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TRANSFERABILITY OF MODE CHOICE MODELS
WITHIN SAUDI ARABIA

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HASAN MUSAED AL-AHMADI

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TRANSFERABILITY OF MODE CHOICE MODELS WITHIN SAUDI ARABIA

By

Hasan Musaed Al-Ahmadi

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ABSTRACT

TRANSFERABILITY OF MODE CHOICE MODELS WITHIN SAUDI ARABIA

By

Hasan Musaed Al-Ahmadi

The main purpose of this research is to determine whether the cost of developing, calibrating, and testing intercity mode choice models for Saudi Arabia corridors can be reduced by transferring models across corridors. To accomplish this purpose, intercity mode choice models were developed and calibrated for two major corridors in Saudi Arabia: the Dhahran-Riyadh corridor and the Jeddah-Riyadh corridor. A general model was developed using data from both corridors, and the accuracy of transferring each specific model was compared with that of the general model.

Several approaches were used to test the transferability of intercity mode choice models. The first approach was to determine if the calibrated model could be used "as is" to predict intercity mode choice in another corridor in Saudi Arabia. The second approach was to determine the accuracy achieved by updating the coefficients and constants of the model using sample data from the corridor where the model was being transferred. In the third approach, it was assumed that the specification of the original model could be used with re-estimated parameters from the test corridor. Finally a modified approach was used. This modified approach

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consisted of two forms. One form of the modified approach was to use a separate scaling factor for each variable, while the other form used distance as the scaling factor.

The results of the attempt to transfer models between corridors without modification was not encouraging. However, the modified approach gave an acceptable goodness of fit. Furthermore, by using the Bayesian updating method, the goodness of fit measure improved in both corridors.

The conclusion reached in this study was that transferring models across corridors in Saudi Arabia is feasible, and the potential cost saving to the kingdom can be significant. It is recommended that additional corridors be studied to verify the universal application of the transfer techniques.

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To my parents, whose love, support, and constant prayer
helped me greatly in my achievement.

To my wife Ebtisam who gave her love, affection, and understanding
in times of stress and strain, and to my son Basam and my daughter
Haneen for giving me continuous enjoyment and numerous laughs
during the difficult time while I was writing this dissertation.

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Gratitude are also extended to Dr. Lidia Kostyniuk for her suggestions which contributed immeasurably both to the research and writing of this dissertation, and to the other members of my doctoral dissertation committee, Dr. K. Rajendra, and Dr. Manderkar for their careful reading of the drafts and specific suggestions.

I wish to express my gratitude to Dr. Richard Lyles for his stimulation, friendly relationship, and help when it was needed. Knowledge grasped from the courses I took with him assisted me throughout this research, and hopefully in my future career.

Appreciation is expressed from the bottom of my heart to Dr. Khalid Abdulghani the Mayor of Jeddah for suggesting this topic and for his help in carryingout this research.

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I would also like to express my appreciation to several fellow students Sayed Maleck and Sami Mohamed for many stimulating discussions we have had.

Thanks and wishes are extended to all my colleagues and "Brothers" at the Islamic Center of Greater Lansing for their encouragement and prayers.

Thanks for King Fahad University of Petroleum and Minerals (KFUPM) for supporting me throughout my studies at Michigan State University.

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Finally I would like to thank my mother, and may father for providing me with my early education. Also, my heartfelt appreciation is extended to all the members of my family for their constant encouragement and their moral support while I was studying in the United States. My special gratitude goes to my wife Ebtisam who has walked every step with me for her patience, care, and encouragement in each step I made toward the completion of the research. I would also express my deep appreciation to my son Basam and my daughter Haneen, whose smiles and childish looks gave me the courage to accomplish my goals. May Allah bless all of us and make us among the righteous (Ameen)

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CHAPTER I

INTRODUCTION

Background: Study Area

Saudi Arabia is located in the southwestern part of Asia. It occupies most of the Arabian Peninsula. The estimated land area for Saudi Arabia is 2,240,000 square kilometers, which is approximately one-third the size of the USA. Saudi Arabia is bounded by the United Arab Emirates, Qatar, Oman, and the Arabian Gulf on the east; the Red Sea on the west; South and North Yemen on the South; and Kuwait, Iraq, and Jordan on the north.

According to the World Almanac and Book of Facts (1987), the population of Saudi Arabia is estimated to be 11,152,000 inhabitants, the birth rate is estimated to be 43.7 per 1,000 population, and the death rate is 15.4 per 1,000 inhabitants.

The temperature in Saudi Arabia varies between the coastal lands and interior land. In the interior, the average mean temperatures in the summer and the winter are around 35°C, and 17°C, respectively. In the coastal region, the average mean temperatures in the summer and the winter are about 30°C, and 24°C, respectively.

Saudi Arabia is one of the rich developing countries. Its wealth comes primarily from oil revenues. The discovery of oil in Saudi Arabia changed the Kingdom of Saudi Arabia from a pre-industrial country to a modern industrial country. This brisk change placed a burden on all public utilities and facilities, especially the transportation system.

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Riyadh is the capital of Saudi Arabia, and Dammam and Jeddah are industrial and commercial cities on the Arabian Gulf and the Red Sea, respectively (see Figure 1.1). The distance between Riyadh and hahran is 467 kilometers, while the distance between Riyadh and Jeddah is 1061 kilometers.

Five modes of transportation serve Riyadh and Dhahran: railroad,airway, bus, taxi, and private car. Four modes serve Riyadh and Jeddah: airways, bus, taxi, and private car. The passenger railway is operated by the Saudi-Arabian Government Railways Organization (SAGRO). The bus mode is operated by the Saudi Arabian Public Transport Company (SAPTCO). SAPTCO is the only bus company allowed to operate buses along these corridors. The taxi mode has been eliminated from this research because very few passengers in Saudi Arabia use the taxi for intercity trips.

Three airports serve the two corridors. King Khaled International Airport serves the Riyadh area, Dhahran International Airport serves the eastern province (Dammam, Khobar, Abgaig, and Dhahran), and King Abdulaziz International Airport serves the Jeddah area. The only air carrier allowed to operate between these airports is the Saudi Arabian Airline (Saudia). Hence, the fare does not change with respect to the day of reservation. The fare is constant within each class and each corridor. However, students receive a 50% discount off the economy fare.

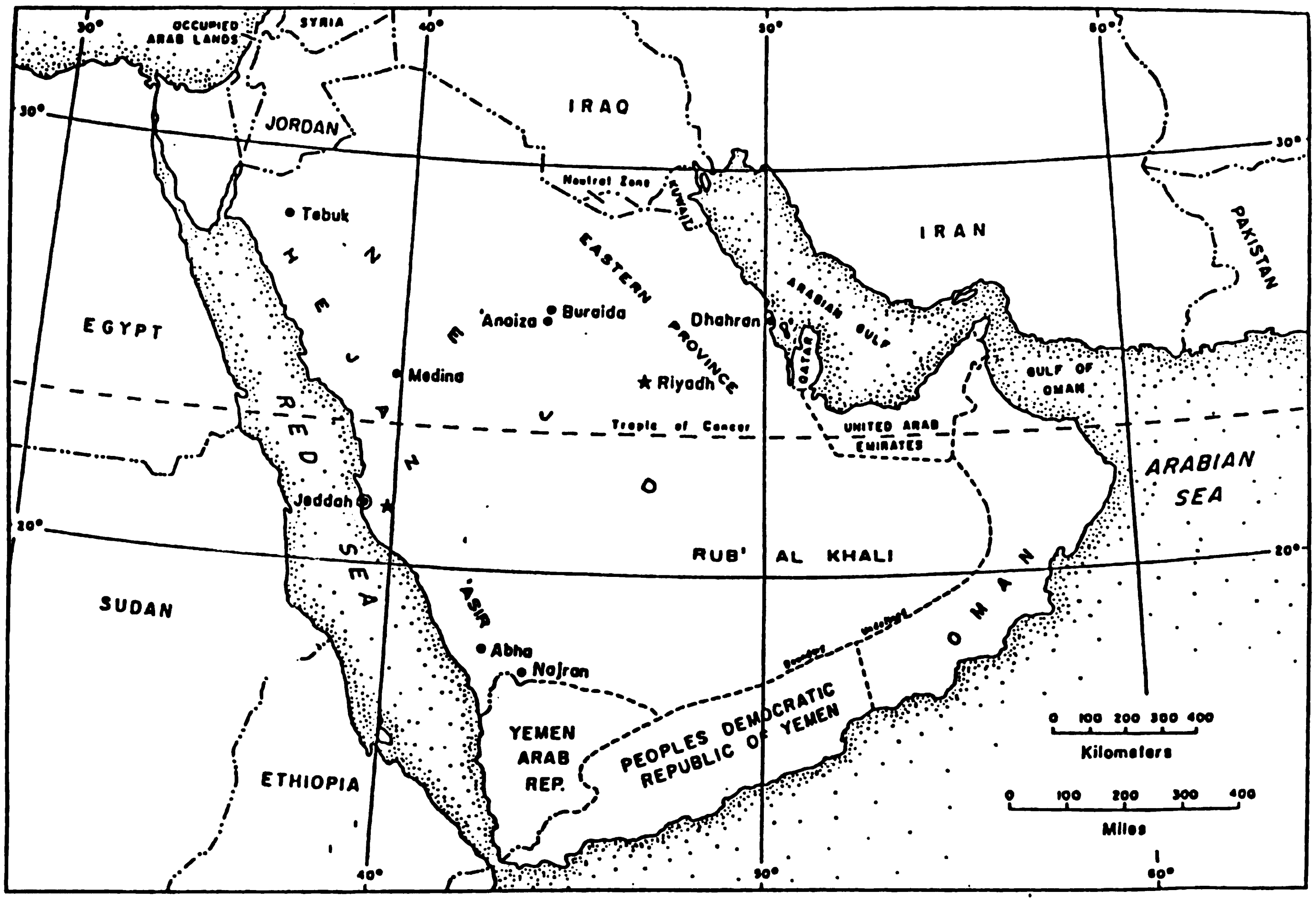

Figure 1.1 Map of Saudi Arabia

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Behavior of the Intercity Tripmaker in Saudi Arabia

Understanding the behavior of the tripmaker will provide the model builder with the most likely variables for inclusion in the model. The definition of a tripmaker in this research is a man who is traveling between cities by himself or with his family. The following paragraphs discuss the characteristics of Saudi behavior when a person makes an intercity trip. These characteristics may not be applicable to Western culture.

In Saudi Arabia, the percentage of females traveling alone from one city to another is very low. This is because the Islam religion forbids women to travel alone. In addition, women are not allowed to drive in Saudi Arabia. They may use an airplane to travel alone, but only under special circumstances, and relatives must meet them at the airport.

Another factor affecting the tripmaker in choosing an intercity mode is the weather. In Saudi Arabia the weather, especially in summer, does not encourage the tripmaker to use ground transportation.

Saudi tripmakers are very concerned with safety, because the risk of becoming involved in an automobile accident is very high. This perception of risk may cause the tripmaker to hesitate to drive his car or use ground transportation for an intercity trip.

Another characteristic of Saudi tripmakers is that they prefer to travel as families (the average family size is around six) for non-business trips. Finally, in Saudi Arabia a unique intercity trip purpose exists. This trip purpose is religious and is called the "Aumra trip". This is not a trip purpose commonly associated with intercity travel in the West.

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Statement of the Problem

The first step in any engineering work is planning. In transportation, planning is especially important because transportation systems are among the most expensive investments to build or modify. The investment in transportation improvements should be based on the understanding of future demand. To achieve this, an understanding of tripmaker behavior is essential.

Understanding the behavior of tripmakers in selecting a travel mode is necessary for public transportation agencies or private carriers to make managerial decisions, and to prevent underdesign or overdesign. For instance, underestimation of future travel demand may lead to congestion, delay, high accident rates on many major roads, and excessive stand-by at major airport terminals. These problems may waste valuable manpower and time, and may impede the economic development of the Kingdom. At the other extreme, if future travel demand is overestimated, too much capital will be tied up in transportation facilities and not used for other more needed aspects of development.

An intercity model must exist to predict the future modal split. The results of this study will provide the transportation agencies with a tool to maximize their revenue and better allocate their resources. In addition, if intercity mode choice models can be transferred directly or through a small effort, such as updating, the benefits would be enormous in that it would significantly reduce the data requirements, calibration time, cost, and detailed analytical expertise required by planners to perform modal split analysis.

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Scope of the Study

There has been significant work done in testing the transferability of intracity mode choice models in the United States. Yet, no research was found that tested the ability of intercity mode choice models to predict the behavior of the tripmaker in corridors other than those where the models were originally calibrated and tested. In this research, the methodology used for intracity mode choice model transferability has been extended to intercity mode choice models.

The primary focus of this study was to evaluate the ability of intercity mode choice models to be transferred across corridors within Saudi Arabia. To test this capability, intercity mode choice models were calibrated for the Dhahran-Riyadh corridor and the Jeddah-Riyadh corridor, and an evaluation was constructed on the transferability of the intercity disaggregate behavioral mode choice models within Saudi Arabia.

A survey was conducted to collect the data required to construct the models. Those data were randomly divided into two data sets. One data set was used for specifying and calibrating the models; the other data set was used for validation purposes.

The term "model" is used to denote an abstraction of reality. In other words, it is an abstract representation of a real-world system that behaves like the real-world system. In constructing any model a hierarchy should be considered. This hierarchy depends on the model's objectives. In this research, the objective of the model is to accurately predict the mode choice of a traveller in selected Saudi Arabia intercity corridors. Given this objective, the steps in intercity mode choice model co

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construction are: develop the theoretical concept of the model (for example, utility maximization); specify the functional form of the model (that is, linear or product form); determine the specification of the model; and, finally, calibrate the model and estimate the values of the variables.

This hierarchy of model construction was used as a guideline to test model transferability. The potential for model transferability decreases as one moves down the hierarchy. For instance, the theoretical concept of the model and the functional form of the model have more potential to transfer than the specification of the model. Furthermore, the estimated parameters have the lowest potential for transferability (27). The theoretical concept and the functional forms are very general and can be extended and adopted to different behavioral contexts (27).

The first step in testing model transferability is to determine if the specification of the variables are transferable. For instance, if the transferable model has some variables that are not applicable in the new context, the model cannot be used to predict the behavior of the tripmaker. If the same specification of variable can be used in both contexts, the specification of the transferable model (the form of the variables only) can be used to calibrate an intercity mode choice model for the new corridor. Statistical testing can then be used to determine if the parameters of the transferable model and the parameters of the new models are equal. A second option is to transfer the model unchanged. A third option is to re-estimate the parameters of the transferable model with a smaller data set than would be used to calibrate a model for the corridor in which the transferability test is being conducted. Each of these approaches was used in this study. A diagram summarizing this research can be seen in Figure 1.2.

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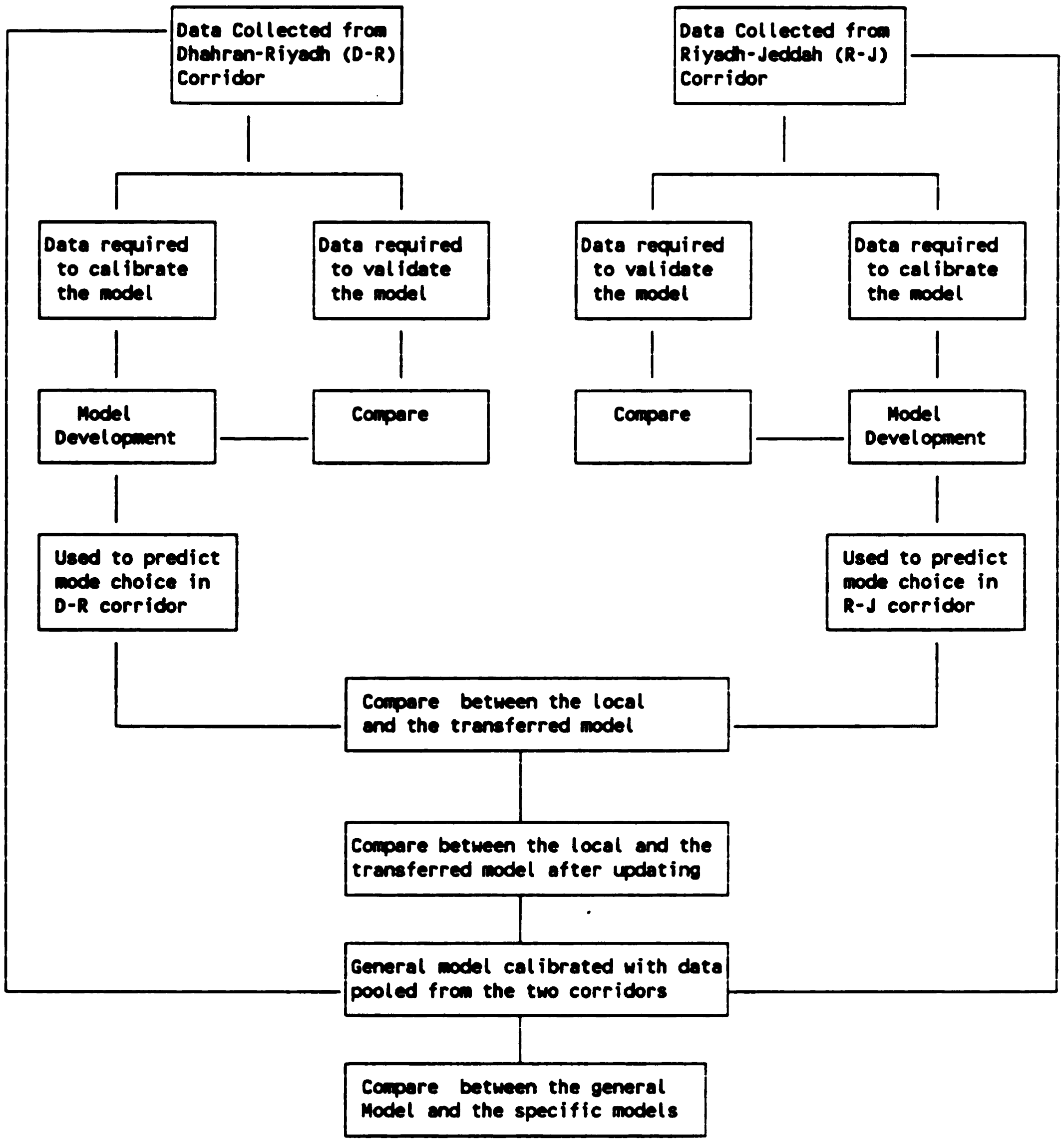

Figure 1.2 Diagram of the Research

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Different hypotheses were used to test the different approaches in this research. These hypotheses are as follows:

1. There is no difference in the prediction accuracy between a local model and a transferred model.
2. There is no difference in the prediction accuracy between a local model and a transferred model after updating the coefficients.
3. There is no difference in the model specification between Saudi Arabia corridors.
4. The parameters of the specification variables for the transferred and local models are equal.
5. Coefficients for level-of-service variables (e.g. time or cost) for the Jeddah-Riyadh model and the Dhahran-Riyadh model are equal.
6. Coefficients for level-of-service variables (e.g. time or cost) for a transferred model after updating and a local model are equal.

