Agri	126,976	126,980	183,939	175,286	238,456		Manisa	2,247,267	2,491,527	3,273,149	3,007,258	4,091,007
Amasya	326,300	327,267	419,322	359,846	489,526		K.Maraş	910,575	937,448	1,090,924	1,099,239	1,495,381
Ankara	6,579,837	7,750,885	9,545,749	8,471,367	9,722,703		Mardin	410,088	423,312	499,901	565,802	769,705
Antalya	1,902,320	2,545,070	2,938,699	2,956,989	3,487,972		Muğla	1,114,967	1,388,447	1,896,362	1,658,266	1,963,150
Artvin	325,210	402,909	299,303	287,630	391,285		Muş	146,969	134,428	160,654	164,078	223,208
Aydın	1,311,294	1,631,623	1,807,663	1,566,776	2,130,048		Nevşehir	428,840	500,933	531,770	494,228	672,337
Balıkesir	1,452,161	1,607,186	1,789,308	1,594,430	2,169,027		Niğde	356,832	363,403	466,999	435,323	592,204
Bilecik	377,583	548,177	573,390	535,381	728,321		Ordu	566,968	656,579	765,811	813,733	1,106,984
Bingöl	85,400	88,616	115,375	121,210	164,892		Rize	411,768	423,288	469,198	460,714	626,746
Bitlis	138,431	125,099	139,942	144,220	196,193		Sakarya	856,483	1,100,508	1,343,891	1,173,629	1,596,579
Bolu	767,034	921,886	859,666	698,021	949,573		Samsun	1,426,481	1,414,780	1,726,504	1,595,304	1,817,597
Burdur	297,976	339,023	415,958	376,173	511,737		Sirir	356,718	165,794	202,072	216,510	294,536
Bursa	3,322,877	3,944,546	5,015,684	4,601,273	5,390,859		Sinop	212,606	215,117	234,318	224,411	305,284
Çanakkale	798,999	954,126	1,017,588	843,815	1,147,907		Sivas	556,429	638,626	737,199	726,512	988,331
Çankırı	206,195	208,997	242,531	219,717	298,898		Tekirdağ	893,035	1,088,822	1,574,939	1,455,139	1,979,539
Çorum	633,346	702,980	871,556	747,881	1,017,400		Tokat	564,579	674,748	809,183	762,138	1,036,796
Denizli	1,159,241	1,398,000	1,817,721	1,780,652	2,021,241		Trabzon	781,090	812,553	927,767	970,276	980,752
Dişarbakır	1,118,803	1,145,069	1,196,370	1,223,428	1,664,324		Tunceli	72,221	65,923	60,015	61,276	83,359
Edirne	498,877	555,011	756,830	635,871	865,025		Ş.Urfa	596,677	867,498	1,250,401	1,235,716	1,681,041
Elazığ	653,023	597,944	630,710	584,740	795,467		Uşak	308,507	359,970	399,655	357,179	485,898
Erzincan	226,406	223,186	224,245	228,294	310,566		Van	316,855	332,823	442,405	450,100	612,306
Erzurum	514,740	496,144	577,505	583,404	793,650		Yozgat	366,837	427,036	506,025	440,629	599,422
Eskişehir	991,376	1,123,171	1,424,621	1,512,380	1,585,297		Zonguldak	1,220,487	1,161,281	989,486	947,027	1,288,315
Gaziantep	1,504,936	1,585,856	1,741,987	1,685,811	1,817,322		Aksaray	188,110	252,073	326,064	272,136	370,208
Giresun	364,661	414,844	475,173	522,584	710,911		Bayburt	35,398	58,263	58,071	78,999	78,999
Gümüşhane	97,278	99,004	128,170	123,162	167,546		Karaman	244,319	397,655	373,994	508,773	508,773
Hakkari	53,442	58,511	74,703	79,544	108,210		Kırıkkale	485,990	587,657	619,138	576,797	784,662
Hatay	1,429,209	1,645,576	1,888,771	1,731,119	2,354,976		Batman		366,415	355,795	484,016	484,016
Isparta	437,354	451,797	570,308	557,265	758,091		Şirnak	106,522	131,006	131,006	178,218	178,218
Mersin	2,348,656	2,696,119	3,079,797	2,948,871	3,364,171		Bartın		157,580	119,085	119,085	158,964
İstanbul	17,333,961	21,288,005	26,278,326	23,607,618	28,842,997		Adana		54,537	63,592	86,509	86,509
İzmir	6,338,207	7,866,279	9,016,134	8,381,585	9,956,363		Iğdır		60,423	62,555	88,695	120,658
Kars	280,524	158,074	186,356	190,705	259,430		Yalova		91,271	91,271	88,695	120,658
Kastamonu	395,629	425,437	508,543	459,145	624,610		Karabük		780,561	615,213	615,213	836,922
Kayseri	926,315	1,083,559	1,373,965	1,332,039	1,464,157		Kilis		199,925	199,925	189,381	257,629
Kırklareli	790,880	811,986	921,207	868,539	1,181,542		Osmaniye		382,143	374,707	509,744	509,744
Kırşehir	242,766	232,428	276,285	263,915	359,024		Düzce		345,581	313,306	426,214	426,214
												Forecasted

* Forecasted

Source: T.C. Başbakanlık Devlet İstatistik Enstitüsü, İl Göstergeleri 1980-2003

Table C.7 Gross Domestic Products by Provinces by Sectors (at Current Prices, 2000)

PROVINCE	AGRICULTURE			INDUSTRY			CONSTRUCTION			TRADE			OTHERS			TOTAL		
	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)
ADANA	482 207 690	44.40	12.7	1 012 874 888	66.50	26.6	140 694 713	48.60	3.7	675 361 343	70.90	17.7	1 484 043 935	39.26	39.26	3 805 182 669	59	100
ADYAMAN	121 829 634	24.10	25.0	137 087 982	55.10	28.2	15 135 797	28.60	3.1	160 082 770	67.60	10.3	160 082 770	67.60	32.89	486 660 930	45	100
AFYON	273 298 192	26.10	31.1	99 780 768	38.90	11.4	48 433 766	42.30	5.3	116 262 968	67.70	13.2	340 709 051	38.78	38.78	878 484 788	45	100
AGRI	123 740 533	57.70	45.5	5 804 405	49.90	2.1	15 457 085	56.00	5.3	19 116 560	74.50	7.0	107 669 456	39.53	39.53	272 088 039	55	100
AMASYA	136 928 835	21.20	29.1	33 882 860	14.40	7.2	20 010 726	18.80	4.3	59 359 481	69.00	12.6	219 822 415	46.77	46.77	470 003 417	41	100
ANKARA	489 295 737	45.80	4.7	1 273 444 038	50.40	12.3	1 226 251 223	108.10	11.8	2 212 372 882	68.90	21.3	5 170 467 933	49.85	49.85	10 371 837 263	69	100
ANTALYA	516 041 362	35.10	16.6	184 698 024	44.80	5.9	210 781 353	17.80	6.8	1 072 432 300	74.80	34.4	1 133 141 749	36.35	36.35	3 117 095 408	55	100
ARTVIN	76 262 653	36.30	22.4	53 840 936	43.70	15.8	13 446 249	39.00	3.9	55 607 605	70.70	16.3	141 860 572	41.57	41.57	340 837 874	51	100
AYDIN	530 195 735	79.10	30.3	130 933 617	54.20	7.5	99 025 126	19.30	5.7	481 125 679	71.40	27.5	505 702 540	28.95	28.95	1 747 086 697	63	100
BALIKESIR	537 854 121	88.00	28.3	321 563 676	58.10	16.9	88 912 449	26.70	4.7	209 228 217	68.70	11.0	742 538 693	39.08	39.08	1 899 897 156	64	100
BILECEK	66 740 910	47.20	20.2	165 962 989	38.10	38.7	24 420 300	21.10	5.7	20 136 003	67.30	4.7	131 110 270	30.61	30.61	428 370 472	46	100
BINGOL	61 870 696	70.90	36.2	14 622 989	72.60	8.6	7 731 599	29.10	4.5	6 823 664	69.00	4.0	79 769 485	46.70	46.70	170 816 530	54	100
BITLIS	87 366 390	58.40	40.8	13 422 411	70.10	6.3	7 938 669	69.40	3.7	13 365 984	69.00	6.2	92 304 673	43.05	43.05	214 388 127	56	100
BOLU	360 272 890	13.80	37.3	178 253 108	44.40	18.5	46 006 483	36.00	4.8	106 381 189	26.20	11.0	274 303 386	28.40	28.40	966 017 056	24	100
BURDUR	115 735 597	30.40	26.3	33 246 072	39.00	7.6	13 944 566	43.20	3.1	76 671 659	68.00	17.4	200 924 483	45.66	45.66	440 074 357	51	100
BURSA	512 190 395	30.10	11.2	1 672 416 833	77.90	36.5	249 224 537	16.70	5.4	623 351 511	69.80	13.0	1 522 754 406	33.25	33.25	4 579 937 632	82	100
CANAKKALE	255 221 846	48.20	25.3	122 232 710	57.60	22.4	51 060 605	54.40	5.1	142 361 511	69.80	14.1	334 400 597	33.12	33.12	1 009 738 204	57	100
CANKIRI	88 891 521	55.00	32.8	12 683 172	70.60	4.6	36 786 039	25.30	3.8	46 498 385	68.00	17.2	212 570 985	41.55	41.55	270 912 672	57	100
CORUM	209 286 472	47.60	24.5	80 358 200	54.20	9.4	36 786 039	31.70	4.3	256 483 416	66.00	30.0	271 635 584	31.79	31.79	854 549 711	57	100
DENIZLI	283 334 357	16.70	19.1	248 759 842	61.80	16.8	87 984 551	38.20	5.9	347 893 303	70.30	23.5	514 153 607	34.71	34.71	1 481 215 700	51	100
DIYARBAKIR	307 548 087	36.90	21.4	243 940 150	64.90	17.0	84 989 644	75.10	5.9	209 964 539	67.20	14.6	502 484 446	41.18	41.18	1 438 926 876	55	100
ELAZIG	311 895 112	68.10	34.1	108 522 065	27.00	19.2	36 776 967	27.30	4.0	127 837 707	68.10	14.0	329 194 130	36.01	36.01	914 212 721	61	100
ERZURUM	190 249 402	40.50	35.1	22 874 379	64.00	7.5	7 407 087	48.90	2.4	60 432 749	68.10	10.0	340 970 425	42.23	42.23	907 198 035	50	100
ERZURUM	210 675 311	52.80	24.6	50 878 641	44.70	5.9	54 015 338	20.80	6.3	132 263 429	69.00	15.4	188 770 049	47.72	47.72	856 611 768	55	100
ESKISEHIR	183 893 157	33.20	12.3	320 534 009	54.80	21.6	57 088 534	48.10	3.9	353 321 369	69.10	23.7	574 176 009	38.56	38.56	1 489 623 508	57	100
GAZIANTEP	231 849 295	89.70	13.7	326 200 429	70.80	19.3	106 670 996	46.50	6.9	430 741 121	69.10	26.4	599 131 692	35.36	35.36	1 694 590 523	71	100
GIRISUN	160 778 513	3.90	24.3	57 395 943	36.60	8.3	34 867 343	59.70	5.3	73 946 459	70.00	12.0	269 552 576	44.63	44.63	615 940 836	34	100
GUMUSHANE	71 484 992	21.80	41.0	1 458 008	60.30	0.8	12 227 138	197.30	7.0	11 996 257	67.00	16.0	77 956 455	44.67	44.67	124 512 786	70	100
HATAY	51 709 016	126.80	31.4	2 857 631	153.60	1.9	13 609 943	63.80	3.4	4 229 224	63.30	2.8	92 290 044	58.07	58.07	184 596 859	64	100
ISPARTA	456 155 092	70.60	24.1	252 492 669	50.60	13.0	63 534 213	44.20	8.4	470 638 260	68.80	24.9	649 010 534	34.37	34.37	1 892 091 738	61	100
ISCELE	198 170 544	45.40	29.3	784 014 510	62.00	12.0	40 633 338	41.60	6.0	58 773 890	70.30	13.3	268 081 597	36.60	36.60	676 071 107	55	100
ISTANBUL	166 019 848	89.00	0.1	7 384 582 580	55.20	26.2	98 022 447	26.40	2.8	588 153 513	69.00	17.3	1 198 057 558	32.00	32.00	3 476 606 789	57	100
IZMIR	724 189 233	81.90	8.3	2 612 793 062	64.70	28.7	1 058 016 938	26.60	3.8	8 610 555 613	67.00	31.3	10 349 325 916	37.57	37.57	27 548 600 621	63	100
KARS	75 454 638	29.70	27.7	10 072 243	49.20	4.3	32 597 123	125.90	6.3	1 800 565 524	69.10	17.0	3 728 515 552	41.92	41.92	9 089 089 361	91	100
KASTAMONU	155 655 838	45.50	27.2	63 186 370	41.00	17.0	35 277 123	49.30	9.2	40 784 970	64.00	14.0	177 458 812	43.63	43.63	253 791 440	59	100
KAYSERİ	197 008 998	57.80	12.3	264 262 666	46.70	17.9	19 531 123	7.80	7.3	340 741 562	69.10	22.3	277 645 597	39.51	39.51	1 576 106 352	56	100
KIRSEHIR	82 335 353	32.90	18.1	472 334 523	79.00	52.3	27 921 515	37.80	3.1	81 701 450	69.10	8.1	200 470 877	22.83	22.83	389 872 797	92	100
KOCALİ	88 020 364	33.20	26.8	34 510 953	36.70	11.2	14 064 854	37.60	4.0	81 701 450	69.10	8.1	194 316 463	31.84	31.84	385 863 063	41	100
KONYA	720 659 419	64.30	3.3	3 015 385 926	71.30	53.2	186 492 697	36.50	3.3	488 084 512	69.20	13.3	1 777 438 812	31.38	31.38	5 665 425 950	74	100
KUTAYHA	146 872 446	30.40	16.1	381 956 715	59.40	16.3	21 116 723	64.90	6.3	459 281 045	71.40	14.7	1 192 061 382	38.46	38.46	3 099 272 072	60	100
MALATYA	77 439 040	72.00	17.8	239 153 594	63.60	41.2	39 244 765	55.10	4.2	61 116 658	71.10	18.0	296 105 876	31.95	31.95	926 917 367	60	100
MANİSA	562 749 058	30.30	21.8	963 204 923	75.60	37.1	73 895 969	20.60	2.9	394 467 366	67.30	15.2	604 306 422	23.28	23.28	1 692 948 237	63	100
KARAHAMZARAS	223 623 223	59.70	21.3	285 497 427	57.40	22.1	148 076 595	236.40	12.2	180 076 595	67.80	14.3	353 074 411	23.00	23.00	2 127 419 109	57	100
MARDIN	140 653 702	65.60	27.8	32 388 570	71.90	16.4	15 534 560	44.00	3.1	67 625 033	67.60	13.4	249 164 218	45.26	45.26	585 960 065	60	100
MUGLA	473 530 124	81.10	25.0	320 068 644	66.20	16.8	104 607 965	65.30	5.3	527 455 328	77.80	27.7	474 274 216	24.93	24.93	1 901 649 479	72	100
MUS	97 622 597	35.90	47.3	6 646 370	48.20	3.2	11 234 429	21.90	5.3	6 906 429	69.00	3.4	63 125 047	40.46	40.46	205 436 842	40	100
NEVSEHIR	206 557 472	50.20	36.6	46 862 938	55.70	8.3	21 425 576	25.50	3.8	107 008 122	79.00	18.3	183 001 724	32.40	32.40	564 659 632	59	100
ORDU	288 670 430	26.80	49.3	60 294 664	57.20	9.2	30 487 328	73.70	5.9	41 333 791	68.00	7.0	194 037 152	25.27	25.27	544 823 385	43	100
OGUZLARI	289 787 416	29.30	35.3	71 614 614	42.50	8.8	45 612 608	42.70	6.0	88 621 170	68.00	11.9	235 369 159	35.35	35.35	765 004 963	46	100
RIZE	109 741 367	39.00	19.6	116 622 681	47.40	20.8	24 315 826	44.00	4.3	84 700 187	80.00	15.1	224 646 195	40.13	40.13	560 226 256	56	100
SAKARYA	361 877 006	65.60	26.2	288 972 017	73.00	20.8	77 299 990	22.80	5.9	253 096 472	68.10	18.3	398 531 271	28.88	28.88	1 379 176 692	63	100
SAMSUN	405 017 576	33.30	23.1	286 549 733	63.70	16.3	100 367 767	57.70	5.7	355 729 762	66.90	20.3	608 303 889	34.84	34.84	1 756 168 727	55	100
SIRT	55 631 443	92.10	24.1	49 516 531	73.50	21.3	8 284 028	17.20	3.8	7 796 592	67.50	3.4	110 596 448	47.67	47.67	232 026 342	59	100

Table C.7 (continued)

PROVINCE	AGRICULTURE			INDUSTRY			CONSTRUCTION			TRADE			OTHERS			TOTAL		
	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)	VALUE (MILLION TL.)	GROWTH RATE (%)	SECTOR SHARE (%)
SIĞIR	154.586.600	25.60	18.6	140.984.585	67.20	17.0	55.981.943	44.70	6.8	131.748.807	67.30	15.9	345.584.583	67.30	41.69	828.936.518	62	100
TEKİRDAĞ	205.674.062	46.00	15.5	524.172.733	63.30	39.4	99.204.240	11.00	7.5	139.735.333	66.90	10.5	361.992.262	67.30	27.20	1.330.775.630	63	100
TOKAT	221.912.499	35.30	24.1	309.069.928	65.20	33.7	24.646.305	49.70	2.7	66.013.080	67.60	7.1	206.814.781	67.30	32.37	916.556.593	55	100
TRABZON	208.943.637	2.60	17.7	165.153.654	38.60	14.0	79.459.919	93.90	6.7	214.698.071	70.60	18.2	509.524.124	67.30	43.27	1.177.576.405	46	100
TUNCELİ	31.265.031	53.50	26.3	1.821.024	162.80	1.3	7.482.845	66.50	6.3	5.623.658	57.70	4.2	72.699.415	67.30	51.15	118.940.973	45	100
SAĞLIKLI	504.331.002	66.30	45.4	129.253.377	43.80	11.1	69.337.172	66.20	6.0	62.006.793	69.70	5.3	366.577.333	67.30	34.14	1.161.707.677	62	100
UŞAK	106.127.124	34.40	23.7	45.542.661	54.10	11.0	22.854.028	40.30	5.3	66.251.048	67.20	21.3	150.565.801	67.30	36.43	413.360.662	51	100
YALOVA	142.890.536	91.00	23.4	35.270.136	41.60	5.8	23.121.967	44.50	3.8	57.319.411	70.30	9.4	351.345.892	67.30	57.59	610.047.942	64	100
YOZGAT	194.694.431	46.80	36.5	58.286.352	133.60	10.9	22.063.087	32.30	4.1	51.175.962	68.30	9.6	207.316.922	67.30	38.68	533.536.754	58	100
ZONGULDAK	98.695.035	42.00	6.7	683.321.959	103.20	46.8	24.988.852	29.80	1.7	186.252.349	70.30	12.7	472.081.929	67.30	32.23	1.484.850.124	60	100
AKSARAY	143.208.692	49.40	40.2	8.278.206	55.10	2.3	17.777.606	21.60	4.8	53.186.274	68.00	14.9	134.526.247	67.30	37.74	356.477.025	54	100
BAŞKENT	25.792.547	49.90	32.1	1.992.500	47.70	2.5	3.926.579	10.10	4.9	9.088.499	68.60	11.3	39.527.485	67.30	49.21	80.327.610	50	100
KARAMAN	231.708.632	38.20	54.4	46.608.194	44.80	10.9	15.372.658	10.50	3.6	27.427.435	68.30	6.4	105.065.125	67.30	24.65	426.182.044	44	100
KIRIKKALE	62.256.780	43.00	7.6	447.794.353	37.30	54.6	27.750.246	113.50	3.4	36.284.850	64.90	4.4	246.489.537	67.30	30.04	820.576.766	47	100
BATMAN	84.391.714	39.40	19.5	167.380.063	108.40	38.6	15.795.706	62.10	3.6	31.480.493	67.80	7.3	134.583.610	67.30	31.04	433.631.586	65	100
SIRNAK	35.702.044	40.40	19.5	3.746.155	131.40	2.0	6.434.861	38.20	3.5	2.033.712	65.50	1.1	134.944.417	67.30	73.80	182.861.189	42	100
BARTIN	37.010.690	50.50	23.5	15.216.341	41.80	9.7	9.686.897	38.50	6.2	11.937.562	68.40	7.6	83.597.938	67.30	53.10	157.448.448	53	100
ARDAHAN	43.024.555	45.00	46.0	2.065.445	74.60	2.3	3.421.302	35.80	3.8	4.596.621	67.50	5.3	36.414.354	67.30	40.60	89.684.277	43	100
İGDIR	48.935.558	39.40	39.7	2.643.508	68.90	2.1	10.763.093	19.40	8.7	5.746.125	68.20	4.7	55.020.267	67.30	44.73	123.006.551	42	100
YALOVA	35.827.381	31.80	7.3	184.425.486	82.00	37.6	23.256.732	4.60	4.7	137.586.217	67.00	28.0	109.467.410	67.30	22.31	490.563.226	64	100
KARABUK	35.016.039	47.60	11.0	109.835.788	25.50	34.5	19.465.288	43.40	6.1	85.490.215	66.60	26.9	67.439.215	67.30	21.26	317.246.545	45	100
KİLİS	55.131.554	131.00	32.8	18.082.115	64.90	10.8	4.715.211	2.20	2.7	62.202.003	66.20	37.1	27.999.159	67.30	16.68	167.870.042	78	100
OSMANİYE	105.556.171	36.00	23.4	27.630.189	30.60	6.1	22.116.485	53.50	4.9	94.518.321	67.40	21.0	201.181.131	67.30	44.61	451.002.297	50	100
DÜZCE	95.294.990	29.6	29.6	94.082.247	30.60	29.2	5.971.556	53.50	1.9	36.102.946	67.40	11.2	90.570.056	67.30	28.13	322.021.797	100	100
TOPLAM	17.464.395.683		14.0	29.015.561.482		23.4	6.469.554.745		5.3	24.867.071.712		20.1	48.486.777.836		37.48	124.315.361.438		100

Source: T.C. Başbakanlık Devlet İstatistik Enstitüsü, İllere Göre Gayri Safi Yurtiçi Hasıla, 2002

Table C.8 Employed Population by Provinces

Employment	1990	2000	2004*	1990	2000	2004*
Türkiye	23 381 893	25 997 141	21 791 000			
Adana	680 887	572 605	487 464	Kocaeli	346 788	502 950
Adıyaman	202 691	209 126	169 387	Konya	731 016	820 932
Afyon	342 833	366 277	287 721	Kütahya	280 097	300 564
Ağrı	177 006	183 856	128 899	Malatya	275 880	311 977
Amasya	166 350	154 295	150 249	Manisa	589 774	577 033
Ankara	1 103 325	1 378 699	1 226 000	K.Maraş	369 972	379 730
Antalya	555 859	760 514	695 559	Mardin	196 750	213 155
Artvin	109 484	80 276	89 594	Muğla	308 316	393 701
Aydın	405 891	449 981	383 157	Muş	158 179	172 521
Balıkesir	466 669	474 981	375 890	Nevşehir	139 556	145 903
Bilecik	85 063	85 543	84 330	Niğde	148 477	157 362
Bingöl	107 835	97 093	69 116	Ordu	394 087	378 259
Bitlis	124 479	119 877	75 647	Rize	162 208	148 372
Bolu	279 368	133 928	92 050	Sakarya	322 109	314 903
Burdur	126 697	110 534	101 093	Samsun	529 584	505 115
Bursa	662 517	825 531	813 826	Sirt	87 423	77 745
Çanakkale	248 824	237 699	188 110	Şinop	133 343	105 160
Çankırı	131 352	123 280	64 177	Sivas	320 956	295 043
Çorum	284 218	247 176	240 695	Tekirdağ	238 301	301 628
Denizli	367 476	423 500	360 608	Tokat	334 279	342 158
Diyarbakır	365 007	398 155	278 559	Trabzon	373 110	410 265
Edirne	218 788	196 389	169 699	Tunceli	60 698	44 618
Elazığ	182 414	193 920	138 042	Ş.Urfa	349 812	429 431
Erzincan	135 623	135 205	127 513	Uşak	133 676	139 909
Erzurum	355 095	321 606	303 309	Van	232 222	277 286
Eskişehir	238 405	244 308	240 844	Yozgat	270 715	283 566
Gaziantep	382 078	374 668	303 473	Zonguldak	358 921	282 210
Giresun	236 071	214 260	239 131	Aksaray	134 812	158 157
Gümüşhane	79 480	82 989	92 622	Bayburt	50 879	43 662
Hakkâri	71 208	76 872	48 509	Karaman	95 100	96 922
Hatay	446 225	518 808	321 382	Kırıkkale	115 718	115 716
İsparta	198 875	222 337	203 347	Batman	111 920	110 083
Mersin	504 854	614 977	523 536	Şırnak	103 333	109 224
İstanbul	2 539 963	3 471 400	3 318 000	Bartın	107 013	97 044
İzmir	1 080 346	1 281 008	1 138 000	Ardeşan	91 218	69 582
Kars	164 164	141 650	97 768	Iğdır	62 884	64 192
Kastamonu	229 339	184 564	96 080	Yalova	72 800	50 036
Kayseri	337 524	367 333	245 033	Karabük	76 725	52 330
Kırklareli	163 623	166 262	143 666	Kilis	38 445	31 140
Kırşehir	104 861	95 310	70 726	Osmaniye	139 460	86 390
				Düzce	156 841	107 798