Definition of Terms

Aumra	A non-obligatory act of worship occurs in Mecca, which can performed at any time of the year.
Islam	The third major religion that had been revealed to the Prophet Mohammed, the messenger of "Allah" 610-632 A.D.
Local model	The calibrated model for the corridor under study.
Transferred model	The local model transferred to another corridor.
Zoning procedure	A method of dividing the survey area into spatial units (zones) suitable for data collection. The designation of zone boundaries is based on selecting units that will be as nearly homogeneous as possible.

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Plan of Presentation

Chapter I contains the background of the study area, issues in the behavior of the intercity tripmaker in Saudi Arabia, and an introduction to the problem. In Chapter II, a review of the literature is presented. It covers the background of intercity modal-split model development, disaggregate model structure, a review of the previous intercity disaggregate models and their critiques, and past work on transferability.

Chapter III presents the methodology used in conducting this study. In this chapter the recommended approach for data collection, model calibration, and model transferability testing is identified. Statistical analysis of the collected data is presented in Chapter IV. Chapter V includes the development of a calibrated model for each corridor, and the general model. In Chapter VI the results of the transferability study are presented. Chapter VII is a summary of the study, and conclusions and recommendations for further study are presented.

Limitations of the Study

This study has the following limitations:

1. This study includes an analysis of tripmakers in the Jeddah-Riyadh corridor and the Dhahran-Riyadh corridor only.
2. Due to limited funds this study was conducted in the spring and early summer (March, April, and May) of 1988 and may not represent the behavior of the tripmaker the rest of the year. For instance, the behavior of the tripmaker in selecting an intercity mode may be different in the winter.

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CHAPTER II

LITERATURE REVIEW

There is no literature concerning mode choice model calibration or transferability specifically for Saudi Arabia. However, several articles related to the goal of this study exist for the United State Of America (USA) and other developed countries. For the purpose of this study, the major emphasis of this review will be on two major areas Intercity Model-Split Model Development and Transferability Issues. After a discussion the background of the Intercity Modal-Split Model Development, the emphasis of the review on the Intercity Modal-Split Model Development will be on: (a) model structure, (b) measurement of level of service variables, (c) review of intercity disaggregate models and (d) critiques of the previous models. Transferability Issues will emphasize previous research on transferability of mode choice models.

Intercity Modal-Split Model Development

Background: Intercity Modal-Split Model Development

Several research efforts were undertaken from the mid-1960s to the present to develop intercity mode choice models. Much of this research was performed to predict patronage of potential new modes as well as existing modes for the Northeast corridor (1). These intercity mode choice models were based on the analysis of aggregate data. These models include the Kraft-Sarc model, Quandt and Baumol model, and the Walmsley model (1). Development of aggregate models provided researchers with knowledge of the various relationships between zone characteristics and

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and mode choice. For example, aggregate models showed which variables the tripmaker was sensitive to (such as out-of-pocket cost, income, and out-of-vehicle time). Moreover, aggregate models showed that segmentation by trip purpose (business and non-business) is important for intercity mode choice analysis.

However, studies of aggregate models demonstrated that these models may have produced biased estimates of model coefficients due to data aggregation (2, 3). Aggregation before the model was calibrated resulted in a loss of information and a decrease in the explanatory power of the model. These conditions occurred because the assumption behind using aggregate data was that the tripmaker characteristics were relatively more homogeneous within zones than between zones. However, several studies showed that the opposite was true, that more variation occurred within zones than between zones (3, 4).

Model coefficients were determined to explain the variations in observed travel behavior. In a purely statistical analysis, the more variation that was explained by the model the more reliable the model was thought to be. But, as previously mentioned, often more variation occurred within zones than between zones. Thus, a model based on aggregate data was less likely to explain the behavior of the individual, and is thus likely to be a poor prediction model.

Another problem with aggregate models was the risk of 'ecological fallacy' (5) in which correlation among aggregate variables does not necessarily reflect actual individual behavior. In other words, an aggregate model based on average observations of socioeconomic variables in a specific zone does not necessarily represent an individual tripmaker's behavior in that zone or the average behavior of the t

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the tripmaker in that zone. This condition may occur because data aggregation before the model construction phase of the analysis may cloud the underlying behavioral relationships and result in a loss of information. Several studies showed that intracity aggregate models produce biased estimates of model parameters (2, 3).

Another limitation of an aggregate model is that it is expected to be non-transferable between contexts because the bias resulting from aggregation is generally different between contexts (6). In other words, the reason that aggregate demand models may not be transferable is that a group of individuals, on average, may not behave the same as an individual who possesses average values of the explanatory variables. These phenomena associated with aggregate models made them questionable for transferability and prediction purposes.

The disaggregate approach was the second generation in modeling methods. The development of disaggregate models provided a more effective tool for predicting an individual's behavior in selecting one mode from among different modes available. The decrease in explanatory power of the aggregate models due to data aggregation was avoided with the disaggregate models. This advantage greatly improved the predictive power of disaggregate models. For example, Watson (7, 8) developed and evaluated aggregate and disaggregate binary (rail versus car) mode choice models in the Edinburgh-Glasgow corridor. His results indicated an error in mode choice prediction for this city pair 12 to 15 times higher for an aggregate model than those for a disaggregate model for the same specification. The result of this study is shown in Table 2.1. The disaggregate model was preferred over the best aggregate model for intercity travel prediction.

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Table 2.1

Comparison Between Aggregate and Disaggregate Model Predictions

Actual train tripmakers	Aggregate Prediction	Disaggregate Prediction
1,183	1,029	1,184
% prediction error	13.02	0.08

The development of disaggregate models was extensively documented (9, 10, 11, 12, 13, 14, 15, 16) and is widely used in urban travel analysis.

The use of disaggregate models is supported by their representation of the individual tripmaker's decision, data efficiency, and superior estimation results. Most disaggregate models are based on the theory of "utility maximization." They assume that a person makes a particular choice from a set of different alternatives depending on the maximum benefit he receives. For example, a person may wish to minimize travel time and cost of the trip, and maximize comfort and convenience in selecting a mode from the available modes.

The primary model form for intercity mode choice utilizing disaggregate data is in a probabilistic form, as seen in the following example:

$$P^i_k = \frac{\text{EXP } V_{ki}}{\sum_j \text{EXP } V_{ji}}$$

Where:

P^i_k = probability of tripmaker i choosing mode k out of j alternatives

V_{ki} = the utility of alternative k to trip maker i
= (X_k, S_i)

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X_k = a row vector of characteristics of alternative k

S_i = a row vector of socioeconomic characteristics of a tripmaker i

From this example, we see that the probability of a tripmaker choosing a particular alternative is a function of the characteristics of the tripmaker; such as, income, age, and sex and of the characteristics of the mode relative to alternative modes.

Disaggregate Model Structure

Model structure is the central theoretical concern for modal-split analysis. Multinomial logit (MNL), nested logit (NL), and multinomial probit (MNP) are the popular types of demand functions tested to date (17,18) (logit and probit models are described in Appendix A). The choice of the types of demand functions depends on the similarity among transport modes and the underlying behavior of travelers (19). When travelers evaluate air, rail, and roadway modes simultaneously, MNL models are usually specified. When travelers evaluate roadway and railway as one composite alternative against air, then MNP or NL models are usually used. The assumption in the simultaneous approach is that the tripmaker considers all attributes of the available alternatives at the same time. For instance, the tripmaker will consider airplane, train, car, and bus at simultaneously. On the other hand, for the sequenced or nested model one assumes a certain hierarchy exists among the choices. For example, the tripmaker compares the air mode and ground mode, then compares the train, bus, and car within the ground mode.

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Unfortunately, software capable of estimating efficient nested logit models does not exist (20). A further problem is that simple computer programs give incorrect results for the nested models with respect to the accuracy of the estimates in the upper levels of the model. Moreover, the nested model is quite complicated to specify and utilize. Hensher and Johnson (15) stated that a simultaneous structure is preferable from theoretical considerations to the nested structure. In a study of decision making Ben-Akiva and Koppelman (18) stated that:

> The problem with ... decisions is that we cannot find a unique 'natural' sequence of partitions that will be generally applicable. Therefore a simultaneous structure is superior to a recursive structure.

Moreover, the number of alternatives available to the tripmaker in this study are within the realistic limit of the simultaneous approach. Furthermore, the simultaneous model is calibrated one time, whereas with the sequential model a number of models have to be calibrated depending on how they are postulated.

Based on the finding of these authors, the simultaneous logit approach will be used to calibrate the models for the corridors under study. The logit model has been the most prominent methodology used in disaggregate travel demand models. The logit model assumes that a person chooses a particular mode from different alternative modes depending on maximum benefit. The multinomial logit model is based on the following assumptions about the random terms of the utilities:

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The logit model has been widely used in intracity modal split analysis (21). In addition, the properties of the logit model have been identified and tested. Moreover, because logit models are stochastic they are more likely to simulate the actual decision process as can be seen from the following paragraph.

First, the tripmaker does not always make rational decisions, and consumer idiosyncrasies cannot be anticipated in a deterministic model. Second, it is usually impossible to include all the variables which influence the choice function. If all the variables influencing the choice function are considered, the model will become a complicated one. There may be essential random elements in the consumer's behavior since it varies from day to day (22). Finally, consumers may not have correct information about the attributes of the alternatives.

Several studies compared probit and logit models. The result of these studies show that the same prediction capability can be obtained by both techniques (17).

In summary, the reasons for the choice of the logit form for the structure of the proposed models are as follows:

1. The logit approach has been widely used and tested in several studies (21).
2. The logit form has a more straightforward estimation procedure than the probit model which requires a complex computational procedure.
3. Many statistics packages have this model, while the others are under development or have not been used.

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Model specification is another important issue in model calibration. There are two specification measures to calibrate the required models: generic specification and alternative specific specification. In a generic specification, the estimated coefficient for any variable is restricted to the same value across the alternatives. The coefficient in an alternative-specific specification can vary from one alternative to another. In other words, a separate coefficient is estimated for each level-of-service (LOS) attribute of each alternative.

There are two major advantages to using generic LOS data in disaggregate mode choice models. First, generic LOS variables are consistent with the economic utility theory. Second, the use of a generic LOS facilitates demand forecasts of new choice alternatives. Moreover, the abstract model attempts to quantify mode characteristics affecting their likelihood of being chosen. It also requires fewer numbers of parameters than the mode-specific model.

A mode-specific constant may be introduced in the abstract choice function to capture mode effects that are not captured by the variables common to all alternatives. However, the best type of specification cannot be known until an empirical study is done.

The previous paragraphs can be summarized by noting that the disaggregate simultaneous abstract logit form has been recommended for the structure of the proposed models unless the empirical study shows that a different form is much better in explaining the behavior of the intercity tripmaker.

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Independence from Irrelevant Alternatives Property (IIA)

One of the most important issues about the logit model is independence from irrelevant alternatives property (IIA). This property states that if two modes are available and a new mode is introduced, the ratio of the probabilities of the two old modes have been unchanged regardless of the choice for the new mode. The IIA property is both one of the strengths of the logit model and its major weakness. The property is advantageous in that the model can be calibrated based on one choice set of alternatives and then used to predict choices from a modified choice set. For example, a mode split model can be calibrated based on currently available modes and then used to explore the impact of introducing a new mode into the system. The problem with the IIA property is that the alternatives included in the choice set are independent of each other. To describe this weakness, due to the IIA property, the classic case of red and blue buses has been used. For instance, assume that both the auto and red bus modes capture 50% of the travel market. Then a new blue bus is introduced which has exactly the same service attributes as the red bus but has a different color. The actual market share now becomes 50, 25, and 25 percent for auto, blue bus, and red bus, respectively. The car share remains the same but the share of the red bus is reduced to 25%. However, the multinomial logit model (MNL) will predict that each of three modes capture 1/3 of the market. This condition increases because IIA requires that the ratio of the red bus share to the auto mode should not be affected by the introduction of the new mode.

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McFadden, Tye, and Train (13) investigated a wide range of computational feasible tests to detect a violation of the IIA assumption. The test involved comparison of logit models estimated with a subset of alternatives from the universal choice set. This test involves a comparison of two likelihood values. One is the likelihood resulting from estimating the restricted sample by using the parameters of the universal set, while the other likelihood value is the one resulting from estimating the restricted sample but without restricting the parameters.

The likelihood ratio test statistic was used to test the IIA assumption. This test statistic is chi-square distributed with degrees of freedom equal to the number of restricted parameters. This test will be used to test the null hypothesis that the IIA model structure holds

$$IIATST = -2(LL_r(\beta^{*}) - LL_u(\beta^{*}))$$

Where $LL_r(\beta^{*})$ is the likelihood from estimating the restricted sample by using the parameters of the universal set, and $LL_u(\beta^{*})$ is the likelihood resulting from estimating the restricted sample without restricting the parameters.

Measurements of Level-of-Service Variables.

There are two major measures of the level-of-service (LOS) attributes: perceived and objective values. Perceived LOS data are those values the individual reports when answering a questionnaire. Objective LOS data are the reported values by the carrier, such as the fare and the published train, bus, and airplane schedules. For auto users, the objective LOS values are the averaged ones. For example, total in-vehicle time is the distance between the two centers of the cities divided by the average travel speed.

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Considerable debate has been found in the literature over whether perceived LOS or objective LOS values should be used in model calibration. This debate stems from the fact that travel decisions are not based on actual time and cost but rather on the expected or perceived values. Thus, for a better behavioral model, perceived LOS values should be used in model calibration.

In practice, this method presents major problems. One problem with perceived data is that the traveler's perception of LOS on the chosen alternative to other alternatives is likely to be in favor of the chosen alternative. This condition exists when a tripmaker is questioned about the attributes of his chosen alternative. He tends to justify his choice by making it seem more attractive than it really is compared to the alternatives rejected. Furthermore, for predicting future modal split, the manner in which LOS values are estimated in the base year would have to be used in estimating the future values. Only objective or engineering values can be used for estimating future LOS values.

There is an argument that perceived data is actually weighted engineering data (26). If models are to be transferred, objective LOS values should be used in the model. Whether perceived or objective values are used in the model, objective values are needed for the base year to estimate future values of the variables included in the model. In this research, perceived data for the chosen mode were collected from the tripmaker. Moreover, objective LOS data for the modes under consideration were collected from the agencies operating those modes. In other words, a model having the two types of measures will be calibrated; the perceived data for the chosen and the objective data for the unchosen modes.

Review of Intercity Disaggregate Models

The first disaggregate intercity mode choice model was developed by Watson (7). He developed a disaggregate binary (rail versus car) mode choice model in the Edinburgh-Glasgow corridor. The disaggregate specification he used was very simple (see Table 2.2). He used four variables to explain the tripmaker's behavior: out-of-pocket cost (C), total travel time (T), waiting time (W), and number of modes used in a one-way trip (N). The expression of "utility" used to calibrate the disaggregate model may be seen in Table 2.2.

Stopher and Prashker (23) developed multinomial logit models to forecast intercity modal split among car, rail, bus, and air. They used 2085 observations from the 1972 National Travel Survey (NTS) to formulate various intercity choice models. The formulation which best explained the tripmaker behavior was segmented for business and non-business trips, as shown in Tables 2.3 and 2.4. The linear additive utility used to calibrate the model was:

$$G(X_k) = a^k_0 + a_1 T_k + a_2 C_k + a_3 F_k + a_4 D_k + a_5 E_k$$

Where

$G(X_k)$ = The utility function describing alternative k

T_k = Line-haul travel time for alternative k

C_k = Line-haul travel cost for alternative k

F_k = Service frequency of alternative k

D_k = Line-haul distance for alternative k

E_k = Access-egress travel time for alternative k

a_0^k = Model constant for alternative k

$a_1, a_2, \ldots, a_5$ = coefficients

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Table 2.2

Watson Intercity Mode-Choice Disaggregate Model

Variable	Coefficient	t-Value
Relative time difference (Td)	-1.05	-6.48
Relative cost difference (Cd)	-0.667	-8.95
Difference in waiting time (Wd)	-0.002	-9.45
Difference in number of journey segments (Ns)	-0.132	-5.95

$$P_{rail} = \{1 + EXP\ [Td(T_{car}-T_{rail}) + Cd(C_{car}-C_{rail}) + Wd(W_{car}-W_{rail}) + Ns(N_{car}-N_{rail}]\}$$

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Table 2.3

Stopher Intercity Mode-Choice Disaggregate Model
for Business Trip

Variable	Coefficient	t-statistics
Line-haul travel time	-0.62	-2.1
Line-haul travel cost	-3.96	-9.79
Service frequency	0.01	-3.44
Line-haul distance	-10.64	-5.78
Access-egress travel time	-0.52	-3.13
Bus constant	-1.65	-4.31
Rail constant	-0.40	-0.93
Air constant	3.13	-5.10
X^2 (d.f)	1016 (8)	
% Predicted Correctly	63.1	

Table 2.4

Stopher Intercity Mode-Choice Disaggregate Model
for Non-Business Trip

Variable	Coefficient	t-statistics
Line-haul travel time	-1.69	-5.65
Line-haul travel cost	-4.25	-7.95
Service frequency	0.012	-4.48
Line-haul distance	-0.523	-0.29
Access-egress travel time	-0.196	-1.59
Bus constant	-1.41	-4.42
Rail constant	-0.365	-0.96
Air constant	2.476	-4.08
X^2 (d.f)	1561 (8)	
% Predicted correctly	77.8	

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The Stopher models are not truly disaggregate since they used average values for travel time, travel cost, service frequencies, and access-egress times for each trip mode in each corridor. Even though the model fit was quite good, it was unable to replicate mode shares in other selected corridors. Furthermore, many computed elasticities were counter-intuitive. For example, a 25% reduction in rail fare was predicted to reduce rail, bus, and auto shares. The authors attributed the unsatisfactory results to the quality of the data used.

Grayson (24) used the same NTS data to calibrate another multinomial (car, rail, bus, and air)intercity logit choice model. His formulation differs from the earlier model by the replacement of access time by access distance to terminal and the inclusion of a variable formed by the product of travel time and family income. This variable follows the hypothesis that the value of time varied linearly with income. The model specification was:

$$U_m = aC_m + bYT_m + cY/2F_m + dYA_m + e_m$$

Where

U_m = utility of mode M

C_m = travel cost of mode M

T_m = travel time of mode M

F_m = frequency of mode M

A_m = access of mode M

Y = family income/2000

a, b, c, d, e_m = Coefficients to be estimated

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With this approach, Grayson obtained a good fit and explanation of the behavior of the tripmaker for all trip purposes (see Table 2.5). Improved results of Grayson's effort relative to those of Stopher and Prashker were probably due in part to the inclusion of access distance in the 1977 NTS data, the use of more accurate road mileage estimates, and improved model specification (inclusion of the income variable and elimination of relative values for attributes).

More recently, Stephanedes et. al (25) calibrated multinomial choice models for business travel in the Twin Cities-Duluth, Minnesota corridor for bus, plane, and auto modes (See Table 2.6). Variables used to build these different intercity mode choice models were out-of-pocket cost (OPTC), household income (HINC), total travel time (TTT), out-of-vehicle travel time (OVTT), distance (DIST), in-vehicle travel time (IVTT), and waiting time (WT) for bus only (other modes had 0 waiting time), household income for auto ($HINC_a$), and mode-specific constants for bus and plane.

All the variables in these models were significant with 90% confidence except the airplane mode-specific constant, which showed a confidence limit around seventy percent. Three-hundred people were randomly contacted at the Twin Cities air and bus terminals and outlying gas stations to ensure completely disaggregate data in the analysis.

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Table 2.5

Grayson Intercity Mode-Choice Disaggregate Model

Variable	Coefficient	t-statistics
Travel cost	- 0.0161	- 5.65
Travel time	- 0.024	-12.66
Service frequency	- 0.0055	- 1.81
Access time	- 0.0007	- 1.66
Bus constant	- 2.552	-14.32
Rail constant	- 3.027	-16.89
Air constant	- 2.7	-14.6
p^2	.303	
% Predicted correctly	82.7	

p^2 = Goodness of fit measure.

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OVTT =
IVTT O
WT O
HINC H
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C_p 1
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Table 2.6

Stephanedes Et al. Intercity Travel Mode-Choice Disaggregate Models

Variable	Minnesota 1	Minnesota 2	Minnesota 3
OPTC/HINC	- 3.43 (-2.74)	---	- 7.75 (-5.07)
OPTC	---	- .69 (-5.10)	---
OVTT/DIST	---	-30.90 (-3.50)	-23.20 (-3.13
IVTT	- 0.01 (-2.03)	- 0.08 (-1.41)	- 0.08 (-1.81)
TTT	- 0.06 (-4.38)	---	---
WT	---	---	- 0.20 (-1.90)
$HINC_a$	---	0.24 (2.13)	---
C_b	4.80 (2.10)	4.68 (2.65)	3.82 (2.95)
C_p	-12.13	24.80 (2.56)	7.62 (1.20)
p^2	0.61	0.64	0.50
% predicted correctly	73	78	69

(**) t-statistic
OPTC One-way out-of-pocket cost.
TTT One-way total travel time,min;
TTT = IVTT+ OVTT
OVTT One-way out-of-vehicle time,min;
OVTT = AT+WT+ET
IVTT One-way in-vehicle travel time,min.
WT One-way wait time,min.
HINC Household income,000$
$HINC_a$ Household income for auto,000$
C_b 1 for bus, 0 else
C_p 1 for plane, 0 else
p^2 A goodness of fit measure.

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From this literature review it can be seen that although these models were disaggregate and were developed for a specific trip purpose, they showed different specifications and different coefficients. This difference between coefficients exists because different variables were used in calibrating the model, leading to different trade-offs between variables.

The ratio of any two coefficients appearing in the same utility function provides an estimate of the trade-off or a marginal rate of substitution between the two corresponding variables. In other words, the ratio of these coefficients represents the relative importance of one variable to another. However, the value of the coefficient for each variable depends on the utility function. Different utility functions will produce a different coefficient value for each variable because in each function the tripmaker weighs the variables differently. However, the ratio between the coefficients of any two variables having the same unit in any utility should be constant (17).

This literature review only indicates the variables that influence the mode choice in Western countries. No mode choice model calibrated in the Arabic culture, or in Saudi Arabia, was found in the literature. Therefore, variables that influence mode choice cannot be known until the empirical study is done.

Critique of the Previous Models

From the previous observations of available intercity mode choice models, several conclusions may be reached. First, all models assume the tripmaker will choose a particular mode from among different alternative modes available to maximize some measure of benefit. Second, these models use the same functional linear lo

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linear logit form. This is because the specification variables are assumed to be independent, and due to the utility theory, the linear additive form is an appropriate model (26). Third, these models differ in terms of their specification and this leads to different coefficients, as explained in the previous section.

The Watson model was developed for a binary (rail versus car) mode choice case. Moreover the model was calibrated using mode specific constants, limiting its use to rail-versus-car modes. This model is not appropriate for this study because a model for choosing a mode among several modes is required. Furthermore, the variables in the Watson model are not satisfactory since they do not include in-vehicle travel time, egress time, and income. The value of waiting time to a rich tripmaker is not the same as to a poor traveler. While the difference in waiting time between the bus mode and the rail mode may not be great, this factor will be important as additional modes are considered.

The absence of trip length or its related measures from the model specification represents a deficiency for this study. Other studies have indicated that intercity travel mode choice depends heavily on trip length and purpose. Different characteristics exist in the choice of mode for an intercity tripmaker as trip length increases (22), and different elasticities in the mode choice model will result as the trip length increases significantly. Some researchers stratified trips by trip length in conducting their intercity mode choice analysis (22). They divided intercity trip length into "long-haul" and "short-haul." If the trip length was more than one thousand kilometers, it was considered a long-haul trip. If the trip length was less than one thousand kilometers, it was considered short-haul (22). Since this study will cons

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will consider only two corridors, this technique is not applicable.

The major drawback of the Stopher model is that it was calibrated with partially aggregated data. Average values for travel time, travel cost, service frequencies, and access-egress times for each trip mode in each corridor were used. In addition, the model was unable to replicate the mode share in selected corridors; therefore the model could not be used effectively in policy analysis.

The Grayson model is also a pseudo-disaggregate model because it was calibrated with partially aggregated data. Moreover, it did not include some of the important specifications explaining the tripmaker's behavior. For example it did not include in-vehicle time, length of trip, or a measure of income (such as out-of-pocket costs related to income).

The Minnesota models were calibrated for the business trip only. The models were calibrated with disaggregate data and were used effectively in policy analysis. The major drawback for the Minnesota models is that they were calibrated with a small sample (only 90 observations were found to be suitable for analysis out of the 300 people interviewed). If the Minnesota models had been calibrated with a large sample size, they might be the best candidate models to test transferability. None of the known intercity models is believed to be a candidate for use in a transferability test conducted in Saudi Arabia. However, it is believed the specification of the variables used to calibrate the Minnesota models is likely to be the most explanatory measures of tripmaker behavior in the Riyadh-Jeddah and the Dhahran-Riyadh corridors.

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Transferability Issues

Previous Research on Transferability of Mode Choice Models

In recent years much work has been undertaken in developing disaggregate mode choice models. Yet little work has been done in evaluating the ability of these models to predict the tripmaker's behavior in contexts other than those where the models have been calibrated. There are no examples of intercity mode choice models in the literature that have been tested for transferability. This may be due to the fact that there are only four known intercity mode choice models, and each of these models has weaknesses which have been discussed.

Additional intercity mode choice models may exist, but they have not been published and were developed for private operators. However, some work has been done in evaluating the ability to transfer intracity models. These studies provide insight into the ability to transfer and test intercity mode choice models.

The actual comprehensive conceptual studies on transferability of intracity mode choice began in the late 1970's (27, 28, 29, 30, 31, 32). Atherton and Ben-Akiva (33) tested the ability of transferring a work-trip modal split model, estimated on Washington D.C. data, to New Bedford and Los Angeles. The model predicted the probability of a traveler choosing to drive alone, share a ride, or use mass transit for a work trip. The independent variables included mode-specific constants, in-vehicle times, out-of-vehicle times, and out-of-pocket costs for the three modes: income, auto availability, and a dummy variable indicating whether the tripmaker was the head of household. The test they performed was based on using the variables of the original (Washington) model to calibrate new models with New

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Bedford and Los Angeles data and then comparing the coefficients of the new models with those of the old model.

The comparison of the coefficients consisted of a statistical test of the null hypothesis that the individual coefficients of the Los Angeles and New Bedford model were equal to their Washington model counterparts. For both the Los Angeles and New Bedford models, only the coefficients on the auto availability variables were significantly different from their Washington counterparts.

Four approaches were used by Atherton and Ben-Akiva to test the ability of the Washington model to explain travel behavior in Los Angeles and New Bedford.

The first approach was transferring the original model. The second approach used the aggregate population share of various modes to adjust the mode-specific constants. The logic behind this approach was that since mode-specific constants capture the mean effects of the unobserved factors, and since these factors cannot be measured or controlled, they were most likely to vary from one city to another. This approach could not be used to forecast analyses because the resulting model was only replicating the existing data and did not explain the behavior of the tripmaker in the new context.

The third and fourth updating approaches assumed the presence of a small, disaggregate sample (44, 89, 177 observations). The third approach ignored the original coefficients and transferred only the model variables. The disaggregate data set was used to calibrate a new model (as specified in the Washington model). Thus all of the model coefficients were recalibrated. The major drawback of this approach was that for a small sample the coefficients could be seriously biased, and if a larger sample

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sample was required it meant the advantage from model transferability was lost. Furthermore, it was better to calibrate a new model for the new context if a larger sample was required.

The fourth approach was to consider the coefficients of the original model as prior information for the true coefficients and use the small sample coefficients to update this prior information. This approach for combining sample information with prior information is known as Bayesian updating (34). The form they used, and the form to be used in this research to update the constants, is as follows:

$$\theta_2 = \frac{(\theta_1/\sigma_1^2)+(\theta_s/\sigma_s^2)}{(1/\sigma_1^2)+(1/\sigma_s^2)}$$

and

$$\sigma_2 = ((1/\sigma_1^2)+(1/\sigma_s^2))^{-\frac{1}{2}}$$

Where

θ_1 = original coefficient

θ_s = sample coefficient

θ_2 = updated coefficient

σ_1 = standard deviation of the original coefficient

σ_s = standard deviation of the sample coefficient

σ_2 = standard deviation of the updated coefficient

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The most significant result of their research was the ability of the original Washington model to explain the behavior of the tripmaker in New Bedford. Furthermore, they found the Baysian updating method gave the best performance. The results of their research verified the ability to transfer disaggregate mode choice models.

Koppelman and Wilmot (35) discussed issues that influenced transferability and methods to evaluate the process. These methods were demonstrated by dividing the Washington, D.C. region into three sectors. Socioeconomic data such as round-trip total travel time, round-trip out-of-vehicle travel time divided by trip distance, number of cars per driver (used as an alternative-specific constant for travel alone), and other dummy variables for government worker (as an example) were collected from each sector. The summation of data from the three sectors was used to build four models: one model for each sector, and a model for the Washington, D.C. region. These models described the choice among drive-alone, shared-ride, and transit alternatives for "breadwinners" working in the central business district (CBD). They then analyzed intraregional transferability of these models. The results of their study indicated that at the 0.01 level the observed choice frequencies differed significantly from those generated by transferable models in five of the six cases. They also found that a model that transferred from sector A to sector B could not necessarily be transferred from sector B to sector A. However, the level of significance used to reach this conclusion was not mentioned in their paper.

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Another study by Koppelman et al. (36) examined the effectiveness of updating procedures to enhance model transferability. This study was concerned with the effect of updating alternative specific constants and the scale of the model parameters, representing the variance of the distribution of the error terms, on the transferability of a disaggregate mode choice model. This study used a disaggregate sample to recalibrate the mode-specific constants and to calibrate a scaler used to scale all of the other coefficients (to keep the ratios between them unchanged). The logic behind recalibrating mode-specific constants was the assumption that the mean effect of unobserved factors was likely to vary from one city to another, and this was reflected in the adjustment of the mode-specific constants. The logic behind adjusting the scale of the other coefficients was that travelers in different cities did not differ in the level of importance they attached to the variables in the mode choice utility. Maintaining the scale of the coefficients assumed constant tradeoffs between measured attributes. This approach was demonstrated and evaluated for both intraregional and interregional transfer of disaggregate models of mode choice for the work trip. One-fifth of the size of sample required to calibrate the full model was recommended for updating.

The results of this study indicated that full-model transfer is better than using only market-share information to adjust the transfer model. Furthermore, the use of updating procedures substantially improved the expected level of model effectiveness. Adjustment of alternative specific constants explained half of the deficiency with respect to local models, while adjustment of the parameter scale provided only a small incremental increase in model effectiveness. In summary, this study

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study indicated that one-half of the difference between full transfer and local estimation was obtained by updating mode specific constants. An additional small increment in model effectiveness could be obtained by updating both the specific constants and parameter scale. In conclusion, the results of their study indicated that model transfer using the previous updating method was better than full-model transfer or the development of a new model estimated with a small sample. Furthermore, the effectiveness of the transfer model could be substantially improved by adoption of the updating procedures.

From the previous work it can be seen that evidence of the transferability of logit mode choice models from one location to another is encouraging. Yet, it also appears that models are not perfectly transferable and a procedure for updating is required. However, the updating procedures are minor efforts compared to the initial model development.

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CHAPTER III

METHODOLOGY

This chapter describes the methodology used in conducting this study, which consist of two major parts: model development and model transferability. The methodology of model development is directed toward data required, sampling strategy, sample size, model calibration, and model testing. The methodology of model transferability is directed toward the recommended approaches for transferring a model.

Model Development

Data Required

Based on the literature, the data needed for specifying, calibrating and testing transferability consist of three categories: socioeconomic variables, level-of-service or supply variables, and data regarding the trip. Some of these variables are qualitative and others are quantitative. In model calibration it cannot be predetermined which variables best explain the tripmaker's behavior unless the impact of the other variables is tested in the preliminary modeling stage. For this reason, the following variables have been collected and used to determine the best fit model for each corridor under study.

For the level-of-service variables which may influence the tripmaker's choice, the following variables have been collected:

1. In-vehicle travel time. This is the time in minutes spent in the mode for a one-way trip.

2. Access time. This is the time in minutes that the tripmaker spends after leaving the origin until he gets into the mode of choice.

3. Egress time. This is the time in minutes the tripmaker spends after leaving the mode terminal until he reaches the destination.

4. Waiting time. This variable is the time in minutes between the time the tripmaker arrives at the terminal and departure of the trip.

5. Total travel time. This variable is the summation of access time, egress time, waiting time, and in-vehicle travel time.

6. Travel cost. Travel cost is the total cost perceived by the tripmaker, such as airplane fare or gas for the auto user. This is mainly out-of-pocket cost. Perceived cost has been found to be more important than actual cost in mode choice decision-making from the traveler's point of view (37). Trip cost has been estimated in Saudi riyals. This total cost for travel consists of two parts. One is in-vehicle cost, which includes fare paid for the major carriers, e.g., airplane or train, and the perceived operation cost for a private car. The other component is the out-of-vehicle cost, which includes costs such as access, egress, and parking costs.

7. Comfort, Privacy, Safety, and Expense are qualitative and attitudinal variables which are used to explain the behavior of the tripmaker in choosing a mode.

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variable

Another category of data collected consisted of socioeconomic variables. Socioeconomic characteristics for a given tripmaker do not vary across alternatives as do the level of service variables. Socioeconomic characteristics enter into the choice function as mode-specific, or as a function of the level-of-service variables, such as out-of-pocket cost divided by income. The following are the socioeconomic variables collected for use in explaining mode choice behavior:

1. Income. This variable is commonly used as an indicator of a trade-off between expense, convenience, and other qualitative variables. Furthermore, it is also used as a proxy for other quantitative variables, such as the number of autos in the household. Income has been considered in the Saudi monetary unit, the Saudi riyal (SR).
2. Car ownership. This variable is used to determine whether the tripmaker owns a car or is captive to other modes. In other words, does the tripmaker have a complete set of choices? Furthermore, the number of autos available to a household may affect the mode choice behavior.
3. License. This variable has been used to determine if the tripmaker actually has a choice between an auto and other modes.
4. Group size. This variable has been used to determine the impact of the size of a group traveling together in the tripmaker's mode choice.
5. Family. This variable has been used to determine if the group traveling together is related. The size of the family traveling between cities often reflects the actual cost of the trip.

6. Age. This variables has been used to determine if age has an impact on intercity mode choice.

7. Nationality. To determine if there is a difference in travel behavior for intercity mode choice between Saudi citizens and non-Saudis, this variable has been introduced into the questionnaire.

8. Permanent residence versus non-permanent residence. This variable will distinguish between tripmakers from outside the country and tripmakers from Saudi Arabia.

Data regarding the trip were collected and are summarized as follows:

1. Trip purpose. The distinction among trip purposes is an important step in mode choice analysis because different tripmaker behaviors are expected in selecting a mode for different trip purposes (22). In order to distinguish between trip purposes, this information should be available to the model builder. Trip purposes include business, personal business, aumra, social, recreational, and work.

2. Duration of stay. The length of time a tripmaker is planning to stay at the destination city has been collected. The categories for this variable are one day, 2-7 days, and more than 7 days.

Moreover, objective LOS data for the modes under consideration have been collected from the agencies operating those modes. In other words, a model having the two types of measures will be calibrated: perceived data for the chosen and objective data for the modes not chosen, except the perceived value will be used for comfort, privacy, expense and safety for all modes.

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Sampling Strategy

Data collection is the preliminary step in any travel demand study. Random sampling, stratified sampling, and choice-based sampling are the three possible procedures for data collection. Random sampling and stratified sampling are usually used when users in the transportation market are evenly distributed. Choice based sampling, which samples passengers on the roadside, trains or planes, is recommended when the demand in the transportation market is unevenly distributed (38). Consequently, choice based sampling has been used to collect the required data.

The choice based sampling technique is the least expensive method for sampling. With the choice based method, observations are drawn based on the outcome of the decision maker process. Choice-based sampling is conducted by identifying the decision group of interest and then randomly choosing individuals from this group.

Sample Requirements

Sample size determination is an important decision in the planning phase of any research. The sample size required in any statistical analysis is dependent upon the desired level of confidence and the size of the interval.

Snedecor and Cochran (39) stated that the sample size depends on the allowable error (L) in the sample mean, the specified degree of confidence that the error will not exceed L, $((1-\alpha)*100\%)$, and the standard deviation. Mathematically it can be represented as follows:

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$$n = \frac{[z(1-\alpha/2)]^2\sigma}{L^2}$$

Where:

n= sample size.

σ= standard deviation.

L= allowable error.

z= normal random variable.

$1-\alpha$=confidence level.

Model Calibration

Calibration is the process of estimating model parameters using collected data. Based on the literature review, a simultaneous logit approach is recommended to be the structure of the models for the corridors under study. The superior method for calibrating a logit model is the maximum-likelihood procedure. The maximum-likelihood procedure is usually used by transportation planners to estimate model parameters. The maximum-likelihood estimation of the model produces goodness-of-fit statistics, such as t-statistics for coefficients and a X^2 statistic for assessing the entire model.

Several statistical packages are available to calibrate logit models. Among these are the Statistical Packages for the Social Science (SPSS), the Statistical Analysis System (SAS), ULOGIT, BLOGIT, and SLOGIT. The Statistical Analysis System (SAS) package was used to perform the preliminary statistics procedure, such as the mean and the standard deviation of the collected data. The BLOGIT package was used to calibrate the model using different model specifications. In this package the

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the maximum likelihood approach iteratively solves for the coefficients in the utility equation. The estimation package will iterate through the problem until the estimated coefficients reach a specific convergence criterion or the estimation completes a specified number of iterations. After iteration has been completed, the estimated model will provide the best fit to the observed pattern of choices in the calibration sample.

Model Validation

The validation process is an integral aspect of the model development process. The model's validation should be tested by using the model to predict modal-split for data other than that used for model calibration (40). Validation data have been collected for use in comparing the predicted and observed modal split to test the model's validation.

A test of reasonableness validation process was also used. This process depends on the reasonableness of the model in terms of the expected coefficient signs, and the reasonableness of the parameters. For example, travel time and travel cost always have negative impacts on travel demand; no model which has a positive travel time or cost coefficient would be considered a reasonable or valid model.

Recommended Methodology for Transferring the Models

After a model has been constructed for one corridor in Saudi Arabia, and the variables which explain the behavior of the tripmaker have been determined, several approaches will be used to transfer the model. Transfer models are those

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models calibrated with one data set (for example, a different area, or a different time) and used to explain the variation in the new data set.