* Forecasted

Source: T.C. Başbakanlık, Türkiye İstatistik Kurumu (TUIK)

Table C.9 Employed Population at NUTS2 Level by Sectors in 2004

YEAR	REGION CODE NUTS2	PROVINCES UNDER NUTS2 LEVEL	TOTAL NUMBER OF EMPLOYEES	AGRICULTURE (1000)	INDUSTRY	SERVICES 1000	AGRICULTURE (%)	INDUSTRY (%)	SERVICES (%)
2004	TRA1	Erzurum, Erzincan, Bayburt	472	310	21	141	66	4	30
2004	TRA2	Ağrı, Kars, Iğdır, Ardahan	317	209	14	94	66	5	30
2004	TRB1	Malatya, Elazığ, Bingöl, Tunceli	461	189	60	212	41	13	46
2004	TRB2	Van, Muş, Bitlis, Hakkari	408	204	38	166	50	9	41
2004	TRC1	Gaziantep, Adıyaman, Kilis	504	125	139	240	25	28	48
2004	TRC2	Şanlıurfa, Diyarbakır	579	275	70	234	48	12	41
2004	TRC3	Mardin, Batman, Şırnak, Siirt	373	171	41	161	46	11	43
2004	TR10	İstanbul	3318	26	1412	1880	1	43	57
2004	TR21	Tekirdağ, Edirne, Kırklareli	574	216	145	213	38	25	37
2004	TR22	Balıkesir, Çanakkale	564	265	90	209	47	16	37
2004	TR31	İzmir	1138	227	378	533	20	33	47
2004	TR32	Aydın, Denizli, Muğla	1079	457	233	389	42	22	36
2004	TR33	Manisa, Afyon, Kütahya, Uşak	1087	561	192	334	52	18	31
2004	TR41	Bursa, Eskişehir, Bilecik	1139	293	440	406	26	39	36
2004	TR42	Kocaeli, Sakarya, Düzce, Bolu, Yalova	812	152	272	388	19	34	48
2004	TR51	Ankara	1226	89	283	854	7	23	70
2004	TR52	Konya, Karaman	747	355	141	251	48	19	34
2004	TR61	Antalya, Isparta, Burdur	1000	343	152	505	34	15	51
2004	TR62	Adana, Mersin	1011	324	218	469	32	22	46
2004	TR63	Hatay, Kahramanmaraş, Osmaniye	643	203	133	307	32	21	48
2004	TR71	Kırıkkale, Aksaray, Niğde, Nevşehir, Kırşehir	499	267	57	175	54	11	35
2004	TR72	Kayseri, Sivas, Yozgat	631	283	123	225	45	20	36
2004	TR81	Zonguldak, Karabük, Bartın	311	102	85	124	33	27	40
2004	TR82	Kastamonu, Çankırı, Sinop	215	83	39	93	39	18	43
2004	TR83	Samsun, Tokat, Çorum, Amasya	1216	740	122	354	61	10	29
2004	TR90	Trabzon, Ordu, Giresun, Rize, Artvin, Gümüşhane	1467	929	121	417	63	8	28
TOTAL			21791	7398	5019	9374	34	23	43

Source: T.C. Başbakanlık, Türkiye İstatistik Kurumu (TUIK)

Table C.10 Vehicle Ownership by Provinces in 2004

Licence Plate Number	Province	TOTAL	Passenger Car	Minibus	Bus	Small Truck	Truck	Motorcycle	Special Purpose Vehicles	Tractor	Total Truck	Passenger Car per 1000 persons
1	Adana	304 589	140 505	7 743	3 140	37 711	14 665	62 733	478	37 614	52 854	72
2	Adıyaman	39 280	16 678	2 218	274	2 434	2 465	5 671	107	9 433	5 006	25
3	Afyon	99 517	33 612	2 976	1 098	9 052	8 517	16 429	220	27 613	17 789	40
4	Ağrı	15 772	5 728	1 499	200	1 242	1 964	340	90	4 709	3 296	10
5	Amasya	52 019	21 436	2 198	377	5 574	2 874	5 694	109	13 757	8 557	59
6	Ankara	936 936	696 157	20 981	12 636	97 967	49 828	17 228	2 415	39 724	150 210	162
7	Antalya	441 936	199 570	9 397	5 751	61 236	17 343	114 455	731	33 453	79 310	102
8	Artvin	15 282	6 983	1 402	159	3 339	2 484	311	89	515	5 912	39
9	Aydın	195 925	78 230	8 049	1 526	24 304	7 067	45 323	349	31 077	31 720	79
10	Balıkesir	217 491	87 206	3 965	3 201	25 287	10 361	42 555	359	44 557	36 007	79
11	Bilecik	29 658	11 935	630	620	3 553	2 694	2 801	115	7 310	6 362	60
12	Bingöl	6 611	2 516	730	193	1 054	718	536	94	770	1 866	10
13	Bitlis	9 389	3 934	747	104	1 054	1 581	117	96	1 756	2 731	10
14	Bolu	54 071	19 419	1 314	762	5 698	5 263	5 779	164	15 672	11 125	72
15	Burdur	61 100	23 148	794	579	4 110	4 403	14 147	137	13 782	8 650	92
16	Bursa	372 916	198 419	7 213	8 163	64 157	19 072	29 087	610	46 195	83 839	85
17	Çanakkale	90 720	32 754	1 593	1 229	9 602	4 330	18 576	221	22 415	14 153	70
18	Çankırı	20 001	4 706	459	238	1 407	1 304	2 357	105	9 425	2 816	17
19	Çorum	86 588	30 715	2 399	629	5 825	5 138	11 914	164	29 804	11 127	53
20	Denizli	192 736	86 308	6 090	2 955	21 944	9 077	33 394	398	32 580	31 419	98
21	Diyarbakır	58 156	20 108	4 035	676	7 015	4 943	5 164	208	16 007	12 166	14
22	Edirne	73 965	28 641	1 562	1 219	6 043	3 411	8 473	168	24 448	9 622	73
23	Elazığ	49 996	25 854	2 466	546	6 043	3 397	5 192	174	6 324	9 614	44
24	Erzincan	28 404	12 073	1 646	197	2 629	1 477	5 553	112	4 717	4 218	38
25	Erzurum	51 239	26 329	2 664	803	6 822	4 648	962	248	8 763	11 718	27
26	Eskişehir	135 189	73 108	2 393	2 015	15 630	9 738	15 608	286	16 411	25 654	101
27	Gaziantep	188 563	77 050	7 841	1 598	19 494	12 408	53 868	334	15 970	32 236	55
28	Giresun	34 824	14 937	5 353	214	7 589	3 791	597	135	2 208	11 515	28
29	Gümüşhane	9 856	3 754	892	93	1 095	1 036	306	73	2 607	2 204	20
30	Hakkari	4 135	1 733	347	40	592	673	160	69	521	1 334	7
31	Hatay	205 607	77 061	8 311	2 392	20 210	13 330	68 438	301	15 564	33 841	59
32	İsparta	83 758	34 403	1 317	1 018	8 451	4 206	20 344	162	13 857	12 819	64
33	Mersin	248 285	102 061	4 515	4 266	34 051	19 440	60 234	487	23 231	53 978	57
34	İstanbul	2 082 340	1 502 720	58 153	40 162	294 332	107 671	55 026	8 874	15 402	410 877	135
35	İzmir	674 140	387 776	12 974	12 785	107 342	30 641	77 937	1 055	43 630	139 038	107
36	Kars	19 933	5 795	1 230	320	1 522	1 568	330	88	9 080	3 178	19
37	Kastamonu	59 076	23 234	2 396	508	3 936	4 636	3 739	226	20 401	8 798	67
38	Kayseri	161 648	93 942	4 817	2 053	19 784	13 373	10 004	312	17 363	33 469	86
39	Kırklareli	52 719	21 720	1 102	882	3 836	2 742	6 798	133	15 506	6 711	66
40	Kırşehir	27 881	13 094	1 055	307	1 834	1 848	2 210	88	7 445	3 770	53
41	Kocaeli	141 575	81 817	4 653	4 467	20 695	12 748	5 634	464	11 097	33 907	62

Table C.10 (continued)

Licence Plate Number	Province	TOTAL	Passenger Car	Minibus	Bus	Small Truck	Truck	Motorcycle	Special Purpose Vehicles	Tractor	Total Truck	Passenger Car per 1000 persons
42	Konya	327 001	135 130	6 970	3 073	35 602	30 546	59 390	761	55 529	66 909	57
43	Kütahya	105 225	46 359	3 854	1 175	9 505	6 887	14 113	294	23 038	16 686	68
44	Malatya	71 465	35 135	3 394	829	8 005	4 178	5 346	198	14 380	12 381	39
45	Manisa	271 578	85 399	5 258	3 993	26 407	12 428	78 553	370	59 170	39 205	66
46	Kahramanmaraş	89 055	39 208	4 531	1 275	8 167	5 998	17 537	179	12 160	14 344	38
47	Mardin	32 398	8 994	2 024	234	2 668	11 960	1 442	146	4 930	14 774	12
48	Muğla	198 572	84 626	7 258	1 994	23 659	6 838	53 463	425	20 309	30 922	110
49	Muş	13 333	3 863	880	137	1 240	1 272	244	89	5 608	2 601	8
50	Nevşehir	51 640	18 102	1 957	470	5 252	4 603	5 294	153	15 809	10 008	58
51	Niğde	45 132	14 461	950	601	3 823	5 362	8 194	123	11 618	9 308	40
52	Ordu	49 448	26 694	6 599	457	8 041	4 304	1 448	208	1 697	12 553	30
53	Rize	28 676	12 715	2 712	359	7 910	4 410	436	99	35	12 419	35
54	Samsun	159 702	67 991	8 694	902	22 593	7 460	13 190	313	38 559	30 366	88
55	Sanlıurfa	108 675	41 481	3 026	783	5 881	13 232	24 424	216	19 632	19 329	34
56	Siirt	7 836	3 310	714	79	994	841	597	73	1 228	1 908	12
57	Sinop	23 408	11 033	1 328	179	2 148	1 491	1 749	72	5 408	3 711	54
58	Sivas	66 094	29 975	2 780	620	5 574	4 282	3 139	240	19 484	10 096	41
59	Tekirdağ	80 849	33 998	2 749	2 517	8 259	4 491	5 353	246	23 236	12 996	50
60	Tokat	85 283	31 018	2 847	950	7 078	4 230	8 568	154	30 438	11 462	36
61	Trabzon	71 398	37 245	6 818	921	16 896	7 996	1 112	255	155	25 147	36
62	Tunceli	3 407	1 208	428	100	352	334	310	82	593	768	15
63	Sakarya	116 831	51 263	3 504	2 338	16 161	9 396	7 796	255	26 118	25 812	32
64	Uşak	60 353	26 082	1 556	813	5 574	2 708	10 883	131	12 606	8 413	79
65	Van	36 318	15 924	3 523	331	4 833	5 989	1 175	152	4 391	10 974	16
66	Yozgat	49 480	16 852	2 046	423	2 362	4 011	1 370	161	22 255	6 534	23
67	Zonguldak	82 253	47 224	4 183	1 574	11 445	6 359	2 854	303	8 311	18 107	81
68	Aksaray	44 475	20 074	1 001	561	3 187	4 673	4 389	124	10 466	7 984	48
69	Bayburt	6 120	2 551	381	97	551	590	179	47	1 724	1 188	28
70	Karaman	43 461	14 751	1 052	322	3 409	1 996	15 240	141	6 550	5 546	59
71	Kırıkkale	23 615	10 783	1 219	449	2 063	1 465	1 589	139	5 908	3 667	28
72	Batman	18 421	6 554	1 497	145	2 962	2 202	980	99	3 982	5 263	13
73	Şırnak	28 018	3 477	548	53	1 020	21 184	350	100	1 286	22 304	9
74	Bartın	20 426	10 317	1 412	311	2 834	1 358	1 093	65	3 036	4 257	61
75	Ardahan	5 560	1 456	629	34	301	435	21	33	2 651	769	12
76	Iğdır	10 914	3 109	815	436	844	3 109	802	60	1 739	4 013	18
77	Yalova	18 913	10 889	594	756	3 250	2 395	846	85	1 178	4 650	60
78	Karabük	30 805	17 690	1 679	397	3 340	2 395	1 204	110	3 990	5 845	84
79	Kilis	16 236	3 623	596	114	549	698	8 329	29	2 298	1 276	34
80	Osmaniye	62 013	25 693	3 115	319	4 567	2 729	16 118	98	9 374	7 394	53
81	Düzce	38 144	17 014	1 714	1 196	5 066	2 792	3 543	128	6 691	7 986	52
TÜRKİYE		10 236 357	5 400 440	318 954	152 712	1 259 867	647 420	1 218 677	28 004	1 210 283	1 935 291	75