The first approach accepts the model as it is. For instance, the calibrated model for the Riyadh-Jeddah corridor is used to explain the behavior of the tripmaker in the Dhahran-Riyadh corridor, and vice-versa. This approach depends on the assumption that disaggregate models have the potential to transfer, because they are based on the behavior of the tripmaker, and this behavior is constant over space. Another assumption required in using the model in its original form is that the factors relevant to the choice process are embodied in the model. However, this assumption is never completely justified because most disaggregate models are not perfectly specified in order to decrease the complexity of the model. The specification of most known models contain constant terms. These constant terms represent all other factors affecting the behavior of the tripmaker not explicitly considered in the model (e.g. comfort, convenience, safety, etc.). Thus the presence of these constants indicates that the model has not captured all factors affecting the tripmaker's choice. Those factors not explicitly explained by the model may vary from one area to another. Thus the value of such constants estimated for one context may not be appropriate for another context. A final assumption is that the relationships estimated between time, cost, income, etc., are transferable.

The second approach is to update the transferable model. In other words the, constant terms as well as the coefficients of the variables in the transfer model are re-estimated using a part of the sample required to calibrate a new model. The size of the sample is about one-fifth the sample required to calibrate the proposed

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model (36). Then coefficients of the transfer model are considered prior information for the true coefficients. The coefficients resulting from calibrating the model with the small sample are used to update this prior information. This approach for combining sample information with prior information is known as "Bayesian updating" (40).

In this case, the constant terms and the coefficients of the variables in the Jeddah-Riyadh model are considered prior information and the constant and the coefficients of the variables are re-estimated with small data from the other corridor (Dhahran-Riyadh corridor). Then the re-estimated coefficient is used to update the transfer model.

The third approach is to transfer the model specification only. Then the model is calibrated with the new data. This approach has been introduced in order to determine the universal set of specifications required to calibrate the mode choice model, and to determine if the parameters estimated for the two corridors are equal.

In summary, the three approaches tested for the transferability of models are:

1. transferring the unchanged model.
2. using the Bayesian updating method to combine the original and small sample coefficients.
3. transferring the specification of the variables of the model only, and recalibrating the model.

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Hypotheses to be Tested

Several sets of hypotheses will be tested in this research. The first set of hypotheses tests whether the disaggregate models are transferable. In other words, a disaggregate model can be calibrated and tested in one area and used to explain the variation in mode choice in another area. In order to perform this test the calibrated model for each corridor will be used to predict the behavior of the tripmaker in the other corridor for the same trip purpose. For example, the original model for the Dhahran-Riyadh corridor will be used to predict tripmaker behavior in the Riyadh-Jeddah corridor.

The second set of hypotheses tests whether the updating method improves the prediction power of the transfer models significantly. In other words, can the prediction power of the transfer model for each corridor be improved significantly if the updating method is used?

The third hypothesis to be tested is whether the specification of the model in the transfer model replicates the data as well as the original specification. The fourth hypothesis is whether the parameters in the transfer model and the parameters after recalibrating the model for the same specification are equal. For instance, are the parameters estimated for Riyadh-Jeddah and Dhahran-Riyadh for the same specification equal?

A fifth hypothesis is whether the coefficient for level-of-service variables (e.g. time or cost) in the transfer model and the original model are equal (assuming both models have the same specification). For example, for the models calibrated for the two corridors under study, are the coefficients for the level-of-service variable equal?

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If this is the case, there is no need to collect level-of-service data for calibrating new models.

The last hypothesis is related to the fifth one. Does the coefficient of level-of-service in the transfer model (e.g. time or cost) before and after updating differ significantly from the original model?

In summary, the following hypotheses will be tested when transferring intercity mode choice model from one area to another:

1. There is no difference in prediction power between the calibrated model for each corridor and the transfer model.
2. There is no difference in prediction power between the original model and the transfer model after updating the coefficients.
3. The goodness of fit produced by the transfer specification and the calibrated specification is the same.
4. The parameters in the transfer model and the estimated parameters in the recalibrated model are equal for the same specification.
5. Coefficients for level-of-service variables (e.g. time or cost) for the two corridor specific models are equal.
6. Coefficients for level-of-service variables (e.g. time or cost) for the original and the transfer model after updating are equal.

Statistics to Test the Hypotheses

Two measures of how the transfer model explains the variation in the behavior of the tripmaker in the new context were used by Ben-Akiva (17) in evaluating the ability of intercity disaggregate model transferability. The first meas

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measure is the X^2 statistic (41). In this test, a comparison is made between the observed value and the predicted choice value for each mode. Larger values of the overall discrepancy between the proposed model and the transfer model indicate disagreement between the two models.

The second measure is the percent of correct estimates for each mode. In this test, a comparison is made in each cell between the predicted value from the transfer model and the observed value. This measure is analogous to the X^2 test, yet it produces additional insight into the differences between the distribution of observed and predicted values. These approaches will also be used to determine the improvement in model prediction before and after updating the transfer model.

The asymptotic "*t*" statistic test of equality of individual coefficient between two models is used to test the hypotheses that the coefficients for the level-of-service variable (e.g. time or cost) for the proposed models are equal, and the coefficient for the level-of-service variable (e.g. time or cost) for the transfer models before and after updating are equal.

The t-test statistic for the null hypothesis $\beta_{c1} = \beta_{c2}$ is as follows:

$$t = \frac{\beta_{c1} - \beta_{c2}}{[\mathrm{var}(\beta_{c1}) + \mathrm{var}(\beta_{c2})]^{\frac{1}{2}}}$$

Where:

β_{c1} = is the coefficient of the variable under consideration e.g. cost in model 1.

β_{c2} = is the coefficient of the variable under consideration e.g. cost in model 2.

$\mathrm{var}(\beta_{c1})$ = the variance of the coefficient of the variable under consideration in model 1.

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$var(\beta_{c1})$ = the variance of the coefficient of the variable under consideration in model 2.

Another statistical measure of the transferability of the disaggregate mode choice model estimated in context j and used to predict mode choice in context i for the same specification is the Likelihood ratio test statistic,

$$TTS_i(\beta_j) = -2(LL_i(\beta_j) - LL_i(\beta_i))$$

where $TTS_i(\beta_j)$ is the transferability test statistic, $LL_i(\beta_j)$ is the log likelihood that the behavior observed in context i was generated by the model estimated in context j, and $LL_i(\beta_i)$) is the log likelihood for the model estimated in the same context i. The Likelihood ratio test statistic is chi-square distributed with degrees of freedom equal to the number of model parameters under the assumption that the number of parameters is fixed. This test has been used by Atherton and Ben-Akiva (33) in their test of transferability between Washington, D.C. and New Bedford, Massachusetts, and by Koppelman and Wilmot (42) in their test of transferability between sectors in the Washington, D.C. area. This test has been used to test the null hypothesis that the parameters in the transfer model and the parameters in the recalibrated model for the same specification are equal.

A goodness of fit measure is used in determining which specification is better in replicating the data. This measure is somewhat analogous to the R^2 used in regression. Since the logit model is asymptotic to 0 and 1 probabilities in its tails, one can never precisely achieve a value equal to 1. At the other extreme, if all the parameters in a logit model are 0, the model predicts that all the choices for any given individual are equally likely. In this case, the model does not explain choice variati

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variation. In order to compare alternative models used to explain the variation of the new data, the rho-square (p^2) goodness of fit measure has been used:

transfer $$p^2 = 1 - \frac{L(\beta)}{L(0)}$$

in which:

L(ß)	=	Log likelihood for the vector of estimated coefficients
L(0)	=	The value of the log likelihood function when all the parameters are zero

This measure is most useful in comparing two specifications developed from identical data. The model which has the higher goodness of fit is the better model for explaining the behavior of the tripmaker in the new context. This measure achieves an upper limit of one when the transferred model predicts perfectly in the new situation, has a zero value when the model predicts as well as the market share model (L(ß) = L(0)), and it may attain a negative value when the transferred model predicts worse than the market share model.

In summary the following methods are used to test the proposed hypotheses:

1. the chi-square test and the percentage right method will be used to test if there is a difference in prediction accuracy between the original model for each corridor and the transfer model. In addition, they will be used to test if there is a difference in prediction accuracy before and after updating the coefficients for the transfer model.
2. "t" test statistics will be used to test if the coefficients for the level-of-service variable (e.g. time or cost) for the calibrated models are equal, and if coefficients for the level-of-service variable (e.g. time or cost) for

the transfer model before and after updating are equal.

3. transferability test statistics (TTS) will be used to test if the parameters in the transfer model and the estimated parameters in the local model are equal, assuming both have the same specification.

4. goodness of fit will be used to determine which specification is better in explaining the tripmaker behavior in the new context. For instance, does the transfer specification or the original one produce a better goodness of fit?

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CHAPTER IV

DATA COLLECTION

The main purpose of this study was to determine the feasibility of intercity mode choice model transferability within Saudi Arabia. Since no intercity mode choice model has been developed to predict the behavior of the Saudi tripmaker, and the data required to achieve this purpose did not exist, data for this research was collected as part of this research study. The researcher contacted the Government Railways Organization, Saudi Arabian Public Transport Company, and the Ministry of Civil Aviation to get permission to distribute the questionnaires. The researcher personally with the help of a graduate student from King Fahd University of Petroleum and Minerals located in Dhahran, distributed the questionnaire forms.

Research Questions

Appendix B shows the questionnaire form distributed for each mode under consideration. While the formats used to code the questionnaire forms are presented in Appendix C. Because many tripmakers in Saudi Arabia are from different countries, and the most prevalent languages among tripmakers are Arabic and English, the questionnaire forms were written in both Arabic and English. These forms were distributed at the airplane terminal, bus terminal, and train station for tripmakers traveling in the corridors under study. Questionnaires were distributed on-board while the subjects waited for the departure. The completed questionnaires were collected at the destination of each trip.

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Tripmakers traveling by car were interviewed at the gas stations located midway between the cities under study. In addition, one-hundred questionnaire forms were placed at the gas stations. However, none of these questionnaires were returned, even though the recipients were asked to complete the questionnaire and return it by mail.

This questionnaire included a wide range of variables characterizing the trip (by mode, trip purpose, origin destination, duration, etc.), the service characteristics of both the chosen mode (travel time, cost, frequency, etc.) and perceived characteristics of other available but unchosen modes (comfort, privacy, expense, and safety), and the tripmaker's characteristics (age, income, occupation, etc.). Moreover, the questionnaires were coded by the name of the four different modes under study: train, airplane, private car, and bus.

Table 4.1 shows the description of the abbreviated variables used throughout this research. Tables 4.2, 4.3, 4.4, and 4.5 show the number of responses, minimum, maximum, mean, and standard deviation values obtained for each variable for plane, bus, train and car serving the Dammam-Riyadh Corridor.

Tables 4.6, 4.7, and 4.8 show the number of responses, minimum, maximum, mean, and standard deviation values obtained for each variable for plane, bus, and car serving the Jeddah-Riyadh Corridor. There is no train service in this corridor.

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Table 4.1

Description of the abbreviated variables

Variable Name*	Variable definition
N	Number of observations
TTH_A	One-way total travel time by AIR ,hrs.
TTH_B	One-way total travel time by BUS ,hrs.
TTH_C	One-way total travel time by CAR ,hrs.
TTH_T	One-way total travel time by TRAIN, hrs.
THS_A	One-way access time for AIR tripmakers, hrs.
THS_B	One-way access time for BUS tripmakers, hrs.
THS_T	One-way access time for TRAIN tripmakers, hrs.
TFH_A	One-way egress time for AIR tripmakers, hrs.
TFH_B	One-way egress time for BUS tripmakers, hrs.
TFH_T	One-way egress time for TRAIN tripmakers, hrs.
THW_A	One-way waiting time for AIR tripmakers, hrs.
THW_B	One-way waiting time for BUS tripmakers, hrs.
THW_T	One-way waiting time for TRAIN tripmakers, hrs.
THW_C	One-way waiting time for CAR tripmakers, hrs.
VH_A	One-way in-vehicle travel time by AIR, hrs.
VH_B	One-way in-vehicle travel time by BUS, hrs.
VH_T	One-way in-vehicle travel time by TRAIN, hrs.
VH_C	One-way in-vehicle travel time by CAR, hrs.
TTC_A	One-way total out-of-pocket cost by AIR, SR.
TTC_B	One-way total out-of-pocket cost by BUS, SR.
TTC_T	One-way total out-of-pocket cost by TRAIN, SR.
TTC_C	One-way total out-of-pocket cost by CAR, SR.
TKC_A	One-way ticket cost by AIR, SR.
TKC_B	One-way ticket cost by BUS, SR.
TKC_T	One-way ticket cost by TRAIN, SR.
OIL	One-way oil cost by CAR, SR.
MPIN	Monthly personal income,SR.
MHINC	Monthly household income,SR.
GROP	Group size.
CAR	Number of cars the tripmaker owns.
STUD	Student.
LICE	License.
AGE	Tripmaker age.
$COMF_A$	Relative comfort for AIR , Scaled from 5 to 1**.
$COMF_B$	Relative comfort for BUS , Scaled from 5 to 1.
$COMF_C$	Relative comfort for CAR , Scaled from 5 to 1.
$COMF_T$	Relative comfort for TRAIN,Scaled from 5 to 1.

Table 4.1 continued

Variable Name*	Variable definition
$PRIV_A$	Relative privacy for AIR, Scaled from 5 to 1.
$PRIV_B$	Relative privacy for BUS, Scaled from 5 to 1.
$PRIV_C$	Relative privacy for CAR, Scaled from 5 to 1.
$PRIV_T$	Relative privacy for TRAIN,Scaled from 5 to 1.
SAF_A	Relative safety by AIR, Scaled from 5 to 1.
SAF_B	Relative safety by BUS, Scaled from 5 to 1.
SAF_C	Relative safety by CAR, Scaled from 5 to 1.
SAF_T	Relative safety by TRAIN, Scaled from 5 to 1.
EXP_A	Relative expense by AIR, Scaled from 5 to 1.
EXP_B	Relative expense by BUS, Scaled from 5 to 1.
EXP_C	Relative expense by CAR, Scaled from 5 to 1.
EXP_T	Relative expense by TRAIN, Scaled from 5 to 1.
DUR	Duration of stay.
DIS	Distance in 1000 KM
ASC-AIR	Mode-specific constant for air.
ASC-BUS	Mode-specific constant for bus.
ASC-CAR	Mode-specific constant for car.
IVTT	One-way in-Vehicle time in hours.
OPTC	One-way Out-of-pocket cost
OVTT	One-way out-of-vehicle time,hrs.
WT	One-way wait time,hrs.
TTT	One-way total travel time,hrs.
COMFORT	Relative comfort, Scaled from 5 to 1.
PRIVACY	Relative privacy, Scaled from 5 to 1.
SAFETY	Relative safety, Scaled from 5 to 1.
EXPENSE	Relative expense, Scaled from 5 to 1.

* Variables with subscript/s are specific to a mode(s) (A for air, B for bus, C, for car)

** 1 is best, 5 is worst.

Table 4.2

Table 4.2

Basic Statistics for Plane Tripmakers in Dhahran in Dhahran-Riyadh Corridor

Variable	N	Minimum	Maximum	Mean	Std Dev
DUR	170	1.0000000	3.0000000	1.7176471	0.6637131
TTHA	170	1.5000000	4.0000000	2.6171176	0.4659830
THSA	170	0.1700000	1.6700000	0.4585882	0.2344257
THWA	170	0.1700000	2.0000000	0.8076471	0.2954353
VHA	170	0.5800000	1.0800000	0.7928235	0.1034850
TFHA	170	0.1700000	2.0000000	0.5578235	0.2361838
TTCA	170	60.0000000	440.0000000	183.0705882	65.2684558
TKCA	170	60.0000000	170.0000000	111.0588235	29.4133379
COMFA	170	1.0000000	4.0000000	1.1941176	0.5136833
COMFB	170	2.0000000	5.0000000	4.0882353	0.8691847
COMFT	170	1.0000000	5.0000000	2.7294118	1.0974768
COMFC	170	1.0000000	5.0000000	2.4117647	0.8810177
PRIVA	170	1.0000000	5.0000000	2.5882353	1.0524035
PRIVB	170	1.0000000	5.0000000	3.6117647	0.9862261
PRIVT	170	1.0000000	5.0000000	2.6117647	0.9802079
PRIVC	170	1.0000000	4.0000000	1.1705882	0.5549825
SAFA	170	1.0000000	5.0000000	1.4705882	0.9047964
SAFB	170	1.0000000	5.0000000	3.0882353	1.1244367
SAFT	170	1.0000000	5.0000000	1.5235294	0.8648490
SAFC	170	1.0000000	5.0000000	2.6529412	1.1729786
EXPA	170	1.0000000	5.0000000	3.9764706	1.2448851
EXPB	170	1.0000000	5.0000000	1.7000000	0.8692648
EXPT	170	1.0000000	4.0000000	1.8941176	0.7848194
EXPC	170	1.0000000	5.0000000	1.9941176	1.1013550
MPIN	170	1.0000000	7.0000000	4.0235294	2.0696538
MHINC	170	1.0000000	7.0000000	5.0647059	1.7308346
GROPS	170	1.0000000	3.0000000	1.0764706	0.2878803
CAR	170	0	9.0000000	2.5764706	1.9604158
STUD	170	1.0000000	2.0000000	1.7294118	0.4455762
SAUDI	170	1.0000000	2.0000000	1.0941176	0.2928549
LICE	170	1.0000000	2.0000000	1.0823529	0.2757138
AGE	170	17.0000000	75.0000000	30.0235294	10.0171173

Table 4.3

Table 4.3

Basic Statistics for Train Tripmakers in Dhahran-Riyadh Corridor

Variable	N	Minimum	Maximum	Mean	Std Dev
DUR	185	1.0000000	3.0000000	2.0918919	0.5287282
TTHT	185	3.8300000	6.6700000	5.1354595	0.5174078
THWT	185	0.0800000	1.5000000	0.4392973	0.2807096
VHT	185	3.0000000	4.5000000	3.9184865	0.2618099
TFHT	185	0.0500000	1.0000000	0.4008649	0.1795293
TTCT	185	20.0000000	280.0000000	98.9135135	60.2780070
TKCT	185	20.0000000	60.0000000	42.3243243	12.1361257
COMFA	185	1.0000000	5.0000000	1.5513514	0.9141466
COMFB	185	1.0000000	5.0000000	3.9297297	1.0217379
COMFT	185	1.0000000	5.0000000	2.0648649	0.9702690
COMFC	185	1.0000000	4.0000000	2.3405405	0.7924438
PRIVA	185	1.0000000	5.0000000	2.8702703	1.0185414
PRIVB	185	1.0000000	5.0000000	3.7027027	0.9573760
PRIVT	185	1.0000000	5.0000000	2.3729730	1.1015426
PRIVC	185	1.0000000	4.0000000	1.3675676	0.6876449
SAFA	185	1.0000000	5.0000000	2.0054054	0.9807788
SAFB	185	1.0000000	5.0000000	3.3405405	1.1169299
SAFT	185	1.0000000	4.0000000	1.3027027	0.6636880
SAFC	185	1.0000000	5.0000000	3.0702703	0.9210299
EXPA	185	1.0000000	5.0000000	4.2810811	0.8827569
EXPB	185	1.0000000	5.0000000	2.3891892	0.8907080
EXPT	185	1.0000000	5.0000000	1.5783784	0.8757404
EXPC	185	1.0000000	5.0000000	2.3081081	1.0306125
MPIN	185	1.0000000	7.0000000	3.0216216	1.8176572
MHINC	185	1.0000000	7.0000000	4.3567568	1.7974228
GROPS	185	1.0000000	5.0000000	1.6756757	1.1290159
CAR	185	0	9.0000000	2.0810811	1.7964091
STUD	185	1.0000000	2.0000000	1.6054054	0.4900898
SAUDI	185	1.0000000	2.0000000	1.3243243	0.4693922
LICE	185	1.0000000	2.0000000	1.3297297	0.4713907
AGE	185	13.0000000	65.0000000	26.5891892	8.4707869

Table 4.4

Table 4.4

Basic Statistics for Bus Tripmakers in Dhahran-Riyadh Corridor

Variable	N	Minimum	Maximum	Mean	Std Dev
DUR	204	1.0000000	3.0000000	2.0441176	0.7381342
TTHB	204	3.9200000	7.0000000	5.5220588	0.5501130
THSB	204	0.0800000	1.0000000	0.3726961	0.1620347
THWB	204	0.0300000	1.5000000	0.4594118	0.2754229
VHB	204	3.0000000	5.5000000	4.3141176	0.3892682
TFHB	204	0.1200000	1.0000000	0.3759804	0.1562476
TTCB	204	44.0000000	210.0000000	80.7254902	20.8837537
TKCB	204	40.0000000	60.0000000	59.8039216	1.9754115
COMFA	204	1.0000000	5.0000000	1.5049020	0.9231428
COMFB	204	1.0000000	5.0000000	2.7990196	0.9693830
COMFT	204	1.0000000	5.0000000	2.1568627	0.8849602
COMFC	204	1.0000000	5.0000000	2.6372549	1.0762937
PRIVA	204	1.0000000	5.0000000	2.6421569	1.0525069
PRIVB	204	1.0000000	5.0000000	3.1029412	1.0382778
PRIVT	204	1.0000000	5.0000000	2.4705882	1.1026692
PRIVC	204	1.0000000	5.0000000	1.6372549	1.2098871
SAFA	204	1.0000000	5.0000000	2.0637255	1.1873130
SAFB	204	1.0000000	5.0000000	2.2941176	0.9632482
SAFT	204	1.0000000	4.0000000	1.4558824	0.7707809
SAFC	204	1.0000000	5.0000000	3.2549020	1.0980168
EXPA	204	1.0000000	5.0000000	4.0490196	1.0952423
EXPB	204	1.0000000	5.0000000	1.9215686	0.9278002
EXPT	204	1.0000000	4.0000000	1.4656863	0.7452966
EXPC	204	1.0000000	5.0000000	2.4950980	0.9900866
MPIN	204	1.0000000	7.0000000	2.6176471	1.3133953
MHINC	204	1.0000000	7.0000000	2.8578431	1.5230211
GROPS	204	1.0000000	4.0000000	1.0441176	0.2859858
CAR	204	0	5.0000000	0.7009804	1.1463366
STUD	204	1.0000000	2.0000000	1.9166667	0.2770653
SAUDI	204	1.0000000	2.0000000	1.8039216	0.3980053
LICE	204	1.0000000	2.0000000	1.3529412	0.4790602
AGE	204	18.0000000	61.0000000	31.0735294	7.9132915

Table 4.5

Basic Statistics for Car Tripmakers in Dhahran-Riyadh Corridor

Variable	N	Minimum	Maximum	Mean	Std Dev
DUR	175	1.0000000	3.0000000	1.9885714	0.5465521
TTHC	175	3.0000000	6.0000000	3.9395429	0.4955246
THWC	175	0.1700000	2.0000000	0.3901714	0.2619412
VHC	175	2.2500000	4.6700000	3.5493714	0.4449101
TTCC	175	32.0000000	150.0000000	73.6742857	24.4646630
OIL	175	22.0000000	99.0000000	51.6742857	14.9786120
COMFA	175	1.0000000	4.0000000	1.6342857	0.8988955
COMFB	175	2.0000000	5.0000000	3.9485714	1.0129539
COMFT	175	1.0000000	5.0000000	3.0628571	1.2417742
COMFC	175	1.0000000	5.0000000	1.8457143	0.9123491
PRIVA	175	1.0000000	5.0000000	3.4514286	1.2533567
PRIVB	175	1.0000000	5.0000000	3.7200000	1.0036714
PRIVT	175	2.0000000	5.0000000	3.0857143	1.0275355
PRIVC	175	1.0000000	4.0000000	1.2342857	0.7247444
SAFA	175	1.0000000	5.0000000	1.4171429	0.7898369
SAFB	175	1.0000000	5.0000000	2.5885714	0.9296432
SAFT	175	1.0000000	5.0000000	1.8228571	1.2306165
SAFC	175	1.0000000	5.0000000	2.7485714	0.9794942
EXPA	175	1.0000000	5.0000000	3.9085714	1.1854897
EXPB	175	1.0000000	5.0000000	2.4285714	1.1060366
EXPT	175	1.0000000	5.0000000	1.8057143	1.1330822
EXPC	175	1.0000000	5.0000000	1.9771429	0.8706866
MPIN	175	1.0000000	7.0000000	4.0457143	1.9113008
MHINC	175	1.0000000	7.0000000	4.8971429	1.9448555
GROPS	175	1.0000000	9.0000000	2.8114286	1.7432582
CAR	175	1.0000000	9.0000000	2.0800000	1.4756257
STUD	175	1.0000000	2.0000000	1.8285714	0.3779645
SAUDI	175	1.0000000	2.0000000	1.1314286	0.3388380
LICE	175	1.0000000	1.0000000	1.0000000	0
AGE	175	17.0000000	54.0000000	25.7485714	5.9870248

Table 4.6

Basic Statistics for Plane Tripmakers in Jeddah-Riyadh Corridor

Variable	N	Minimum	Maximum	Mean	Std Dev
DUR	228	1.0000000	3.0000000	2.1228070	0.7165796
TTHA	228	2.1700000	5.3300000	3.5390351	0.6246070
THSA	228	0.1700000	1.7500000	0.6050877	0.2728452
THWA	228	0.0800000	2.0000000	0.8633333	0.4036074
VHA	228	0.6700000	1.8300000	1.3718860	0.1498735
TFHA	228	0.1700000	1.7500000	0.6988158	0.3096266
TTCA	228	120.0000000	1310.00	360.7982456	145.2124180
TKCA	228	120.0000000	360.0000000	246.8421053	32.1153151
COMFA	228	1.0000000	5.0000000	1.4517544	1.0462210
COMFB	228	1.0000000	5.0000000	4.1535088	0.7075029
COMFC	228	1.0000000	5.0000000	2.7324561	0.9992945
PRIVA	228	1.0000000	5.0000000	2.5482456	1.1807362
PRIVB	228	1.0000000	5.0000000	3.4385965	0.9295453
PRIVC	228	1.0000000	5.0000000	1.1535088	0.5210426
SAFA	228	1.0000000	5.0000000	1.5789474	0.9745189
SAFB	228	1.0000000	5.0000000	3.3114035	0.9170205
SAFC	228	1.0000000	5.0000000	2.9298246	1.1123599
EXPA	228	1.0000000	5.0000000	4.0964912	1.1796311
EXPB	228	1.0000000	5.0000000	1.7631579	0.7831106
EXPC	228	1.0000000	5.0000000	1.7500000	0.9771621
MPIN	228	1.0000000	7.0000000	4.5219298	1.6959272
MHINC	228	1.0000000	7.0000000	4.7324561	1.6158355
GROPS	228	1.0000000	5.0000000	1.1798246	0.5538300
CAR	228	0	7.0000000	1.7807018	1.5466820
STUD	228	1.0000000	2.0000000	1.9736842	0.1604249
SAUDI	228	1.0000000	2.0000000	1.2280702	0.4205113
LICE	228	1.0000000	2.0000000	1.1403509	0.3481149
AGE	228	19.0000000	64.0000000	33.6666667	9.8434143

Table 4.7

Table 4.7

Basic Statistics for Bus Tripmakers in Jeddah-Riyadh Corridor

Variable	N	Minimum	Maximum	Mean	Std Dev
DUR	223	1.0000000	3.0000000	2.2107623	0.5414951
TTHB	223	10.7500000	17.4200000	14.5096413	1.4317666
THSB	223	0.1700000	1.0000000	0.3854260	0.1746494
THWB	223	0.1700000	1.1700000	0.4895516	0.1805192
VHB	223	10.0000000	16.0000000	13.3602242	1.3271457
TFHB	223	0.0800000	1.0000000	0.2729148	0.1834849
TTCB	223	100.0000000	415.0000000	175.1659193	63.6970186
TKCB	223	100.0000000	130.0000000	122.5156951	12.1665794
COMFA	223	1.0000000	4.0000000	1.5560538	0.9030712
COMFB	223	1.0000000	5.0000000	2.4618834	1.2545880
COMFC	223	1.0000000	5.0000000	3.0672646	0.9725768
PRIVA	223	1.0000000	5.0000000	2.5874439	1.0527631
PRIVB	223	1.0000000	5.0000000	2.4080717	1.1852423
PRIVC	223	1.0000000	5.0000000	1.5874439	0.9349202
SAFA	223	1.0000000	5.0000000	1.6726457	0.9517720
SAFB	223	1.0000000	5.0000000	1.8026906	1.0207716
SAFC	223	1.0000000	5.0000000	2.4708520	0.8477860
EXPA	223	2.0000000	5.0000000	3.9103139	0.6916695
EXPB	223	1.0000000	4.0000000	1.4125561	0.6079238
EXPC	223	1.0000000	5.0000000	2.6995516	1.2171262
MPIN	223	1.0000000	4.0000000	2.2242152	0.8131499
MHINC	223	1.0000000	7.0000000	2.2780269	0.9122844
GROPS	223	1.0000000	4.0000000	1.2197309	0.5624639
CAR	223	0	5.0000000	0.3273543	0.7137742
STUD	223	1.0000000	2.0000000	1.9282511	0.2586522
SAUDI	223	1.0000000	2.0000000	1.9147982	0.2798098
LICE	223	1.0000000	2.0000000	1.3452915	0.4765329
AGE	223	11.0000000	60.0000000	33.3991031	7.7962453

Table 4.8

Table 4.8

Basic Statistics for Car Tripmakers in Jeddah-Riyadh Corridor

Variable	N	Minimum	Maximum	Mean	Std Dev
DUR	153	2.0000000	3.0000000	2.3202614	0.4681092
TTHC	153	8.0000000	16.3300000	11.7444444	1.3979331
THWC	153	0.7500000	3.0000000	1.7781699	0.5361994
VHC	153	7.0000000	15.0000000	9.9662745	1.3398222
TTCC	153	100.0000000	270.0000000	194.0326797	39.5205507
OIL	153	60.0000000	200.0000000	133.6797386	26.3797305
COMFA	153	1.0000000	5.0000000	1.9084967	1.0659779
COMFB	153	2.0000000	5.0000000	3.8169935	0.8065351
COMFC	153	1.0000000	5.0000000	1.9542484	0.9551789
PRIVA	153	1.0000000	5.0000000	2.8562092	1.2535124
PRIVB	153	2.0000000	5.0000000	3.5228758	0.9254086
PRIVC	153	1.0000000	5.0000000	1.1241830	0.5995641
SAFA	153	1.0000000	5.0000000	2.0065359	1.0668247
SAFB	153	1.0000000	5.0000000	3.0915033	1.1774162
SAFC	153	1.0000000	5.0000000	2.5686275	0.9784837
EXPA	153	1.0000000	5.0000000	3.7450980	1.3885311
EXPB	153	1.0000000	5.0000000	2.2483660	0.8906018
EXPC	153	1.0000000	5.0000000	2.0196078	0.9629354
MPIN	153	1.0000000	7.0000000	4.5751634	1.5074063
MHINC	153	1.0000000	7.0000000	4.8954248	1.5094588
GROPS	153	1.0000000	9.0000000	4.1045752	1.6981546
CAR	153	1.0000000	9.0000000	1.9150327	1.6056959
STUD	153	1.0000000	2.0000000	1.9869281	0.1139557
SAUDI	153	1.0000000	2.0000000	1.2418301	0.4295981
LICE	153	1.0000000	1.0000000	1.0000000	0
AGE	153	17.0000000	51.0000000	32.8692810	7.9287060

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Sample Size

Sample size was based on the income variable because it contained the highest variation among the variables. The average monthly income in Saudi Arabia is 4,500 SR, with a standard deviation of 1,250 SR (43). From the survey, the sample mean for household income for the Dhahran-Riyadh corridor was 4,233 SR/month, with a standard deviation of 1,959 SR. For the Riyadh-Jeddah corridor, the mean household income was 3,868 SR/month, with a standard deviation of 1,830 SR. So, with a 5% risk, the error will exceed 10% of the mean [z(.975)=1.96], the sample size required by the sample size equation for each mode in each corridor is shown in Table 4.9.

From Tables 4.2, 4.3, ..., 4.9 it can be seen that the number of observations collected are greater than the size of the sample required to calibrate the intercity mode choice model for each corridor.

Table 4.9

Sample Size Based on Income

Corridor Name	Monthly Mean Income (SR)	Standard Deviation	Sample Size Required
Dammam Riyadh Corridor	4,233	1,959	83
Jeddah Riyadh Corridor	3,868	1,830	86

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CHAPTER V

THE CALIBRATION PROCESS

In the previous chapter the results of the data collection process were presented. In Chapter II and Chapter III, the theoretical considerations and the framework for the empirical work were described. Using that framework, model calibration procedures were illustrated, and the recommended approach for transferring intercity mode choice models from one corridor to another were presented. In this chapter, the intercity mode choice models generated by the BLOGIT computerized statistical estimation package for the two corridors under study will be presented. The result of testing the transferability of these models will also be presented.

The Theoretical Model

The intercity mode choice model for the non-business trip within each corridor has the following form:

$$P^i_k = \frac{\text{EXP } V_{ki}}{\sum_j \text{EXP } V_{ji}}$$

Where:

P^i_k = probability of a tripmaker i choosing mode k out of j alternatives

V_{ki} = the utility of alternative k to trip maker i
= (X_k, S_i)

X_k = a row vector of characteristics of alternative k

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S_i = a row vector of socioeconomic characteristics of a tripmaker i

The probability of a tripmaker choosing a particular mode alternative is a function of the characteristics of the tripmaker, such as income, age, and sex and of the characteristics of that mode relative to alternatives modes. If a variable appears only in the utility function of mode K, then it is a mode-specific variable which assumes a value of zero in all $j \neq k$ model utilities. If a variable appears in the utility function of all modes, it is considered a generic variable, which takes on different values across the utilities for different modes.

Model Specification

Different specifications for the models have been evaluated to determine which specification best replicates the data for each corridor. These specifications include the variables that have been found in the literature review to influence the tripmaker choice (such as out-of pocket cost (OPTC), egress travel time (EGTT), access travel time (ATT), household income (HINC), total travel time (TTT), out-of-vehicle travel time (OVTT), distance (DIST), in-vehicle travel time (IVTT), and waiting time (WT)).Composite variables such as OPTC/HINC and OVTT/DIST are used to modify the impact of the pure level-of-service variables OPTC and OVTT. It is hypothesized that tripmakers with different levels of income perceive travel cost differently. Similarly, out-of-vehicle time is hypothesized as becoming less important as the length of the trip increases.

Different model specifications were tested, as can be seen in Tables 5.1, and 5.2. Each model estimate is based on a different modal utility function. Modal specifications were formulated based on prior experience in intercity mode

Variab Nam
ASC-A
ASC-B
OPTC-
OPTC
OVT/I
IVTT
TTT
WT
TTT*N
IVTT*
EGR*I
MHIN
MHIN
p²

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Table 5.1

Model Results for Mode Choice Models for the Dhahran-Riyadh Corridor
(Non-Business Trips; Train is Not Included)

Variable Name	Estimated Variable Coefficients*				
	Model 1	Model 2	Model 3	Model 4	Model 5
ASC-AIR	-6.75 (-5.60)	-5.90 (-5.14)	-3.98 (-3.51)	2.79 (5.20)	2.52 (4.69)
ASC-BUS	0.94 (1.95)	3.21 (6.94)	2.68 (5.51)	3.83 (8.82)	3.97 (8.94)
OPTC-MHINC	-0.06 (-8.15)	--	-0.06 (-8.77)	--	--
OPTC	--	-0.02 (-8.61)	--	-0.02 (-8.76)	-0.02 (-8.71)
OVT/DIS	--	0.06*(0.38)	0.22*(1.02)	--	--
IVTT	-4.82 (-8.27)	-2.64 (-6.76)	-2.40 (-6.24)	--	--
TTT	2.63 (6.27)	--	--	--	--
WT	--	--	-0.75*(-1.15)	--	--
TTT*MHINC	--	--	--	-0.11 (-6.14)	--
IVTT*MHINC	--	--	--	--	-0.22 (-7.43)
EGR*MHINC	--	--	--	0.36 (5.64)	0.72*(0.70)
MHINC/FREQ	--	--	--	0.18 (1.94)	0.34 (5.25)
$MHINC_A$	--	0.43 (5.75)	--	--	--
p^2	0.33	0.30	0.26	0.33	0.36

* The estimated coefficient is not significantly different from zero at the 0.05 level.
(**) t-statistic.

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Table 5.1, Cont'd.

Variable Name	Estimated Variable Coefficients*				
	Model 6	Model 7	Model 8	Model 9	Model 10
ASC-AIR	41.17 (4.30)	38.52 (4.29)	2.33 (3.33)	40.16 (4.00)	0.96*(1.04)
ASC-BUS	2.82 (3.75)	0.50*(0.77)	5.17 (7.88)	-1.58*(-1.64)	-0.13*(-0.14)
OPTC-MHINC	-0.08 (-6.36)	-0.09 (-3.32)	--	-0.08 (-5.89)	--
OPTC	--	--	-0.02 (-7.67)	--	-0.03 (-6.13)
OVT/DIS	-0.28*(-0.69)	--	--	--	--
$IVTT_{B,C}$	0.01*(0.01)	-3.53 (-4.00)	--	-0.08*(-0.16)	--
$IVTT_A$	-40.10 (-4.30)	-45.90 (-5.06)	--	-40.23 (-4.09)	--
TTT	--	3.29 (4.90)	--	--	--
WT	1.52*(1.33)	--	--	--	--
IVTT*MHINC (sp. bus, car)	--	--	-0.80 (-8.99)	--	-0.37 (-3.70)
IVTT*MHINC (sp. air)	--	--	-3.04 (-8.16)	--	-10.07 (-4.69)
EGR*MHINC	--	--	0.09*(0.59)	--	--
MHINC/FREQ	--	--	0.06*(0.72)	--	--
COMFORT	0.73 (6.10)	0.75 (5.75)	0.75 (5.86)	0.79 (5.73)	0.70 (4.86)
PRIVACY	0.29 (2.81)	0.30 (2.59)	0.09*(0.86)	0.30 (2.47)	--
SAFETY	0.22*(1.86)	0.32 (2.60)	0.42 (3.69)	0.31 (2.48)	0.48 (3.32)
$MHINC_A$	--	--	--	--	8.91 (4.05)
LIC_B	--	--	--	3.73 (4.80)	3.02 (3.94)
DUR_A	--	--	--	2.20 (3.42)	--
ρ^2	0.65	0.69	0.62	0.71	0.73

* The estimated coefficient is not significantly different from zero at the 0.05 level.

(**) t-statistic.

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Table 5.1, Cont'd.