Source: T.C. Başbakanlık, Türkiye İstatistik Kurumu (TUIK)

APPENDIX D

GRAPHS ON RELIABILITY OF DATA

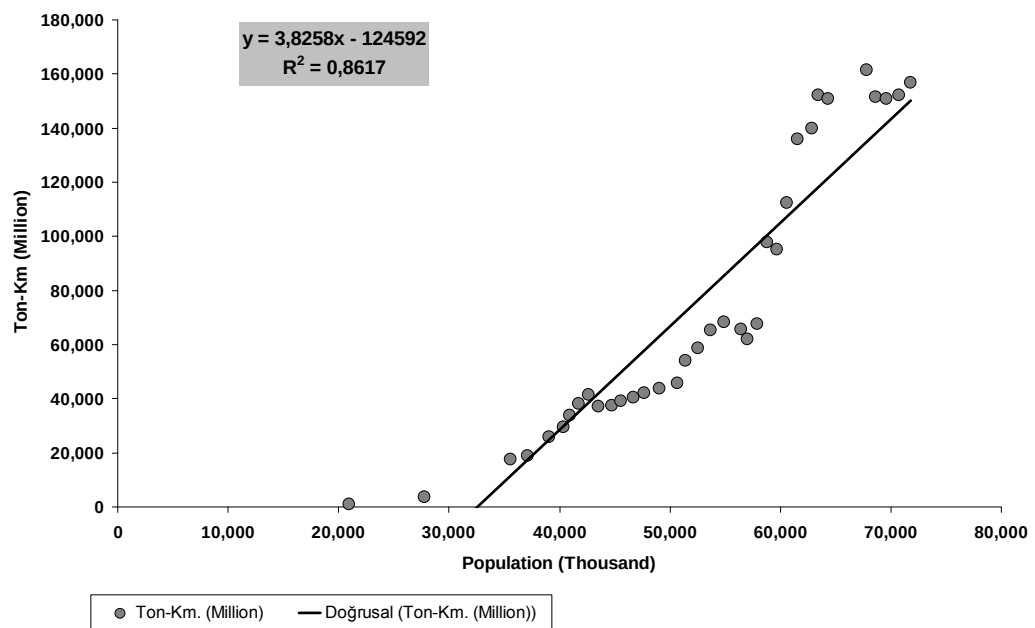
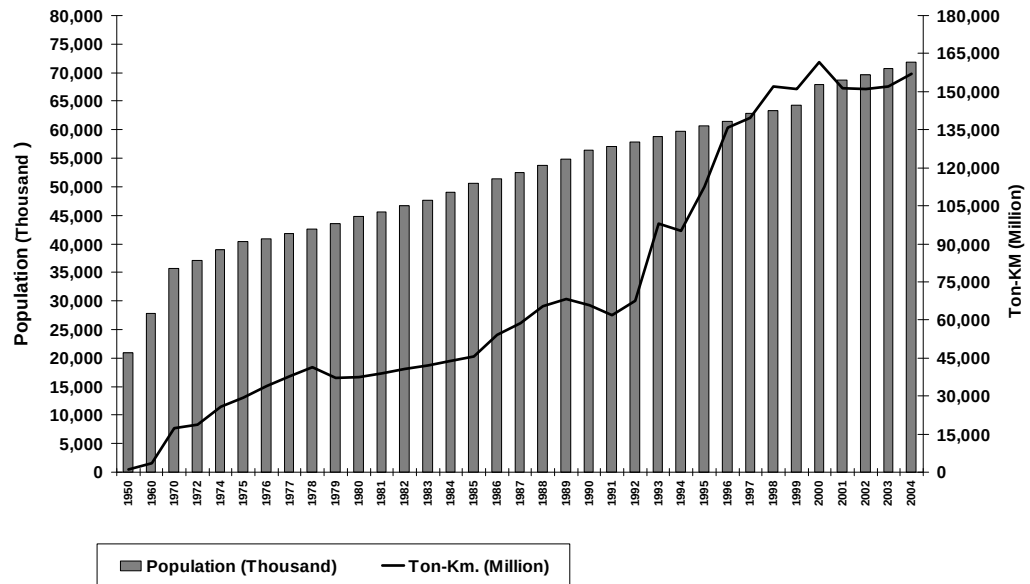


Figure D-1 Comparing Pairs of National Ton-Km and Population

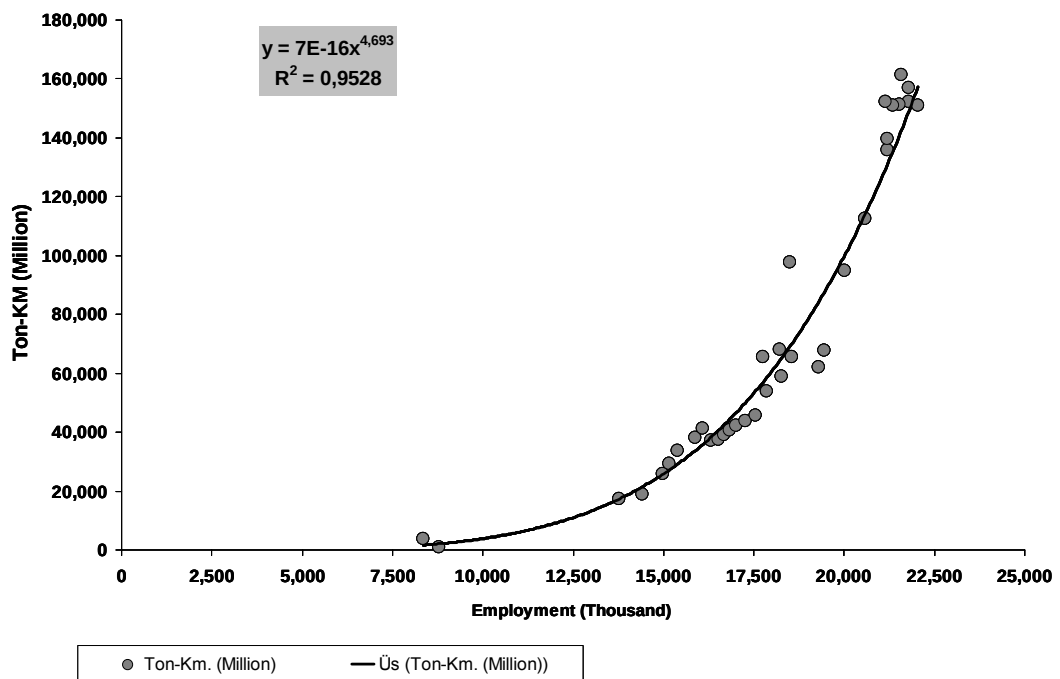
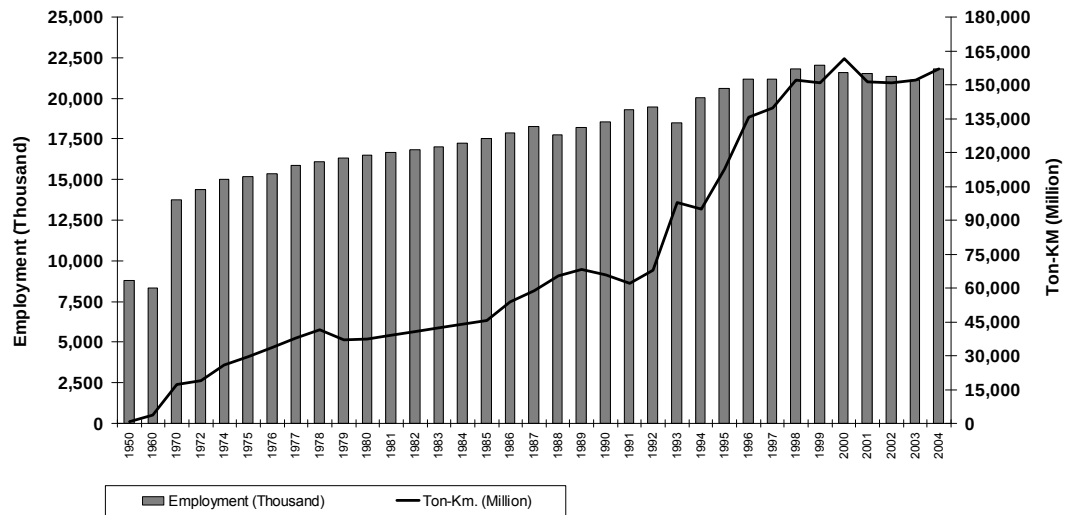


Figure D-2 Comparing Pairs of National Ton-Km and Employment

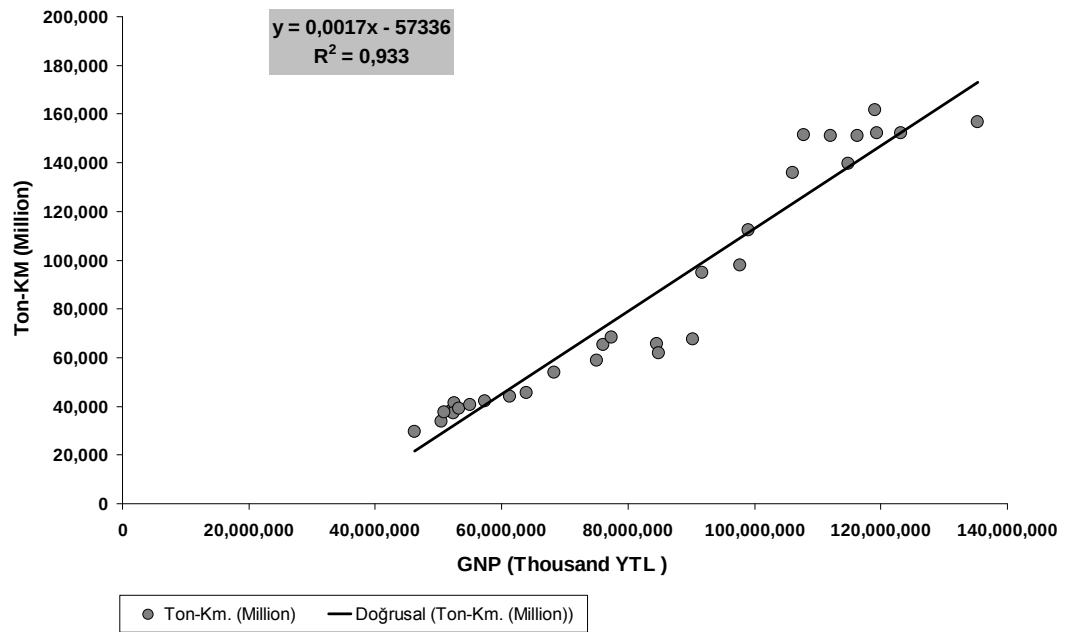
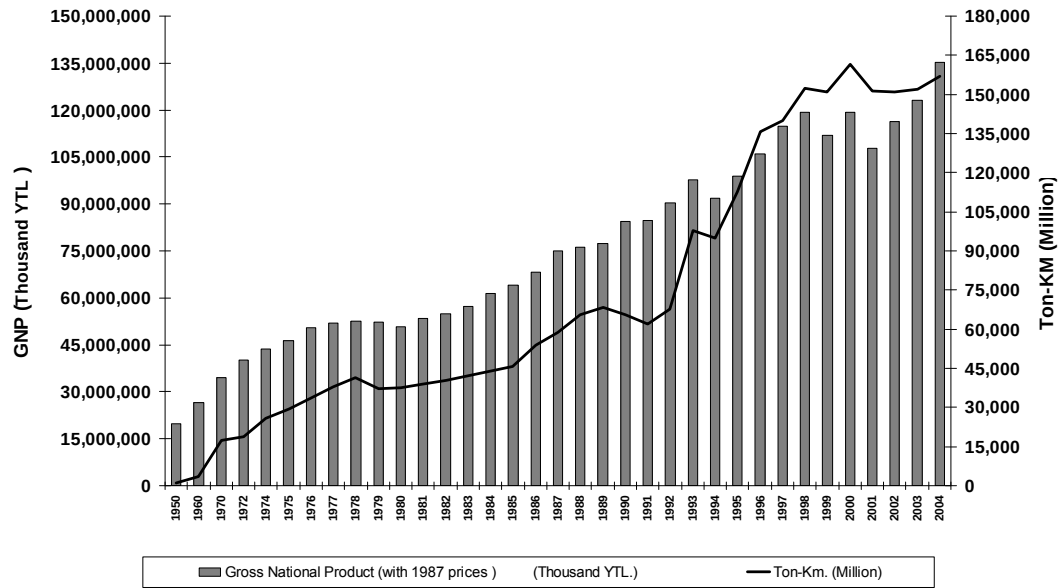


Figure D-3 Comparing Pairs of National Ton-Km and GNP

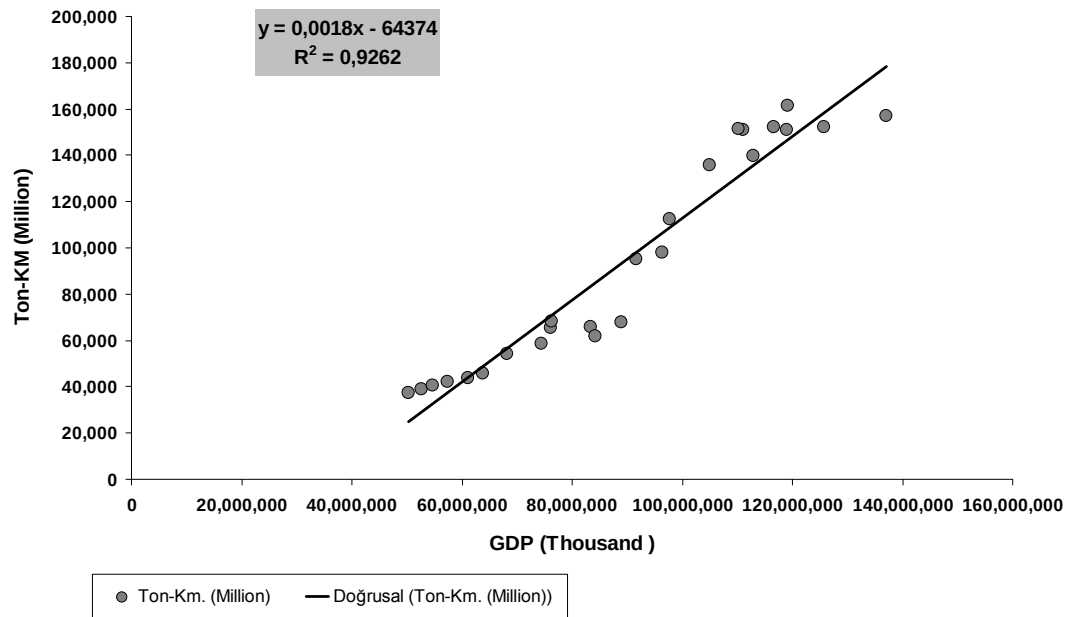
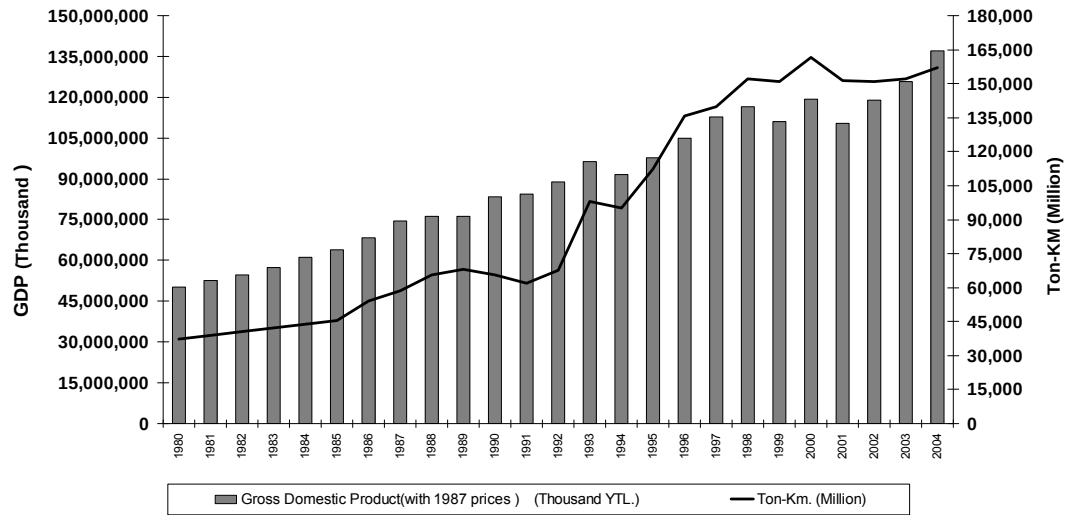


Figure D-4 Comparing Pairs of National Ton-Km and GDP

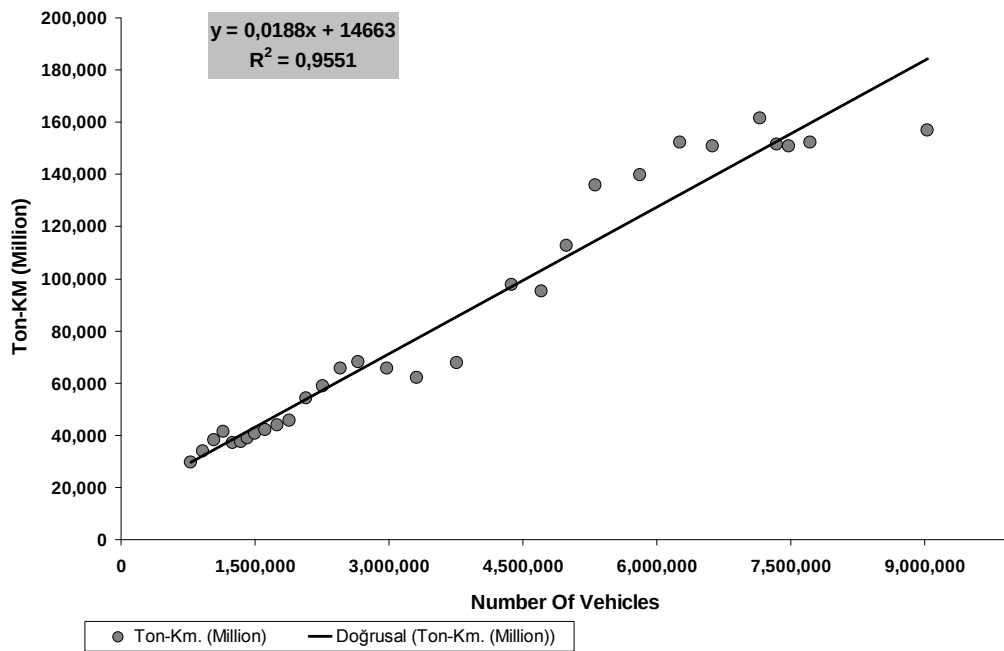
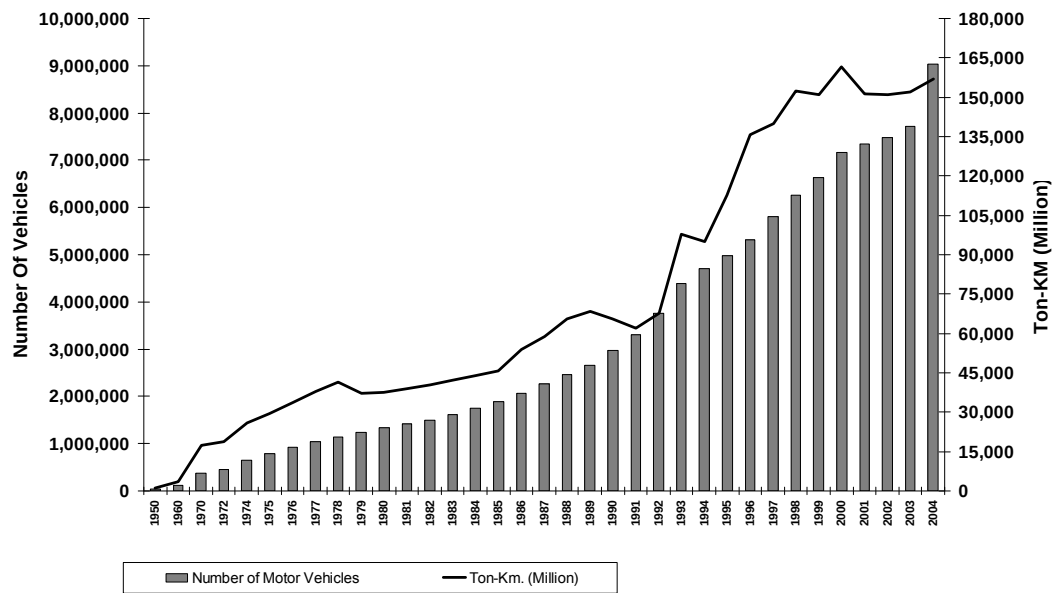