Variable Name	Estimated Variable Coefficients* Model 11	Model 12	Model 13	Model 14
ASC-AIR	2.23 (3.04)	0.06*(0.05)	0.87*(1.13)	40.34 (3.88)
ASC-BUS	0.06*(0.07)	-1.37*(-1.33)	3.09 (3.63)	5.33 (6.45)
OPTC	-0.03 (-7.20)	-0.03 (-5.69)	-0.01 (-2.29)	-0.03 (-6.17)
$IVTT_{B,C}$	--	--	--	-0.56*(-1.04)
$IVTT_A$	--	--	--	-43.46 (-4.21)
$(IVTT*MHINC)_{B,C}$	-0.78 (-7.90)	-0.32 (-3.02)	-0.90 (-8.46)	--
$(IVTT*MHINC)_A$	-3.01 (-7.71)	-9.71 (-4.18)	-3.50 (-8.07)	--
COMFORT	0.75 (5.01)	0.73*(4.47)	0.94 (5.82)	0.67 (4.50)
SAFETY	0.50 (3.44)	0.47 (2.86)	0.63 (4.40)	0.50 (3.30)
$MHINC_A$	--	8.77 (3.66)	--	0.39 (2.05)
$MHINC_B$	--	--	--	-0.72 (-5.54)
LIC_B	3.11 (4.84)	3.25 (3.92)	2.53 (4.02)	--
DUR_A	2.19 (4.11)	2.95 (3.91)	1.82 (3.67)	2.08 (3.10)
$SAUD_B$	2.60 (5.31)	2.17 (4.40)	--	--
$GROP_C$	--	--	4.71 (5.71)	--
p2	0.71	0.78	0.73	0.75

* The estimated coefficient is not significantly different from zero at the 0.05 level.
(**) t-statistic.

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Variable Name
ASC-AI
ASC-BU
OPTC-M
OPTC
OVT/DI
IVTT
TTT
WT
TTT*MH
IVTT*MH
EGR*MH
MHINC/F
$MHINC_A$
$MHINC_o$
p^2

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Table 5.2

Model Results for Mode Choice Models for the Jeddah-Riyadh corridor
(Non-Business Trips)

Variable Name	Estimated Variable Coefficients* Model 1	Model 2	Model 3	Model 4	Model 5
ASC-AIR	-0.27*(-0.30)	-3.71 (-3.16)	-1.42*(-1.69)	0.80*(1.30)	0.77*(1.24)
ASC-BUS	2.01 (5.90)	1.96 (4.66)	1.48 (2.69)	6.36 (8.78)	6.36 (8.85)
OPTC-MHINC	-0.04 (-9.99)	--	-0.04 (-9.99)	--	--
OPTC	--	-0.01 (-9.04)	--	-0.01 (-7.99)	-0.01 (-7.79)
OVT/DIS	--	0.06*(0.20)	0.75*(1.86)	--	--
IVTT	0.08*(0.47)	-0.31 (-2.86)	-0.41 (-3.83)	--	--
TTT	-0.53 (-3.01)	--	--	--	--
WT	--	--	-0.94*(-1.89)	--	--
TTT*MHINC	--	--	--	-0.16 (-8.76)	--
IVTT*MHINC	--	--	--	--	-0.26 (-8.49)
EGR*MHINC	--	--	--	0.27 (2.55)	0.74 (6.76)
MHINC/FREQ	--	--	--	0.80 (6.98)	0.16*(1.45)
$MHINC_A$	--	1.13 (9.12)	--	--	--
$MHINC_b$	--	--	--	--	--
p^2	0.36	0.42	0.35	0.58	0.57

* The estimated coefficient is not significantly different from zero at the 0.05 level.
(**) t-statistic.

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Table 5.2, Cont'd.

Variable Name	Estimated Variable Coefficients*				
	Model 6	Model 7	Model 8	Model 9	Model 10
ASC-AIR	3.60*(1.14)	0.23*(0.32)	-1.32 (-2.25)	2.63*(0.80)	0.19*(0.27)
ASC-BUS	1.76 (2.83)	6.33 (7.86)	1.34 (1.96)	1.69 (2.12)	6.41 (7.91)
OPTC-MHINC	-0.04 (-8.82)	--	--	-0.02 (-4.65)	--
OPTC	--	-0.01 (-7.44)	-0.01 (-7.43)	--	-0.01 (-7.63)
OVT/DIS	0.39*(0.84)	--	--	--	--
$IVTT_{B,C}$	-0.29 (-2.49)	--	--	-0.33 (-2.73)	--
$IVTT_A$	-3.54*(-1.88)	--	--	-2.35 (-1.10)	--
WT	-0.82*(-1.45)	--	--	--	--
TTT*MHINC	--	--	--	--	-0.16 (-7.93)
IVTT*MHINC (sp. bus, car)	--	-0.17 (-5.03)	-0.20 (-5.81)	--	--
IVTT*MHINC (sp. air)	--	-0.37*(-1.22)	-1.00*(-1.76)	--	--
EGR*MHINC	--	0.21*(1.59)	--	--	0.26 (2.21)
MHINC/FREQ	--	0.67 (5.26)	--	--	0.74 (5.77)
COMFORT	0.48 (5.36)	0.38 (3.58)	0.40 (3.86)	0.44 (4.32)	0.39 (3.68)
PRIVACY	0.18*(1.94)	0.23*(0.20)	--	0.13*(1.22)	0.02*(0.02)
SAFETY	0.37 (3.94)	0.38 (3.35)	0.44 (3.98)	0.51 (4.76)	0.38 (3.31)
$MHINC_A$	--	--	0.14*(0.16)	--	--
LIC_B	--	--	1.32 (2.74)	2.12 (4.56)	--
DUR_A	--	--	--	3.06 (2.63)	--
p^2	0.47	0.53	0.59	0.58	0.64

* The estimated coefficient is not significantly different from zero at the 0.05 level.
(**) t-statistic.

Variable Name
ASC-AIR
ASC-BUS
OPTC/MHI
OPTC
$IVTT_{B,C}$
$IVTT_A$
(IVTT*MHI
(IVTT*MHI
COMFORT
SAFETY
$MHINC_A$
$MHINC_B$
LIC_B
DUR_A
$SAUD_B$
$GROP_C$
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(**) t-sta

Table 5.2, Cont'd.

Variable Name	Estimated Variable Coefficients*			
	Model 11	Model 12	Model 13	Model 14
ASC-AIR	-0.49*(-0.66)	-1.36 (-2.25)	-0.70*(-0.99)	-0.55*(-0.15)
ASC-BUS	1.61*(1.76)	0.10*(0.13)	2.82 (3.43)	7.69 (7.80)
OPTC/MHINC	-0.00 (-3.72	--	--	--
OPTC	--	-0.01 (-7.27)	-0.00 (-4.18)	-0.01 (-7.44)
$IVTT_{B,C}$	--	--	--	-0.43 (-3.05)
$IVTT_A$	--	--	--	-2.79*(-1.14)
$(IVTT*MHINC)_{B,C}$	-0.16 (-4.66)	-0.17 (-5.06)	-0.18 (-5.58)	--
$(IVTT*MHINC)_A$	-0.91*(-1.33)	-0.67 (-2.54)	-0.78 (-2.99)	--
COMFORT	0.32 (2.74)	0.37 (3.43)	0.38 (3.35)	0.42 (3.88)
SAFETY	0.49 (4.15)	0.46 (3.99)	0.50 (4.31)	0.43 (3.77)
$MHINC_A$	--	--	--	0.53 (3.36)
$MHINC_B$	--	--	--	-1.64 (-6.77)
LIC_B	0.95*(1.77)	0.93*(1.90)	1.31 (2.45)	--
DUR_A	2.40*(1.91)	2.97 (2.40)	2.75 (2.64)	3.30 (2.69)
$SAUD_B$	2.11 (4.19)	1.94 (4.16)	--	--
$GROP_C$	3.57 (5.94)	--	3.39 (5.86)	--
p^2	0.69	0.63	0.66	0.65

* The estimated coefficient is not significantly different from zero at the 0.05 level.
(**) t-statistic.

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choice modelling, and the impact of introducing additional explanatory variables. For instance, models 1, 2 and 3 have the same specification as the Minnesota 1, 2, and 3 models, respectively, described in Chapter II. The specification of Models 4 and 5 are analogous to that used by Grayson (discussed in Chapter II). The rest of the models consist of modal utilities that have additional variables than the ones in models 1 to 6. These different specifications of modal utility have been used in model calibration.

Some of these models exhibited poor statistical goodness-of-fit and/or counter-intuitive signs and were rejected. For example, model 7 in Table 5.1 produced a very good fit but it has a counter-intuitive sign in the variable total travel time (TTT). Model 12 for the Dhahran-Riyadh corridor produced a very good fit, but is not selected because the monthly household income variable (MHINC) was used as an airplane mode-specific variable, which is highly correlated with the variable IVTT*MHINC. Furthermore, trial model 11 (Table 5.2) has the highest goodness-of-fit measure but it has not been selected because the variable indicating the size of the group (GROP) is highly correlated with the total trip cost. Finally model, 13 for the same corridor was not selected for the same reason.

Previous intercity mode choice models used in-vehicle travel time as a generic variable. For this study, this practice is not justified because models with generic in-vehicle travel time (IVTT) show lower goodness of fit than those with a generic IVTT variable for bus and car, and a mode-specific in-vehicle travel time for air. This means that the traveller views the in-vehicle travel time for the bus or car similarly but differently from that for the airplane.

Of all the model specifications tested, the most satisfactory model for the Dhahran-Riyadh corridor with and without the train mode, and the Riyadh-Jeddah corridor are given in Tables 5.3, 5.4, and 5.5 respectively, which is the same specification as model 14 in Tables 5.1 and 5.2.

The following model specification was determined to be the best in explaining the behavior of the tripmaker for the two corridors under study:

Utility for air mode (p) for tripmaker k =

$$a_0^P + a_1 OPTC_P + a_2 IVTT_P + a_3 MHINC_K + a_4 SAFETY_P + a_5 COMFORT_P + a_6 DUR$$

Utility for bus mode (b) for tripmaker k =

$$a_0^B + a_1 OPTC_B + a_7 IVTT_B + a_8 MHINC_K + a_4 SAFETY_B + a_5 COMFORT_B$$

Utility for train mode (t) for tripmaker k =

$$a_0^T + a_1 OPTC_T + a_7 IVTT_T + a_4 SAFETY_T + a_5 COMFORT_T$$

Utility for car mode (c) for tripmaker k =

$$a_1 OPTC_C + a_7 IVTT_c + a_4 SAFETY_C + a_5 COMFORT_C$$

The definition of these terms are:

OPTC — Out-of-pocket cost. This is total out-of-pocket cost perceived by the tripmaker (such as airplane fare, parking cost and gas for the auto). Trip cost is expressed in Saudi riyals (SR). This total cost for travel consists of two parts. One is in-vehicle cost, which includes fare paid for the major carriers, e.g. airplane, or train, and the perceived operation cost for a private car. The other component is the out-of-vehicle cost which includes costs such as access, egress, and parking costs.

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IVTT — In-vehicle travel time. This is the time in hours spent in the mode for a one-way trip.

MHINC — Monthly household income. This variable is the monthly household income for the tripmaker. Income is expressed in Saudi riyals (SR).

DUR — Duration of stay. This is a mode-specific socioeconomic variable to air only and is defined as 1 if duration of stay is one day or less, 0 otherwise. This variable divides the population into two subgroups, and its coefficients measure a difference between the subgroups.

COMFORT — Comfort is a qualitative and attitudinal variable used to explain the behavior of the tripmaker in choosing a mode. This variable is scaled from 5 to 1 in the questionnaire form, where 1 represent a perception of very good comfort of the mode, and 5 represent very poor comfort. In the calibration process a reversed scale was used to be more meaningful. For instance, 5 represent a perception of very good comfort for the mode, and 1 is very poor.

SAFETY — Safety is a qualitative and attitudinal variable used to explain the behavior of the tripmaker in choosing a mode. This variable is scaled from 5 to 1 in the questionnaire form, where 1 represent a perception of very good safety of the mode, and 5 represent very poor safety. In the calibration process a reversed scale was used to be more meaningful. For instance, 5 represent a perception of very good safety for the mode, and 1 is very poor.

Table 5.3

Dhahran-Riyadh Corridor Mode-Choice Model
for Non-Business Trips (Train Included)

INDEPENDENT VARIABLES	COEFFICIENT	t-STAT	STANDARD ERROR
ASC-AIR	42.00	3.26	12.9
ASC-BUS	4.08	9.50	0.42
ASC-TRAIN	0.44	1.80	0.25
IVTT (specific to Train CAR, and BUS)	-.84	-2.44	0.34
IVTT (specific to AIR)	-47.79	-3.70	12.92
OPTC (generic)	-.013	-5.94	0.0022
HINC (specific to AIR)	0.236	1.65	0.142
HINC (specific to BUS)	-.58	-6.33	0.092
COMFORT (generic)	0.61	8.00	0.076
SAFETY (generic)	0.39	4.82	0.082
DUR (specific to air)	1.88	3.45	0.55

LOG LIKELIHOOD L(B) =-307.2
LOG LIKELIHOOD L(0) =-665.4
-2(L(0)-L(B)) = 716.2
LOCAL RHO SQUARED =0.538
LOCAL RHO-BAR SQUARED =0.535

ASC-AIR = Mode-specific constant for air
ASC-BUS = Mode-specific constant for bus
ASC-TRAIN = Mode-specific constant for train
IVTT = In-vehicle time in hours
OPTC = Out-of-pocket cost
HINC = Monthly household income
COMFORT = Qualitative variable
SAFETY = Qualitative variable
DUR = Duration of stay

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Table 5.4

Dhahran-Riyadh Corridor Mode-Choice Model for Non-Business Trips (Train is not Included)

INDEPENDENT VARIABLES	COEFFICIENT ESTIMATE	t-STAT	STANDARD ERROR
ASC-AIR	40.34	3.88	10.4
ASC-BUS	5.33	6.45	0.83
IVTT (specific to CAR and BUS)	-0.56	-1.04	0.539
IVTT (specific to AIR)	-43.45	-4.21	10.33
OPTC (generic)	-0.031	-6.17	0.0052
HINC (specific to AIR)	0.39	2.0	0.191
HINC (specific to BUS)	-0.716	-5.54	0.129
COMFORT (generic)	0.670	4.5	0.147
SAFETY (generic)	0.492	3.3	0.149
DUR (specific to air)	2.1	3.1	0.68

LOG LIKELIHOOD L(B) =-100.2
LOG LIKELIHOOD L(0) =-395.5
-2(L(0)-L(B)) = 590.6
LOCAL RHO SQUARED =0.746
LOCAL RHO-BAR SQUARED =0.743

ASC-AIR = Mode-specific constant for air
ASC-BUS = Mode-specific constant for bus
IVTT/DIS = In-vehicle time in hours
OPTC/DIST = Out-of-pocket cost
HINC = Monthly household income
COMFORT = Qualitative variable
SAFETY = Qualitative variable
DUR = Duration of stay

Table 5.5

Jeddah-Riyadh Corridor Mode-Choice Model
for Non-Business Trips

INDEPENDENT VARIABLES	COEFFICIENT	t-STAT	STANDARD ERROR
ASC-AIR	-0.5486	-0.15	3.754
ASC-BUS	7.6891	7.797	0.986
IVTT (specific to CAR and BUS)	-.4263	-3.05	0.1398
IVTT (specific to AIR)	-2.795	-1.14	2.439
OPTC (generic)	-.0088	-7.43	0.0012
HINC (specific to AIR)	0.530	3.36	0.158
HINC (specific to BUS)	-1.646	-6.79	0.242
COMFORT (generic)	0.416	3.88	0.107
SAFETY (generic)	0.430	3.77	0.114
DUR (specific to air)	3.30	2.69	1.225

LOG LIKELIHOOD L(B) =-140.3
LOG LIKELIHOOD L(0) =-395.5
-2(L(0)-L(B)) = 510.4
LOCAL RHO SQUARED =0.645
LOCAL RHO-BAR SQUARED =0.641

ASC-AIR = Mode-specific constant for air
ASC-BUS = Mode-specific constant for bus
IVTT = In-vehicle time in hours
OPTC = Out-of-pocket cost
HINC = Monthly household income
COMFORT = Qualitative variable
SAFETY = Qualitative variable
DUR = Duration of stay

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The coefficients of the parameters all have the expected signs in the selected models. The coefficients of in-vehicle travel time, total out-of-pocket cost, and household income specific to bus are negative, as expected, while household income specific to air, comfort, and safety are positive, as expected. The cost, comfort, and safety variables are generic. However, the in-vehicle travel time variable is generic for bus and car, and mode-specific for air. This assumes that out-of-pocket cost has the same marginal effect on each alternative's utility, but a minute in a bus or a car has a different marginal effect on mode choice than a minute on the plane.

It is clear from the t-stat values in Tables 5.3, 5.4 and 5.5 that the null hypothesis that the true value of each coefficient is zero can be rejected at the 0.05 significance levels except for in-vehicle travel time (IVTT) specific to bus and car in the Dhahran-Riyadh corridor model (without train), and in-vehicle travel time (IVTT) specific to air in the Jeddah-Riyadh corridor model. However, these variables are kept for transferability testing.

The goodness-of-fit measure rho-square (p^2) for the Jeddah-Riyadh corridor and Dhahran-Riyadh corridor models with and without train, are 0.645, 0.534, and 0.746, respectively. The p statistics for these models represent a very good fit.

The adjusted likelihood ratio index (rho-squared bar) for the Jeddah-Riyadh corridor and Dhahran-Riyadh corridor models with and without train are 0.641, 0.531, and 0.743, respectively.

The null hypothesis that all the parameters are zero ($\beta_1=\beta_2=\beta_3...\beta_k=0$) is tested by the X (chi-square) test (-2(L(0)-L(B))), which has a degree of freedom equal to the number of model parameters. The critical X^2 value with degrees of fre

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freedom equal to the model parameters, and a 0.05 level of significance (e.g. $X^2_{.05,9}$), is 16.92, while the calculated X^2 test statistic for the Jeddah-Riyadh corridor model is 510. In other words, the null hypothesis that all the parameters are jointly zero is rejected at the 95% level. Moreover, the null hypothesis that all the coefficients, except, the mode-specific constants, are zero is tested by

$$-2(L(C)-L(\beta))$$

with degree of freedom equal to **K-J+1**, where **K** is the number of model parameters, **J** is the number of alternatives in the universal choice set, and **L(C)** is the log likelihood for a model with only constants. This statistic is calculated as follows:

$$L(C) = \Sigma^{J}_{i=1} N_i \ln \frac{N_i}{N}$$

where N_i is the number of travelers selecting mode i and N is the total sample size. From Tables 5.3, 5.4 and 5.5, the X^2 test statistic with 8 degrees of freedom for the null hypothesis $\beta_3 = \beta_4 = \beta_5 ... \beta_9 = 0$

is -2(-395.5+145.4)=500.2 for the Jeddah-Riyadh model;

-2(-395.5+100.200)=590.6 for the Dhahran-Riyadh model (without train); and

-2(-665.4+309.740)=711.2 for the Dhahran-Riyadh model (with train).

The critical value with 8 degrees of freedom for a .05 level of significance ($X^2_{.05,8}$) is 15.51, which is lower than the calculated X^2. Hence, the null hypothesis that all the coefficients, except the mode-specific constants, are zero is rejected.

The overall prediction ratios for the Jeddah model and Dhahran model with and without trains are 84%, 74%, and 89%, respectively, as can be seen in Tables 5.6, 5.7 and 5.8. In other words, 89% of tripmakers in the Dhahran-Riyadh corridor sar

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sample are correctly predicted by the model. A comparison of observed and predicted cell frequencies in Table 5.6 shows that the correctly predicted value for the car mode is larger than the other modes. While, a comparison of observed and predicted cell frequencies in Table 5.8 shows that the correctly predicted value for the air and bus mode is larger than the car mode.

In order to test models for transferability, the same type of modes must exist in each corridor. The Dhahran-Riyadh corridor model (without train) and the Jeddah-Riyadh corridor model were tested for model transferability. Furthermore, these two models were also tested for the "Independence from Irrelevant Alternatives" assumption.

In summary, model specification for both corridors is the same, and consists of out-of-pocket cost (OPTC), household income specific to air and bus tripmakers ($HINC_A$, $HINC_B$) respectively, in-vehicle travel time (IVTT), safety (SAFETY) and comfort (COMFORT), and mode specific-constants for bus and plane.

Table 5.6

Prediction Success Table for the Jeddah-Riyadh Corridor Model -- The Calibration Process

	ALTERNATIVES		
	AIR	BUS	CAR
Number of tripmakers choosing this alternative	120	120	120
Number of tripmakers correctly predicted by the model	96	102	104
PREDICTION RATIO	0.80	.85	.87
OVERALL PREDICTION RATIO = 0.84			
x^2 = 9.63			

Table 5.7

Prediction Success Table for the Dhahran-Riyadh Corridor Model (with Train) -- The Calibration Process

	ALTERNATIVES			
	TRAIN	AIR	BUS	CAR
Number of tripmakers choosing this alternative	120	120	120	120
Number of tripmakers correctly predicted by the model	78	107	91	80
PREDICTION RATIO	0.65	0.89	.76	.67
OVERALL PREDICTION RATIO = 0.74				
x^2 = 36.45				

Table 5.8

Prediction Success Table for the Dhahran-Riyadh Corridor Model (without Train) -- The Calibration Process

	ALTERNATIVES		
	AIR	BUS	CAR
Number of tripmakers choosing chose this alternative	120	120	120
Number of tripmakers correctly predicted by the model	108	108	104
PREDICTION RATIO	0.90	.90	.87
OVERALL PREDICTION RATIO = 0.89			
x^2 = 4.53			

Test of the Independence from Irrelevant Alternatives Assumption

An "Independence from Irrelevant Alternatives (IIA)" Test was performed to determine if this assumption has been violated. This test involves a comparison of two likelihood values. One is the likelihood resulting from estimating the restricted sample by using the parameters of the universal set, while the other likelihood value is the one resulting from estimating the restricted sample but without restricting the parameters.

The Likelihood ratio test statistic is used to test the IIA assumption. This test statistic is chi-square distributed with degrees of freedom equal to the number of restricted parameters. This test was used to test the null hypothesis that the IIA model structure holds:

$$IIATS(B) = -2(LL_r(B) - LL_u(B)),$$

where $LL_r(B)$ is the likelihood from estimating the restricted sample by using the parameters of the universal set, and $LL_u(B)$ is the likelihood resulting from estimating the restricted sample without restricting the parameters.

It can be seen from Tables 5.9, and 5.10 that the null hypothesis of a logit model structure cannot be rejected. In other words, the IIA assumption is not violated.

Table 5.9

IIA Test for the Jeddah-Riyadh Corridor Model

	BUS*	CAR*	AIR*
$LL_r(B)$	-56.9	-61.7	-37.9
$LL_u(B)$	-55.0	-58.6	-31.4
$-2(LL_r(B) - LL_u(B))$	3.8	6.2	13.0
Degrees of freedom	8	8	5
x^2 statistic	$x^2_{8,01}$20.09	$x^2_{8,01}$20.09	$x^2_{5,01}$15.09

* Alternative excluded from the available modes

$LL_r(B)$ = The likelihood of the restricted sample by using the parameters of the universal set.

$LL_u(B)$ = The restricted likelihood resulting from estimating the restricted sample without restricting the parameters.

Table 5.10

IIA Test for the Dhahran-Riyadh Corridor Model

	BUS*	CAR*	AIR*
LL_r(B)	-32.8	-35.1	-53.6
LL_u(B)	-28.1	-24.3	-48.6
-2(LL_r(B)- LL_u(B)	9.4	21.6	10.0
Degrees of freedom	8	8	5
x^2 statistic	$x^2_{8,005}$21.96	$x^2_{8,005}$21.96	$x^2_{5,005}$16.75

* Alternative excluded from the available modes

LL_r(B) = The likelihood of the restricted sample by using the parameters of the universal set.

LL_u(B) = The restricted likelihood resulting from estimating the restricted sample without restricting the parameters.

Model Validation

Model validation was conducted by using the calibrated model to predict modal-split for data other than that used for model calibration. Two-hundred forty-four observations from the Jeddah-Riyadh corridor and one-hundred eighty-nine observations from the Dhahran-Riyadh corridor not used in model calibration were used to test model validity. A FORTRAN computer program was written to calculate the model prediction of each mode from the validation data (Appendix D). The prediction result of the model validation is presented in Tables 5.11, and 5.12.

Validation tests were conducted by comparing the estimated and observed ridership modal split using the X^2 statistics. Since there is no evidence at the 2.5% level of significance for the Dhahran-Riyadh corridor case and at the 5% level of significance for the Jeddah-Riyadh corridor case that there is a difference between the observed and the predicted modal split, the null hypothesis that there is no significant difference between the predicted values from the model and the observed ones cannot be rejected. Hence, there is no significant difference between the observed and predicted mode choice for the validation sample, and each model adequately fits the observed validation data for its corridor.

Table 5.11

Prediction Success Table for the Jeddah-Riyadh Corridor Model -- The Validation Process

	ALTERNATIVES		
	AIR	BUS	CAR
Number of tripmakers in validation sample choosing this alternative	108	103	33
Number of tripmakers correctly predicted by the model	88	83	32
PREDICTION RATIO	0.81	.80	.97
OVERALL PREDICTION RATIO = 0.83			
x^2 = 7.6			

Table 5.12

Prediction Success Table for the Dhahran-Riyadh Corridor Model -- The Validation Process

	ALTERNATIVES		
	AIR	BUS	CAR
Number of tripmaker in validation sample choosing this alternative	50	84	55
Number of tripmakers correctly predicted by the model	46	72	44
PREDICTION RATIO	0.92	.86	.80
OVERALL PREDICTION RATIO = 0.86			
x^2 = 4.2			

Aggregate Elasticities of the Estimated Models

Aggregate point elasticities for the Jeddah-Riyadh corridor model (Jeddah model) and for the Dhahran-Riyadh corridor model (Dhahran model) are presented in Tables 5.13, 5.14, 5.15, 5.16, 5.17, 5.18, 5.19, and 5.20. A direct elasticity is the percentage change in market share caused by a 1 percent change in the attribute of that mode. Cross elasticity is the percent change in market share for alternative i caused by a 1 percent change in an attribute of another alternative j. Interpreting the estimated elasticities is as follows: the direct elasticity for in-vehicle travel time specific to air in the Jeddah-Riyadh corridor is -1.01. This means that a one percent increase in the in-vehicle travel time by air, all else remaining constant, causes a 1.01% decrease in the overall probability of air choice. The variables OPTC and $MHINC_B$ can be interpreted similarly, while COMFORT, and SAFETY $HINC_A$ have an opposite interpretation because they have an opposite sign. For instance, the direct elasticity for the air mode variable "comfort" in the Jeddah-Riyadh corridor model is 0.42; this means that a one-percent increase in the comfort in the air mode, all else remaining constant, causes a 0.42% increase in the overall probability of air choice.

The elasticity of the air-mode choice probability in the Jeddah-Riyadh corridor model with respect to in-vehicle travel time (IVTT) is -1.01, which is much lower than that in the Dhahran-Riyadh corridor model (-3.98). This result is expected because tripmakers on longer trips are usually less elastic with respect to level-of-service variables than on short trip. The opposite relationship was found for the out-of-pocket cost (OPTC) elasticity for the Jeddah-Riyadh corridor model and the

Dhahran-Riyadh corridor model. However, the trend of direct elasticities for bus and car are opposite to that for the air mode, and this may be due to the different perception of level of service between air and bus or car.

From the estimation of the elasticities of the in-vehicle travel time (IVTT) variable it can be expected that the Saudi Arabian Airlines can benefit more by decreasing in-vehicle travel time (IVTT) than by decreasing the cost especially in the Dhahran-Riyadh corridor. For example, the direct elasticities for in-vehicle travel time (IVTT) and total-out-of-pocket cost (OPTC) specific to air in the Dhahran-Riyadh corridor are -3.98 and -0.5 respectively. This means that a one-percent decrease in in-vehicle travel time (IVTT), or out-of-pocket cost (OPTC), all else remaining constant, causes a 3.98% or 0.5% increase in the overall probability of air choice.

The bus tripmakers are more sensitive to out-of-pocket cost (OPTC) than in-vehicle travel time (IVTT) in the Dhahran-Riyadh corridor. This indicates that tripmakers selecting bus in this corridor are more sensitive to cost than time. However, for bus tripmakers in the Jeddah-Riyadh corridor the opposite relationship exists.

The HINC elasticity in the Jeddah-Riyadh corridor is approximately twice that in the Dhahran-Riyadh corridor.

The elasticity associated with the DUR variable is relatively low, indicating that the choice probabilities can be expected to be relatively insensitive to the duration of the trip.

Table 5.13

Direct Elasticities for Variables in the Jeddah-Riyadh Corridor Model

	AIR	BUS	CAR
IVTT (specific to a)	-1.01	0.00	0.00
IVTT (specific to c and b)	0.00	-1.14	-1.0
OPTC	-0.86	-0.415	-.36
COMFORT	0.42	0.217	0.349
SAFETY	0.44	0.298	0.333
HINC (specific to a)	0.467	0.00	0.000
HINC (specific to b)	0.00	-1.0	0.000
DUR	0.02	0.00	0.000

Table 5.14

Direct Elasticities for Variables in the Dhahran-Riyadh corridor Model

	AIR	BUS	CAR
IVTT (specific to a)	-3.98	0.00	0.00
IVTT (specific to c and b)	0.00	-0.48	-0.39
OPTC	-0.50	-.56	-0.431
COMFORT	0.29	0.33	0.53
SAFETY	0.20	0.31	0.31
HINC (specific to a)	0.18	0.00	0.00
HINC (specific to b)	0.00	-0.52	0.00
DUR	0.08	0.00	0.00

Table 5.15

Cross Elasticities for Variables in the Jeddah-Riyadh Corridor Model for Air Mode with Respect to Bus and Car Attributes

	BUS	CAR
IVTT (specific to a)	0.00	0.000
IVTT (specific to c and b)	0.589	0.553
OTPC	0.159	0.190
COMFORT	-0.109	-0.195
SAFETY	-0.150	-0.186
HINC (specific to a)	0.000	0.000
HINC (specific to b)	0.476	0.000
DUR	0.000	0.000

Table 5.16

Cross Elasticities for Variables in the Jeddah-Riyadh Corridor Model for BUS Mode with Respect to AIR and CAR Attributes

	AIR	CAR
IVTT (specific to a)	0.458	0.000
IVTT (specific to c and b)	0.000	0.444
OPTC	0.318	0.166
COMFORT	-0.191	-0.154
SAFETY	-0.206	-0.147
HINC (specific to a)	-0.15	0.000
HINC (specific to b)	0.000	0.000
DUR	-0.014	0.000

Table 5.17

Cross Elasticities for Variables in the Jeddah-Riyadh Corridor Model for CAR Mode with Respect to AIR and BUS Attributes

	AIR	BUS
IVTT (specific to a)	0.553	0.000
IVTT (specific to c and b)	0.000	0.554
OPTC	0.555	0.256
COMFORT	-0.230	-0.108
SAFETY	-0.231	-0.147
HINC (specific to a)	-0.314	0.000
HINC (specific to b)	0.000	0.522
DUR	-0.006	0.000

Table 5.18

Cross Elasticities for Variables in the Dhahran-Riyadh Corridor Model for AIR Mode with Respect to BUS and CAR Attributes

	BUS	CAR
ASC-AIR	0.000	0.000
ASC-BUS	-.225	0.000
IVTT (specific to a)	0.00	0.000
IVTT (specific to c and b)	0.108	0.100
OPTC	0.103	0.109
COMFORT	-0.757	-0.139
SAFETY	-0.638	-0.833
HINC (specific to a)	0.000	0.000
HINC (specific to b)	0.116	0.000
DUR	0.000	0.000

Table 5.19

Cross Elasticities for Variables in the Dhahran-Riyadh Corridor Model for BUS Mode with Respect to AIR and CAR Attributes

	AIR	CAR
IVTT (specific to a)	1.82	0.000
IVTT (specific to c and b)	0.000	0.292
OPTC	0.216	0.322
COMFORT	-0.137	-0.393
SAFETY	-0.889	-0.231
HINC (specific to a)	-0.063	0.000
HINC (specific to b)	0.000	0.000
DUR	-0.047	0.000

Table 5.20

Cross Elasticities for Variables in the Dhahran-Riyadh Corridor Model for CAR Mode with Respect to AIR and BUS Attributes

	AIR	BUS
IVTT (specific to a)	2.16	0.000
IVTT (specific to c and b)	0.000	0.368
OPTC	0.286	0.460
COMFORT	-0.152	-0.250
SAFETY	-0.107	-0.246
HINC (specific to a)	-0.116	0.000
HINC (specific to b)	0.000	0.4043
DUR	-0.035	0.000

CHAPTER VI

TRANSFERABILITY ANALYSIS

In the previous chapter, several intercity mode choice models were calibrated, and one model for each corridor was selected as best explaining the behavior of the tripmaker. In this chapter, the calibrated models for the two corridors under study will be tested for model transferability. These models are presented in Tables 5.4 and 5.5. These two models have the same specification and both were calibrated with an equal number of observations (360).

Several approaches were used to test model transferability. The first approach is to transfer these models without any modification. For instance, the calibrated model for the Riyadh-Jeddah corridor is used with data from the Dhahran-Riyadh corridor to explain the behavior of the tripmaker in the Dhahran-Riyadh corridor, and vice-versa. The second approach is to transfer the model specifications only and develop new coefficients. The constant terms as well as the coefficients of the variables are re-estimated using a part of the sample required to calibrate a new model. The sample size used was one-fifth of the sample required to calibrate the models. The Bayesian updating method was used to update the coefficients of the models. The coefficients of the models are used as prior information on the value of the true coefficients. The coefficients resulting from calibrating the model with the small sample are used to update this prior information. Updating the constants was conducted as follows:

$$\theta_2 = \frac{(\theta_1/\sigma_1^2)+(\theta_s/\sigma_s^2)}{(1/\sigma_1^2)+(1/\sigma_s^2)}$$

and

$$\sigma_2 = ((1/\sigma_1^2)+(1/\sigma_s^2))^{-\frac{1}{2}}$$

Where

θ_1 = original coefficient

θ_s = sample coefficient

θ_2 = updated coefficient

σ_1 = standard deviation of the original coefficient

σ_s = standard deviation of the sample coefficient

σ_2 = standard deviation of the updated coefficient

In this case, the constant terms and the coefficients of the variables for the Jeddah-Riyadh corridor are considered prior information and the constant and the coefficients of the variables are re-estimated with data from the Dhahran-Riyadh corridor. Then the re-estimated coefficient is used to update the transfer model.

The third approach is to transfer the model specification only, and calibrate the model with new data. This approach has been introduced to determine the universal set of specifications required to calibrate the mode choice model and to determine if the parameters estimated for the two corridors are equal.

Several measures were used to evaluate how well the transfer model explains the variation in the behavior of the tripmaker. The first measure is the X^2 test statistic. In this test a comparison is made between the observed value and the predicted value for each mode. Large values of the overall discrepancy between the model developed for a specific corridor and the transfer model indicate disagreement between the two models.

The second measure is the percentage right estimate for each individual. In this test a comparison is made between the predicted value from the transfer model and the observed value. This measure is analogous to the X^2 test, yet it produces insight to the difference between the distribution of observed and predicted values. These tests will also be used to determine the improvement in model prediction before and after updating the transfer model.

The asymptotic t statistic test of equality of individual coefficients between the two models has been used to test the hypotheses that the coefficients for level-of-service variable (e.g. time or cost) for the proposed models are equal, and the coefficients for level-of-service variables (e.G. Time or cost) for the original and the transfer model after updating are equal.

The following methods were used to test the proposed hypotheses:

1. The chi-square test and the percentage right method were used to test if there is a difference in prediction accuracy between the original model for each corridor and the transfer model. In addition, these tests were used to test if there is a difference in prediction accuracy before and after updating the coefficients for the transfer model.
2. The t-test statistic was used to test if the coefficients for level of service variable (e.g. time or cost) for the calibrated models are equal, and if coefficients for level-of-service variable (e.g. time or cost) for the transfer model after updating and the local model are equal.

3. The Transferability Test Statistic (TTS) was used to test if the parameters in the transfer model and the estimated parameters in the local model are equal.

4. The goodness-of-fit test was used to determine which specification is better in explaining the tripmaker behavior in the new context.

Evaluation of The Transferability of the Models

The transfer approaches delineated in Chapter III will be evaluated using the measures outlined. The following convention was used in these tests:

DHA- The local model for the Dhahran-Riyadh corridor using the entire calibration data.

JED- The local model for the Jeddah-Riyadh corridor using the entire calibration data.

DHA-JED- The local model for the Dhahran-Riyadh corridor using the entire calibration data, transferred as it is to the Jeddah-Riyadh corridor.

JED-DHA- The local model for the Jeddah-Riyadh corridor using the entire calibration data transferred as it is to the Dhahran-Riyadh corridor.

DHA-SM- The calibrated model for the Dhahran-Riyadh corridor using a small sample to update the Jeddah-Riyadh corridor model.

JED-SM- The calibrated model for the Jeddah-Riyadh corridor using a small sample to update the Dhahran-Riyadh corridor model.

JED-UP The updated Jeddah-Riyadh model (using the Bayesian updating method) to be transferred to the Dhahran-Riyadh corridor.

DHA-UP The updated Dhahran-Riyadh model (using the Bayesian updating method) to be transferred to the Jeddah-Riyadh corridor.

The first approach used was to transfer the Jeddah-Riyadh corridor model to the Dhahran-Riyadh corridor as it is, and vice-versa. The Likelihood Ratio Test statistic measure of the transferability and transfer ρ^2 resulting from this approach are presented in Tables 6.1, and 6.2 for the Jeddah-Riyadh corridor and the Dhahran-Riyadh corridor, respectively. The null hypothesis that the parameters in the Jeddah-Riyadh model and the parameters in the Dhahran-Riyadh corridor model are equal was rejected in both cases. Moreover, the comparison in goodness-of-fit measure (ρ^2) between the original model (or the local model) and the transferred model shows a very large difference (e.g., local ρ^2 for the DHA model is 0.746 and transfer ρ^2 for the JED-DHA is 0.25, while local ρ^2 for the JED model is 0.645 and transfer ρ^2 for the DHA-JED is -4.91).