Figure D-5 Comparing Pairs of National Ton-Km and Number of Vehicles

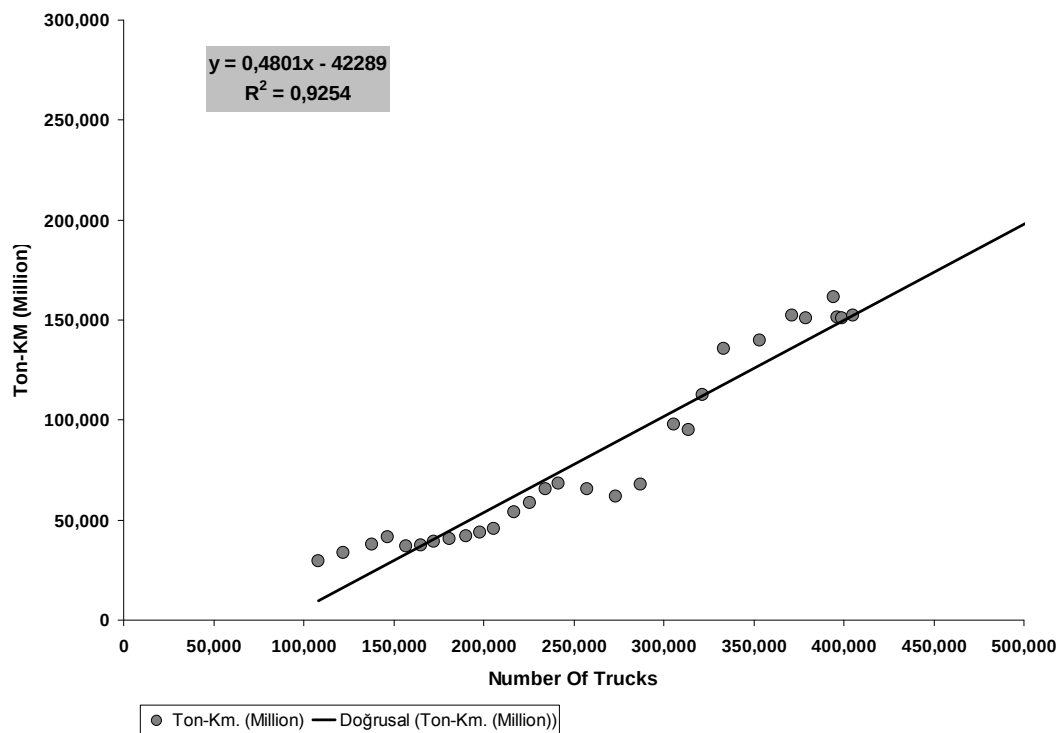
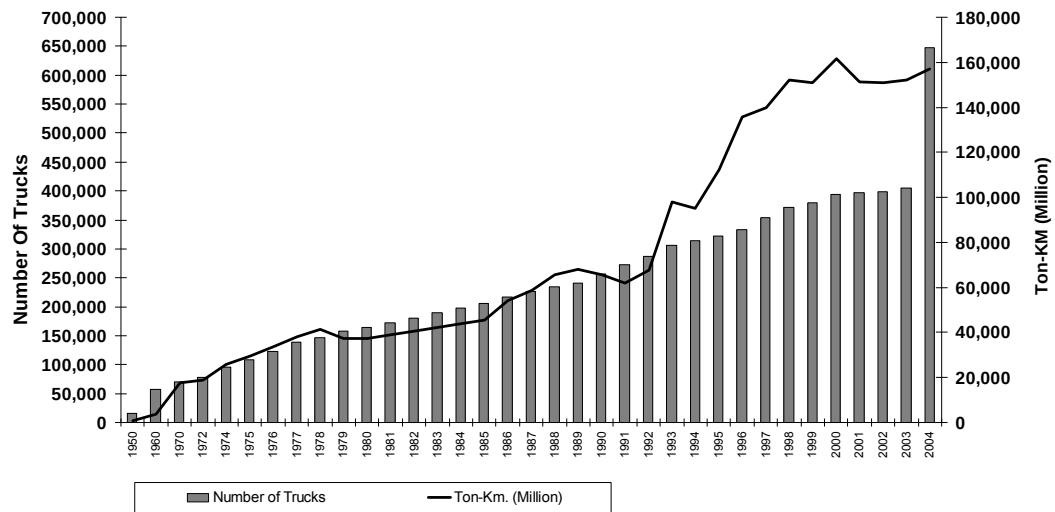


Figure D-6 Comparing Pairs of National Ton-Km and Number of Trucks

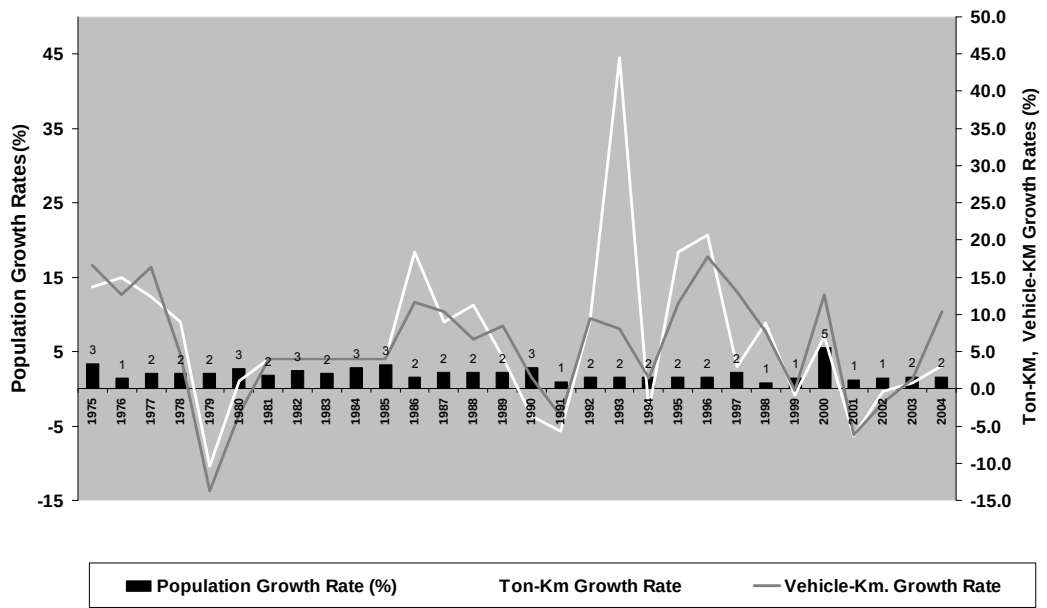


Figure D-7 Comparing Pairs of Population, Ton-Km and Vehicle-Km Growth Rates of Türkiye

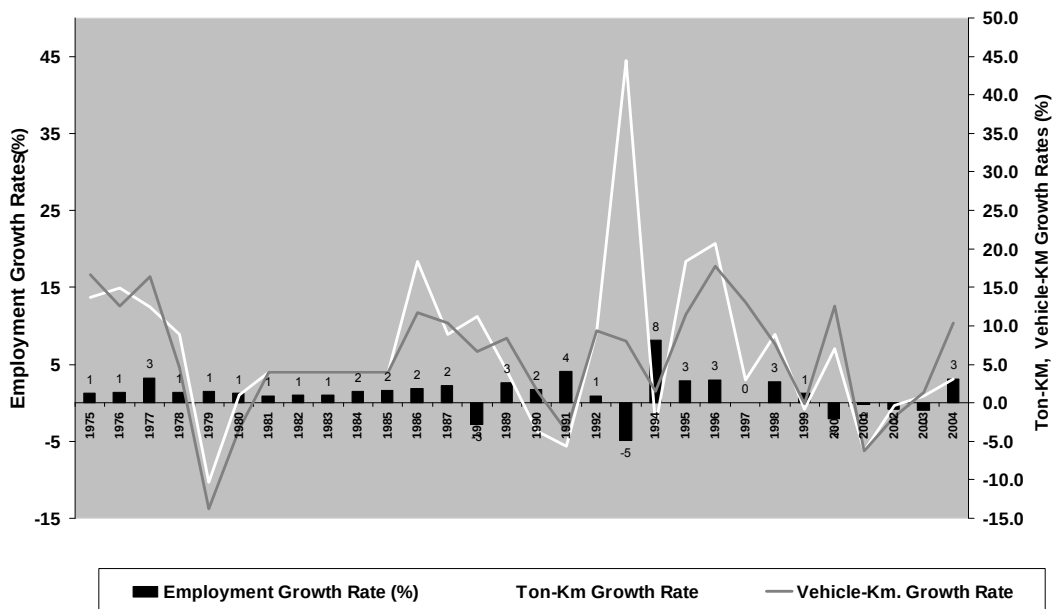


Figure D-8 Comparing Pairs of Employment, Ton-Km and Vehicle-Km Growth Rates

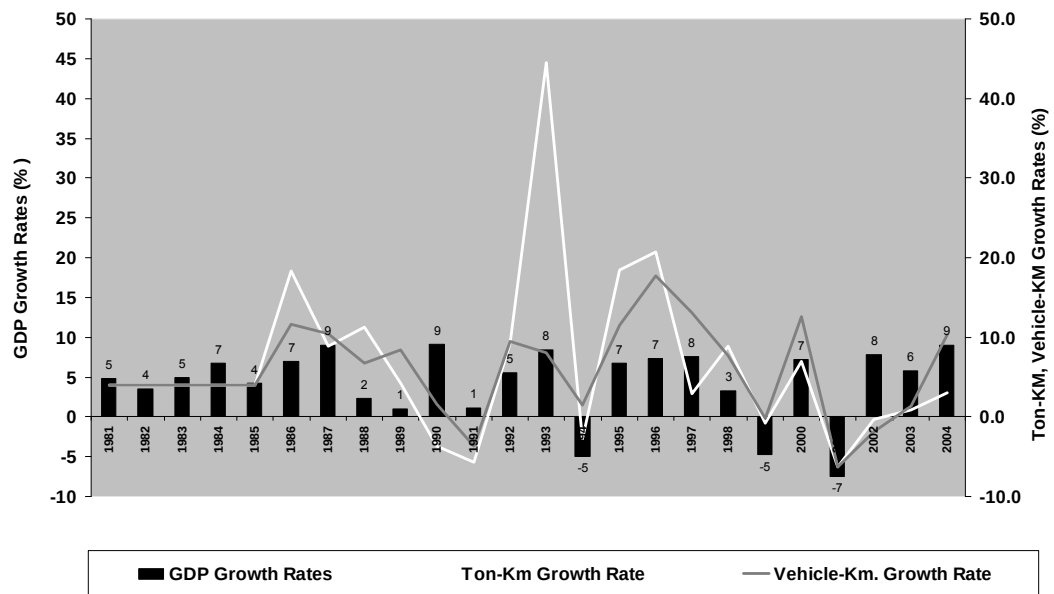


Figure D-9 Comparing Pairs of GDP, Ton-Km and Vehicle-Km Growth Rates

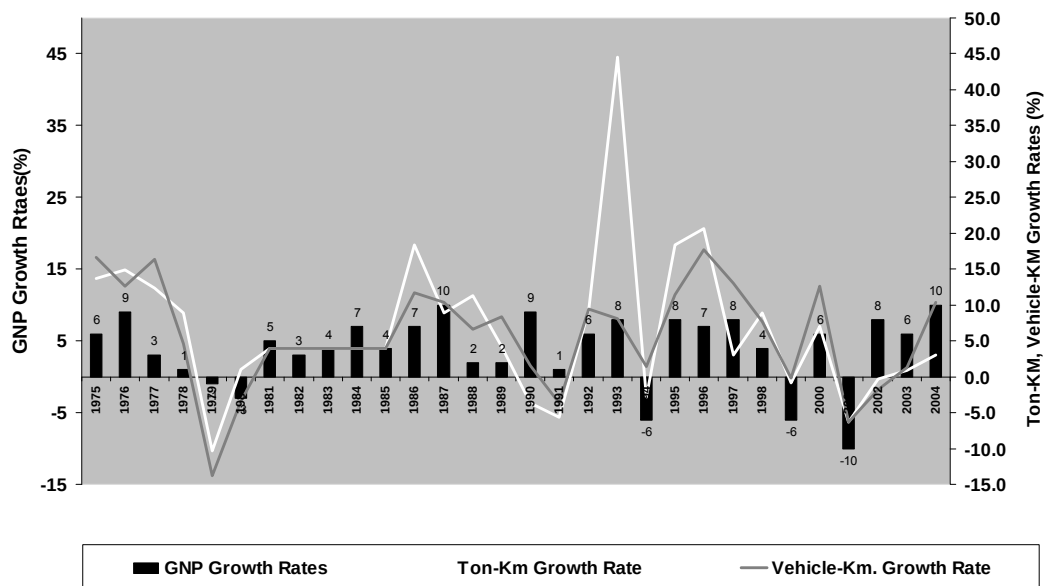


Figure D-10 Comparing Pairs of GNP, Ton-Km and Vehicle-Km Growth Rates

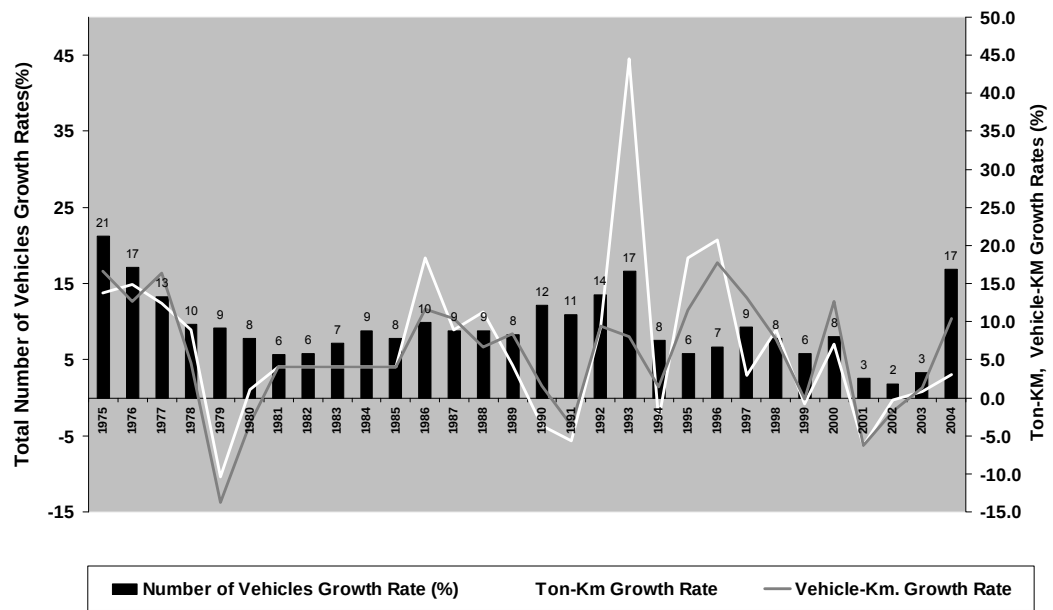


Figure D-11 Comparing Pairs of Total Number of Vehicles, Ton-Km and Vehicle-Km Growth Rates

APPENDIX E

EUROPEAN UNION COMMODITY GROUPS

Table E.1 European Union Commodity Groups

Level	Code	Description
1	01	Products of agriculture, hunting, and forestry; fish and other fishing products
2	01.1	Cereals
2	01.2	Potatoes
2	01.3	Sugar beet
2	01.4	Other fresh fruit and vegetables
2	01.5	Products of forestry and logging
2	01.6	Live plants and flowers
2	01.7	Other substances of vegetable origin
2	01.8	Live animals
2	01.9	Raw milk from bovine cattle, sheep and goats
2	01.A	Other raw materials of animal origin
2	01.B	Fish and other fishing products
1	02	Coal and lignite; peat; crude petroleum and natural gas; uranium and thorium
2	02.1	Coal and lignite and peat
2	02.2	Crude petroleum
2	02.3	Natural gas
2	02.4	Uranium ores
1	03	Metal ores and other mining and quarrying products
2	03.1	Iron ores
2	03.2	Non-ferrous metal ores (except uranium)
2	03.3	Chemical and (natural) fertilizer minerals
2	03.4	Salt
2	03.5	Sand, gravel, clay, other stones, earth and minerals
1	04	Food products, beverages and tobacco
2	04.1	Meat, raw hides and skins and meat products
2	04.2	Fish and fish products, processed and preserved
2	04.3	Fruit and vegetables, processed and preserved
2	04.4	Animal and vegetable oils and fats
2	04.5	Dairy products and ice cream
2	04.6	Grain mill products, starches, starch products and prepared animal feeds
2	04.7	Beverages
2	04.8	Other food products n.e.c. and tobacco products (except in parcel service or grouped in bulk)
2	04.9	Various food products and tobacco products in parcel service or grouped
1	05	Textiles and textile products; leather and leather products
2	05.1	Textiles
2	05.2	Wearing apparels and furs
2	05.3	Leather and leather products
1	06	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media
2	06.1	Products of wood and cork (except furniture)
2	06.2	Pulp, paper and paper products
2	06.3	Printed matter and recorded media

Table E.1 (continued)

Code	Description
07	Coke, refined petroleum products and nuclear fuel
07.1	Coke oven products
07.2	Liquid refined petroleum products and waste oils
07.3	Gaseous, liquefied or compressed petroleum products
07.4	Solid or waxy refined petroleum products
07.5	Nuclear fuel
08	Chemicals, chemical products, and man-made fibres; rubber and plastic products
08.1	Basic mineral chemical products
08.2	Basic organic chemical products
08.3	Nitrogen compounds and fertilizers (except natural fertilizers)
08.4	Basic plastics and synthetic rubber in primary forms
08.5	Pharmaceuticals and paracheicals
08.6	Rubber or plastic products
09	Other non-metallic mineral products
09.1	Glass, glassware, ceramic goods
09.2	Cement, lime and plaster
09.3	Other construction materials, manufactures
10	Basic metals; fabricated metal products, except machinery and equipment
10.1	Basic iron and steel and ferro-alloys and first processed iron and steel (except tubes)
10.2	Non-ferrous metals and products thereof
10.3	Tubes
10.4	Structural metal products
10.5	Boilers, hardware, other metal manufactures
11	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks
11.1	Agricultural and forestry machinery
11.2	Domestic appliances n.e.c. (White goods)
11.3	Office machinery and computers
11.4	Electric machinery and apparatus n.e.c.
11.5	Electronic components and emission and transmission appliances
11.6	Television and radio receivers; sound or video recording or reproducing apparatus and associated goods (Brown goods)
11.7	Medical, precision and optical instruments, watches and clocks
11.8	Other machines, machine tools, weapons and parts
12	Transport equipment
12.1	Automobile industry products
12.2	Other transport equipment
13	Furniture; other manufactured goods n.e.c.
13.1	Furniture and furnishings
13.2	Other manufactured goods

Table E.1 (continued)

Code	Description
14	Secondary raw materials; municipal wastes and other wastes not specified elsewhere in CPA
14.1	Household and municipal waste
14.2	Other waste
15	Mail, parcels
15.1	Mail
15.2	Parcels, small packages
16	Equipment and material utilised in the transport of goods
16.1	Containers and swap bodies in service, empty
16.2	Pallets and other packagings in service, empty
17	Goods moved in the course of household and office removals; baggage transported separately from passengers; motor vehicles being moved for repair; other non-market goods n.e.c.
17.1	Household removal
17.2	Baggage and articles accompanying travellers
17.3	Vehicles for repair
17.4	Plant equipment, scaffolding
17.5	Other non-market goods n.e.c.
18	Grouped goods: a mixture of types of goods which are transported together
18.0	Grouped goods
19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.
19.1	Unidentifiable goods in containers or swap bodies
19.2	Other unidentifiable goods
20	Other goods n.e.c.
20.0	Other goods not elsewhere classified

APPENDIX F

STATISTICAL ANALYSIS RESULTS

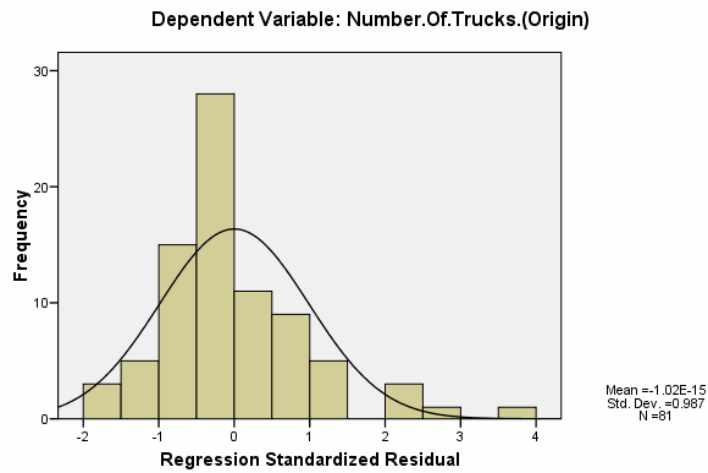


Figure F.1 Histogram of Residuals of Equation 4.4

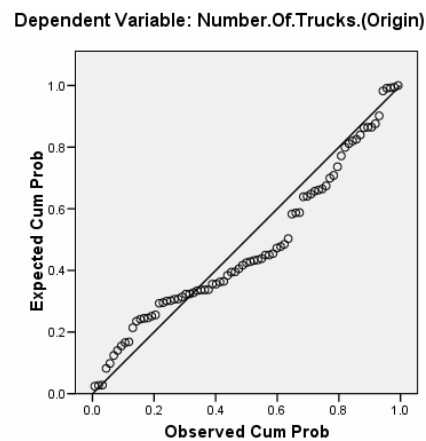


Figure F.2 Normal P-P Plot of Regression Residuals of Equation 4.4

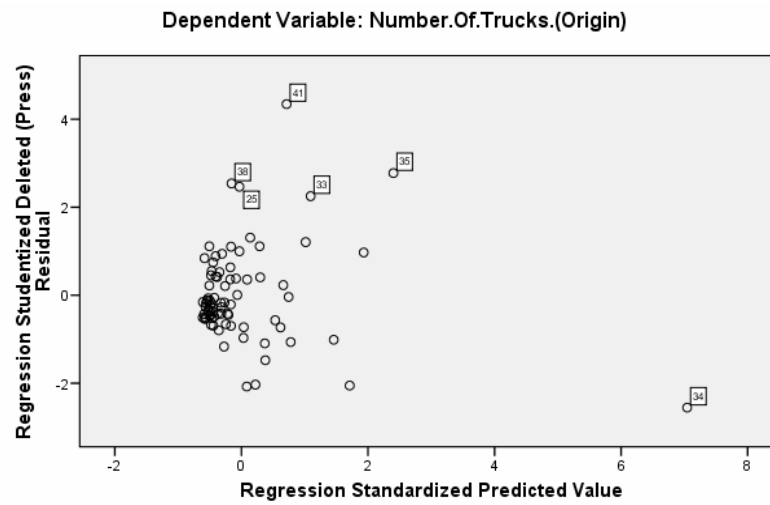


Figure F.3 Scatter Plot of Residuals of Equation 4.4

Table 4.1 One Sample Kolmogorov-Smirnov Test on the Normality of Residuals of Equation 4.4

		Unstandardized Residual
N		81
Normal Parameters ^{a,b}	Mean	.0000000
	Std. Deviation	190870.327217
Most Extreme Differences	Absolute	.145
	Positive	.145
	Negative	-.097
Kolmogorov-Smirnov Z		1.306
Asymp. Sig. (2-tailed)		.066

a. Test distribution is Normal.

b. Calculated from data.

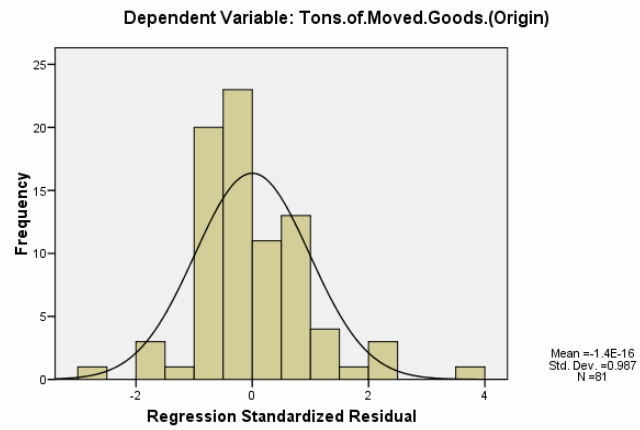


Figure F.4 Histogram of Residuals of Equation 4.5

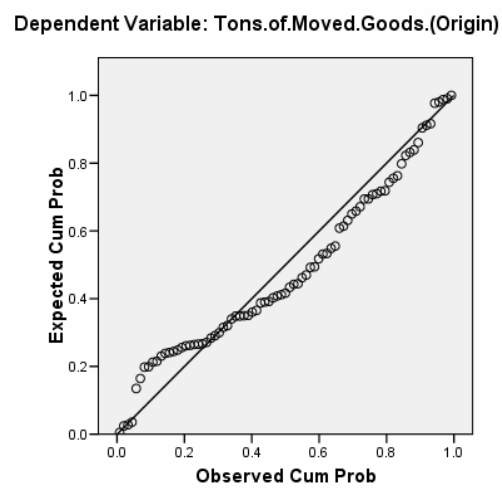


Figure F.5 Normal P-P Plot of Regression Residuals of Equation 4.5

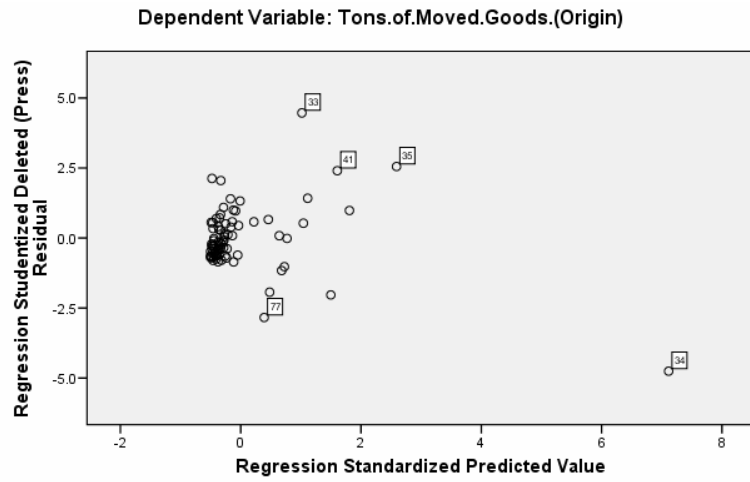


Figure F.6 Scatter Plot of Residuals of Equation 4.5

Table F.2 One Sample Kolmogorov-Smirnov Test on the Normality of Residuals of Equation 4.5

		Unstandardized Residual
N		81
Normal Parameters ^{a,b}	Mean	.0000000
	Std. Deviation	2287957.99037
Most Extreme Differences	Absolute	.121
	Positive	.100
	Negative	-.121
Kolmogorov-Smirnov Z		1.089
Asymp. Sig. (2-tailed)		.186

a. Test distribution is Normal.

b. Calculated from data.

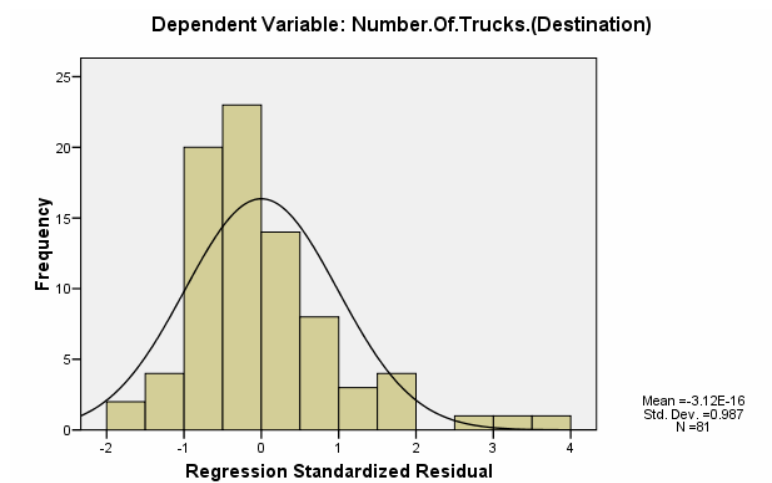


Figure F.7 Histogram of Residuals of Equation 4.6

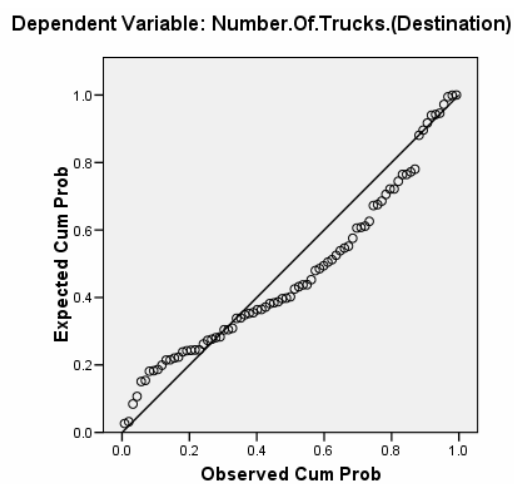


Figure F.8 Normal P-P Plot of Regression Residuals of Equation 4.6

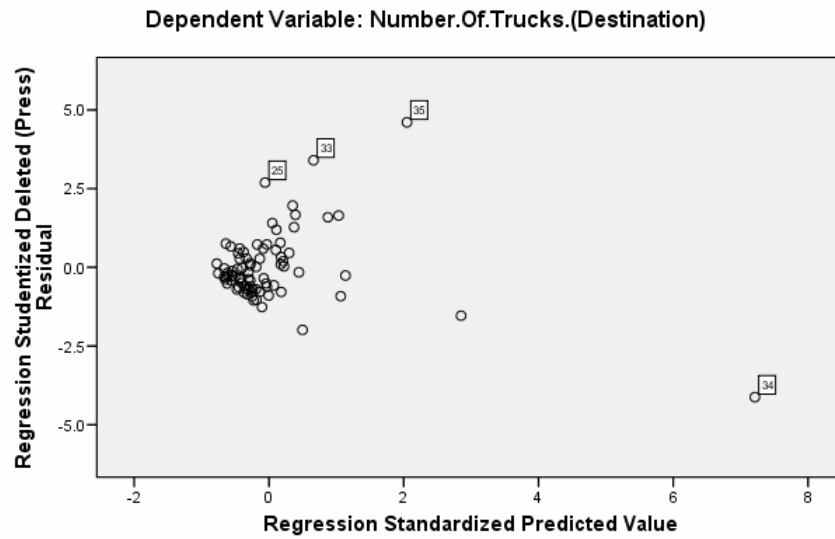


Figure F.9 Scatter Plot of Residuals of Equation 4.6

Table F.3 One Sample Kolmogorov-Smirnov Test on the
Normality of Residuals of Equation 4.6

		Unstandardized Residual
N		81
Normal Parameters ^{a,b}	Mean	.0000000
	Std. Deviation	201445
Most Extreme Differences	Absolute	.126
	Positive	.126
	Negative	-.104
Kolmogorov-Smirnov Z		1.137
Asymp. Sig. (2-tailed)		.150

a. Test distribution is Normal.

b. Calculated from data.

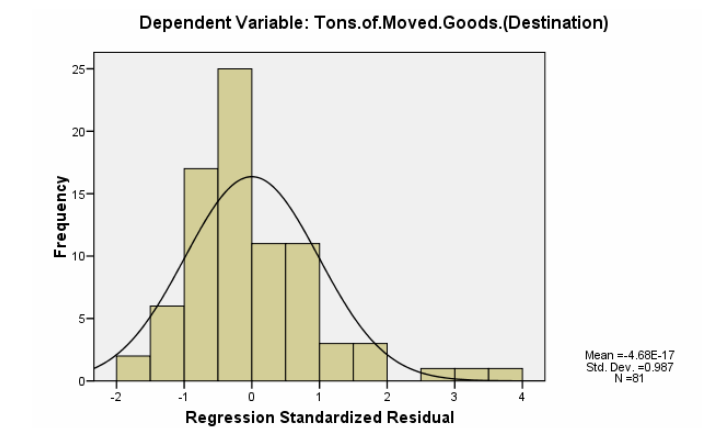


Figure F.10 Histogram of Residuals of Equation 4.7

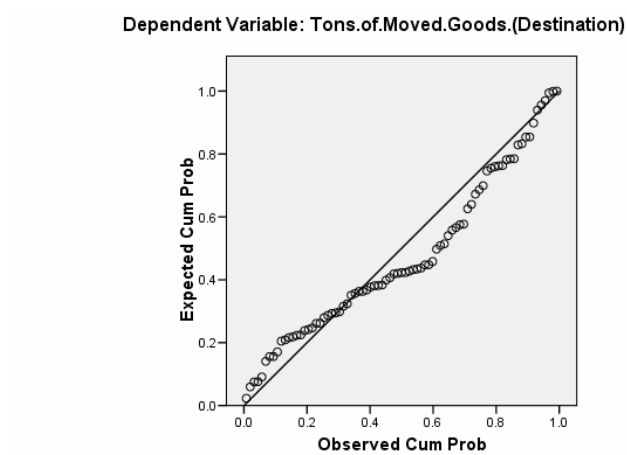


Figure F.11 Normal P-P Plot of Regression Residuals of Equation 4.7

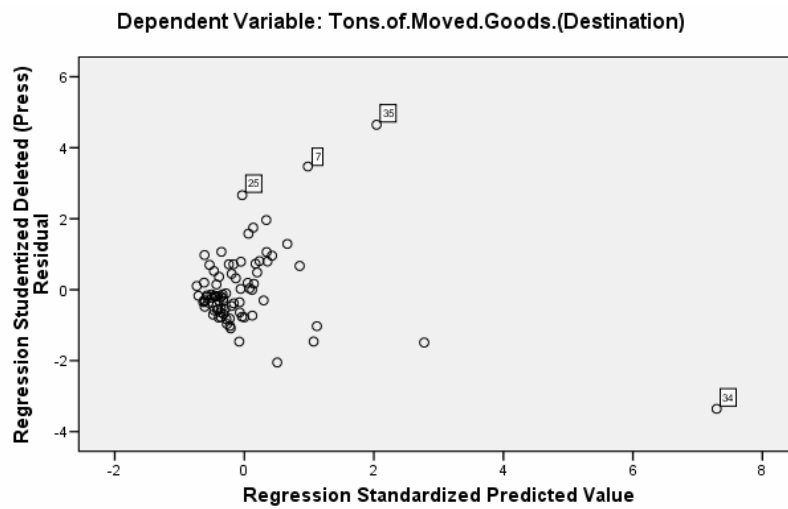


Figure F.12 Scatter Plot of Residuals of Equation 4.7

Table F.4 One Sample Kolmogorov-Smirnov Test on the Normality of Residuals of Equation 4.7

		Unstandardized Residual
N		81
Normal Parameters ^{a,b}	Mean	.0000000
	Std. Deviation	2.006815
Most Extreme Differences	Absolute	.147
	Positive	.147
	Negative	-.091
Kolmogorov-Smirnov Z		1.327
Asymp. Sig. (2-tailed)		.059

a. Test distribution is Normal.

b. Calculated from data.

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HHH Fellow	Rutgers University (State University of New Jersey)	1994-1995
MS	METU Civil Engineering, Ankara	1989
BS	METU Civil Engineering, Ankara	1986
High School	Aydınlıkevler High School, Ankara	1980

WORK EXPERIENCE

Year	Place	Enrollment
1999-Present	KGM, Transportation and Cost Analysis Division	Director
1998-1999	KGM, Motorways Maintenance and Operation Div.	Deputy Director
1994	Federal Highway Administration, Washington D.C.	Intern, (HHH Fellow)
1989-1997	KGM, Planning Division	Chief Engineer
1986-1989	KGM, Planning Division	Engineer
1985-1986	Aydın Pelin-Can Binzet Engineering-Consultancy	Engineer
1985 August	METİŞ	Intern, (Eng. Student)
1984 July	DSİ	Intern (Eng. Student)

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

1. Ünal L., "Seismic Analysis of Bridges - Computer Programs and Case Studies", 1989, M.Sc. Thesis Dissertation, Ankara.

2. Ünal L., “Trans European North South Motorway Project and Environmental Impact Assessment” at the International Conference on Environment and Developments towards 21st Century, 27 - 31 May 1990, Ankara, Turkey.
3. Ünal L., “Karayolu ve Çevresel Etkileri”, Karayolları Vakfı Dergisi, Mayıs 1993, Ankara.
4. Ünal L., “Geleceğin Finansman Modeli Kamu-Özel İşbirliği (Karayolu Projelerinde Özelleştirme)” 1. Yapı İşletmesi Kongresi, 18-19 Ekim 1996, İzmir.
5. Ünal L., “The Existing Highway System in Turkey and Sector Development Expectations for the Years 2000” at the Conference on the Developments of Transportation System for the Years 2000, 15 - 16 May 1997, İzmir, Turkey, (Turkish).
6. Ünal L., “The Economic Lost of the Country Because of Applying Short Range Solutions in Highway Sector” at the Conference on the Developments of the Civil Engineering Area, 15 - 16 Sep. 1997, Ankara, Turkey, (Turkish).
7. Ünal L., “21. Yüzyılda Ulaştırma ve Akıllı Ulaşım Sistemleri” 4. Ulaştırma Kongresi 03-05 Haziran 1998, Denizli.
8. Ünal L., “Ülkemizde Karayollarında Kısa Vadeli Çözümlerin Uygulanması Nedeni İle Yurt Ekonomisinin Kayıpları” Trafik. 8 (1998):1-4, Gazi Üniversitesi.
9. Ünal L., “Ücretli Yol Geliştirme”, Karayolları Genel Müdürlüğü ABD Eğitim Seminerleri, 13 Ocak 2000, Ankara
10. Ünal L., “Otoyolu Bakım İşletme Hizmetlerinin Özelleştirilmesi”, Karayolları Genel Müdürlüğü ABD Eğitim Seminerleri, 13 Ocak 2000, Ankara
11. Ünal L., “Akıllı Ulaşım Sistemleri” Bülten, TMMOB İnşaat Mühendisleri Odası, 2001, Ankara
12. Ünal L., “Ülkemizde İller Arası Yük Hareketi”, 1. Karayolu Ulusal Kongresi, 01-03 Nisan 2008, Ankara.
13. Ünal L., “Ülkemizde Yol Güvenliği ve Trafik Kültürü”, 1. Karayolu Ulusal Kongresi, 01-03 Nisan 2008, Ankara.

HOBBIES

Reading, Swimming, Trekking, Turkish Art Music