The calibrated model for the Jeddah-Riyadh corridor yields a lower value in the transferability test statistic (TTS) and the ρ^2 difference between the original model and the transferred model is less than that for the Dhahran-Riyadh corridor. In other words, the calibrated model for the Jeddah-Riyadh corridor in its original form explains the variation of the Dhahran-Riyadh corridor data set better than the Dhahran-Riyadh model explains the variation in the Jeddah-Riyadh corridor. However, neither transferred model is acceptable.

Table 6.1

Transferability Test of the Jeddah-Riyadh Model
Before and After Updating the Coefficients

Variable Name	Estimated Variable Coefficients		
	JED-DHA Model	DHA Model	JED-UP Model
ASC-AIR	-0.55 (-0.15)	40.34 (3.88)	2.15 (0.60)
ASC-BUS	7.69 (7.80)	5.33 (6.45)	6.69 (8.00)
OPTC	-0.01 (-7.43)	- 0.03 (-6.17)	-0.01 (-7.64)
$IVTT_{B,C}$	-0.43 (-3.05)	- 0.56 (-1.04)	-0.41 (-2.90)
$IVTT_A$	-2.80 (-1.14)	-43.46 (-4.21)	-4.05 (-1.70)
COMFORT	0.42 (3.88)	0.67 (4.50)	0.46 (4.51)
SAFETY	0.43 (3.77)	0.49 (3.30)	0.43 (3.97)
$MHINC_A$	0.53 (3.36)	0.39 (2.05)	0.54 (3.72)
$MHINC_B$	-1.65 (-6.79)	-0.72 (-5.54)	-1.23 (-6.69)
DUR_A	3.30 (2.69)	2.08 (3.10)	3.43 (3.84)
Local p^2	---	0.75	---
Transfer p^2	0.25	---	0.09
L(0)	-395.5	-395.5	-395.5
$LL_D(ß^*_D)$	---	-100.2	---
$LL_D(ß^*_J)$	-298.3	---	-339.7
$TTS_D(ß^*_J)$	395.6	---	519
Critical $\chi_{.05,10}$	18.3	18.3	18.3

where:

(**)	t-statistic
$TTS_D(ß^*_J)$	Transferability test statistic
$LL_D(ß^*_J)$	The log likelihood of the behavior observed in Dhahran-Riyadh corridor generated by the model estimated in Jeddah-Riyadh corridor
$LL_D(ß^*_D)$	The log likelihood for the model estimated in Dhahran-Riyadh corridor.
p^2	Goodness of fit measure.

Table 6.2

Transferability Test of the Dhahran-Riyadh Model
Before and After Updating the Coefficients

Variable Name	Estimated Variable Coefficients		
	JED Model	DHA-JED Model	DHA-UP Model
ASC-AIR	-0.55 (-0.15)	40.34 (3.88)	8.63 (1.51)
ASC-BUS	7.69 (7.80)	5.33 (6.45)	5.62 (7.20)
OPTC	-0.01 (-7.43)	- 0.03 (-6.17)	-0.02 (-60.56)
$IVTT_{B,C}$	-0.43 (-3.05)	- 0.56 (-1.04)	-0.56 (-1.99)
$IVTT_A$	-2.80 (-1.14)	-43.46 (-4.21)	-5.37 (-1.42)
COMFORT	0.42 (3.88)	0.67 (4.50)	0.50 (3.99)
SAFETY	0.43 (3.77)	0.49 (3.30)	0.53 (3.98)
$MHINC_A$	0.53 (3.36)	0.39 (2.05)	0.39 (2.31)
$MHINC_B$	-1.65 (-6.79)	-0.72 (-5.54)	-0.77 (-6.12)
DUR_A	3.30 (2.69)	2.08 (3.10)	2.09 (16.14)
Local p^2	0.65	---	---
Transfer p^2	---	-4.91	-0.24
L(0)	-395.5	-395.5	-395.5
$LL_J(ß^*_J)$	-140.3	---	---
$LL_J(ß^*_D)$	---	-2339	-488.6
$TTS_J(ß^*_D)$	---	4398	696.5
Critical $X_{.05,10}$	18.3	18.3	18.3

where

(***)	t-statistic
$TTS_J(ß^*_D)$	Transferability test statistic
$LL_J(ß^*_D)$	The log likelihood of the behavior observed in Jeddah-Riyadh corridor generated by the model estimated in Dhahran-Riyadh corridor
$LL_J(ß^*_J)$	The log likelihood for the model estimated in Jeddah-Riyadh corridor.
p^2	Goodness of fit measure

In summary, transferring the Jeddah-Riyadh model to the Dhahran-Riyadh corridor, and vice-versa, does not work because this produces a very low goodness of fit, and a very large difference between the observed values and those predicted by the transferred model.

The second transfer approach is to use a Bayesian updating method. In this approach the constant terms, as well as the coefficients of the variables in the transfer model, are re-estimated using a portion of the sample required to calibrate a new model. The sample size recommended for this updating in reference (16) is about one-fifth the sample required to calibrate the model (75 observations were used to estimate the small sample model). The coefficients of the transferred model are considered prior information of the true coefficients, and the coefficients resulting from calibrating the model with the small sample are used to update this prior information.

In this case the constant terms and the coefficients of the variables in the Jeddah-Riyadh model were considered prior information and the constant and the coefficients of the variables were re-estimated with small data from the Dhahran-Riyadh corridor, and vice-versa.

Tables 6.1, and 6.2 show the updated parameter values for each corridor as well as the statistical test result. The result of the Likelihood Ratio Test statistic shows a rejection of the null hypothesis that the parameters in the Jeddah-Riyadh model and the parameters in the Dhahran-Riyadh model after updating are equal, and vice-versa.

The comparison in goodness of fit measure (p^2) between the original model and the transferred model after updating shows a very large difference (e.g., p^2 for the DHA model (calibrated model) is 0.746 and p^2 for the JED-DHA-UP (updated transferred model) is 0.09). However, the calibrated model for the Jeddah-Riyadh corridor yields a higher value of the TTS score and a lower p^2 after updating than transferring the model in its original form. This is the opposite result of the other corridor, where updating the Dhahran-Riyadh model results in a lower value of the TTS test and a higher p^2 than transferring the model without any modification.

From Tables 6.3, and 6.4 it can be seen that the hypothesis that the coefficients of IVTT specific to bus and car, IVTT specific to air (JED model only), COMFORT, SAFETY, DUR, and MHINC specific to air are equal in the original model and the updated transferable one can not be rejected at the 95% significance level. The hypothesis of equal coefficients for IVTT specific to air (DHA model), OPTC and MHINC specific to bus between the updated transferable model and the original model is rejected at the 95% significance level. This mix of results in the level of significance of service variables and socioeconomic variables led to the conclusion that in performing another study both types of variables must be collected.

Table 6.3

Comparison Between the Calibrated Jeddah-Riyadh Model and the Updated Dhahran-Riyadh Model

	JED-Model		DHA-UP Model		
	Coefficients	Standard Error	Coefficients	Standard Error	t-Stat
ASC-AIR	-0.55	3.75	8.63	5.73	-1.34
ASC-BUS	7.69	10.99	5.62	0.78	1.65
$IVTT_{C,B}$	-0.43	0.14	-0.56	0.28	0.44
$IVTT_A$	-2.79	2.44	-5.37	3.79	0.57
OPTC	-0.01	0.00	-0.02	0.00	3.27
$MHINC_A$	0.53	0.16	0.39	0.17	0.63
$MHINC_B$	-1.65	0.24	-0.77	0.13	-3.21
COMFORT	0.42	0.11	0.50	0.13	-0.52
SAFETY	0.43	0.11	0.53	0.13	-0.58
DUR_A	3.30	1.23	2.09	0.13	0.98
p^2	0.645		-0.235		
L(0)	-395.5		-395.5		
$LL_J(\beta^-_J)$	-140.3		---		
$LL_J(\beta^-_D)$	---		-488.6		
$TTS_J(\beta^-_D)$	---		696.5		
Critical $\chi^2_{.05,10}$	18.3		18.3		

where

(***) t-statistic

$TTS_J(\beta^-_D)$ Transferability test statistic

$LL_J(\beta^-_D)$ The log likelihood of the behavior observed in Jeddah-Riyadh corridor generated by the model estimated in Dhahran-Riyadh corridor

$LL_J(\beta^-_J)$ The log likelihood for the model estimated in Jeddah-Riyadh corridor.

p^2 Goodness of fit measure

Table 6.4

Comparison Between the Calibrated Dhahran-Riyadh Model and the Updated Jeddah-Riyadh Model

	JED-UP Model		DHA-Model		t-Stat
	Coefficients	Standard Error	Coefficients	Standard Error	
ASC-AIR	2.15	3.59	40.35	10.41	-3.47
ASC-BUS	6.69	0.84	5.33	0.83	1.16
$IVTT_{B,C}$	-0.41	0.14	-0.56	0.54	0.27
$IVTT_A$	-4.05	2.38	-43.46	10.33	3.72
OPTC	-0.01	0.00	-0.03	0.01	4.30
$MHINC_A$	0.54	0.15	0.39	0.19	0.64
$MHINC_B$	-1.23	0.18	-0.72	0.13	-2.29
COMFORT	0.46	0.10	0.67	0.15	-1.19
SAFETY	0.43	0.11	0.49	0.15	-0.36
DUR_A					
p^2	0.09		0.746		
L(0)	-395.5		-395.5		
$LL_D(\beta^-_D)$	---		-100.2		
$LL_D(\beta^-_J)$	-339.7		---		
$TTS_D(\beta^-_J)$	519.0		---		
Critical $\chi^2_{.05,10}$	18.3		18.3		

where

(**) t-statistic

$TTS_D(\beta_J)$ Transferability test statistic

$LL_D(\beta_J)$ The log likelihood of the behavior observed in Dhahran-Riyadh corridor generated by the model estimated in Jeddah-Riyadh corridor

$LL_D(\beta_D)$ The log likelihood for the model estimated in Dhahran-Riyadh corridor.

p^2 Goodness of fit measure

The prediction power of the transferred model improved for the Dhahran-Riyadh model after updating, and deteriorated for the Jeddah-Riyadh corridor. Transferring the Jeddah-Riyadh model (after updating) to the Dhahran-Riyadh corridor, and vice-versa, yields a very low goodness of fit, and a very large difference between the estimated parameter for the local model and the transferred model. In addition, the null hypothesis of equality of the parameters in the transfer model after updating and the parameters of the original model was rejected. Hence these models are not transferable after updating.

The third approach is to transfer the model specification only, and to determine if the parameters estimated for the two corridors are equal. As explained in the model calibration section, both models have the same specification. This means that this specification is a universal one required to calibrate an intercity mode choice model in Saudi Arabia.

The asymptotic t statistic test of equality of individual coefficients between the two models has been used to compare the individual coefficients in the Jeddah-Riyadh model and the Dhahran-Riyadh model. Table 6.5 shows a comparison between the individual coefficients in the Jeddah-Riyadh model and in the Dhahran-Riyadh model. The most significant differences are between the coefficients for out-of-pocket cost (OPTC), in-vehicle travel time specific to air ($IVTT_A$), monthly household income specific to bus ($MHINC_B$), and the mode-specific to air and bus. The comfort variable, duration variable, in-vehicle travel time specific to bus, and car ($IVTTB_{,B,C}$), and the monthly household income variable specific to air ($MHINC_A$), are not significantly different at the 90% level.

The difference between the individual coefficients also supports the previous conclusion that these two models are not transferable. These differences in the individual estimated parameters, especially for the level-of-service variables, led to a study of the difference in means between the independent variables used in calibrating each model. Table 6.6 shows the mean value of the independent variables for each mode, and the specific ratio between the Jeddah-Riyadh variables and the Dhahran-Riyadh variables. The same comparison is also applied to the standard deviation of each variable. In comparing the means of each mode for each variable, it can be seen that the level-of-service (LOS) variables contribute most to the large difference between the estimated and the transferred parameters. The specific ratio of each variable is approximately equal to one except for those related to the level-of-service variables in-vehicle travel time (IVTT) and out of pocket cost (OPTC). Moreover, these level-of-service variable ratios are approximately identical to the objective ratio (obtained from the agency operating that mode), as can be seen in Table 6.7.

Table 6.5

Jeddah-Riyadh Versus Dhahran-Riyadh Coefficients

Variable	Estimated Variable Coefficients[1]			
Name	Jeddah-Riyadh Model	Dhahran-Riyadh Model	t-stat	Ratio[2]
ASC-AIR	-0.55 (-0.15)	40.34 (3.88)	-3.70	-0.01
ASC-BUS	7.69 (7.80)	5.33 (6.45)	1.83	1.44
OPTC	-0.0088 (-7.43)	-0.032 (-6.17)	4.34	0.28
$IVTT_{B,C}$	-0.426 (-3.05)	0.56 (-1.04)	0.24	0.76
$IVTT_A$	-2.795 (-1.14)	-43.46 (-4.21)	3.83	0.06
COMFORT	0.416 (3.88)	0.67 (4.50)	-1.39	0.62
SAFETY	0.43 (3.77)	0.492 (3.30)	-0.331	0.87
$MHINC_A$	0.53 (3.36)	0.39 (2.05)	0.56	1.36
$MHINC_B$	-1.646 (-6.79)	-0.72 (-5.54)	-3.37	2.29
DUR_A	3.30 (2.69)	2.08 (3.1)	0.98	1.58
p^2	0.645	0.746		
L(B)	-140.3	-100.2		
L(0)	-395.5	-395.5		

1 The estimated coefficient is not significantly different from zero at the 0.05 or greater value.

2 Ratio = Parameter in Jeddah-Riyadh model/ parameter in Dhahran-Riyadh model

(**) t-statistic

Table 6.6

Comparison Between the Variables Used in Calibrating Dhahran-Riyadh Model and Jeddah-Riyadh Model

Variable Name	Jeddah-Riyadh Corridor (1)			Dhahran-Riyadh Corridor (2)			Specific Ratio (1)/(2)			Overall Ratio
	AIR	BUS	CAR	AIR	BUS	CAR	RATIO^A	RATIO^B	RATIO^C	AVERAGE
IVTT	1.37 0.15)	13.36 (1.33)	9.97 (1.34)	0.79 (0.10)	4.31 (0.39)	3.94 (0.50)	1.73 (0.46)	3.10 (3.41)	2.53 (2.71)	2.45 (2.52)
OPTC	360.80 (45.20)	127.16 (63.70)	194.00 (39.50)	183.00 (65.30)	80.70 (20.90)	73.67 (24.46)	1.97 (2.22)	1.58 (3.05)	2.63 (1.61)	2.06 (2.30)
MHINC	4.73 (1.62)	2.28 (0.91)	4.89 (1.51)	5.06 (1.73)	2.86 (1.52)	4.90 (1.94)	0.94 (0.94)	0.80 (0.60)	1.00 (0.78)	0.91 (0.77)
COMFORT	4.55 (1.05)	3.54 (1.25)	4.05 (0.96)	4.81 (0.87)	3.20 (0.97)	4.15 (0.91)	0.95 (1.20)	1.11 (1.29)	0.97 (1.05)	1.01 (1.18)
SAFETY	4.42 (0.97)	4.20 (0.95)	3.43 (0.98)	4.53 (0.90)	3.71 (0.96)	3.25 (0.98)	0.98 (1.08)	1.13 (0.99)	1.06 (1.00)	1.05 (1.02)
DUR	2.12 (0.72)	2.21 (0.54)	2.32 (0.47)	1.72 (0.66)	2.04 (0.74)	1.99 (0.55)	1.23 (1.08)	1.08 (0.73)	1.17 (0.85)	1.16 (0.89)

where

(***)	Standard deviation
Ratio^A	The ratio of the variable in Jeddah-Riyadh corridor data set to that in Dhahran-Riyadh corridor data set for Air mode only.
Ratio^B	The ratio of the variable in Jeddah-Riyadh corridor data set to that in Dhahran-Riyadh corridor data set for BUS mode only.
Ratio^C	The ratio of the variable in Jeddah-Riyadh corridor data set to that in Dhahran-Riyadh corridor data set for CAR mode only.
Overall Ratio	The summation of the three specific ratio divided by three.

Table 6.7

The Ratio of the Objective Level-of-Service Variable

Variable Name	Jeddah-Riyadh corridor (1)			Dhahran-Riyadh corridor (2)			Ratio (1)/(2) for		
	AIR	BUS	CAR	AIR	BUS	CAR	AIR	BUS	CAR
$IVTT_O$	1.5	13.4	8.8	1.0	4.5	3.84	1.5	3.0	2.3
$IVTT_R$	1.37	13.36	9.96	0.79	4.3	3.94	1.7	3.1	2.5
$COST_O$	240	115	115	120	60	50	2.0	1.9	2.3
$OPTC_R$	360	127	194	183	81	73.7	2.0	1.6	2.6

where

$IVTT_O$ In-vehicle objective values.
$IVTT_R$ In-vehicle reported values.
$COST_O$ Ticket costs for bus or air, and oil cost for car.
$OPTC_R$ Total reported out-of-pocket cost.

Furthermore, the overall ratio is related to the ratio of the distance between the cities under consideration. The distance between Jeddah and Riyadh is 1061 KM while the distance between Dhahran and Riyadh is 467 KM, so the ratio is 2.27, and the overall average of the ratio of the level of service variable is 2.26 ((2.45+2.06)/2).

These two observations were used to recalibrate each model to improve transferability. For instance, the in-vehicle travel time value and out-of-pocket cost in each observation will be multiplied by its respective specific ratio. Thus to use the Dhahran-Riyadh model to explain the variation of the data in the Jeddah-Riyadh corridor, the in-vehicle travel time for air, bus, and car in the Dhahran-Riyadh corridor was multiplied by 1.7, 3.1, and 2.5, respectively, and the out-of-pocket cost value for air, bus, and car was multiplied by 2.0, 1.6, and 2.6, respectively. This calibrated model was then used to test for transferability. In addition, IVTT and OPTC in the Dhahran-Riyadh corridor data set were divided by the distance between Dhahran and Riyadh (467 KM) to recalibrate another Dhahran-Riyadh corridor model. The same procedure was applied to the Jeddah-Riyadh model. In these tests, the following additional identification conventions will be used:

JED-DHA-LOS — The calibrated model for the Jeddah-Riyadh corridor using the entire modified calibrated data (LOS case) transferred as it is to the Dhahran-Riyadh corridor.

DHA-JED-LOS — The calibrated model for the Dhahran-Riyadh corridor using the entire modified calibrated data (LOS case) transferred as it is to the Jeddah-Riyadh corridor.

JED-LOS-UP — The updated modified Jeddah-Riyadh model by Bayesian updating method to be transferred to the Dhahran-Riyadh corridor (LOS case).

DHA-LOS-UP — The updated modified the Dhahran-Riyadh model by Bayesian updating method to be transferred to the Jeddah-Riyadh corridor (LOS case).

JED-DHA-DIS — The calibrated model for the Jeddah-Riyadh corridor using the entire modified calibrated data (distance case) transferred as it is to the Dhahran-Riyadh corridor.

DHA-JED-DIS — The calibrated model for the Dhahran-Riyadh corridor using the entire modified calibrated data (distance case) transferred as it is to the Jeddah-Riyadh corridor.

JED-DIS-UP — The updated modified Jeddah-Riyadh model to be transferred to the Dhahran-Riyadh corridor (distance case).

DHA-DIS-UP — The updated modified Dhahran-Riyadh model to be transferred to the Jeddah-Riyadh corridor (distance case).

Tables 6.8, and 6.9 show the value of the modified parameter before and after updating for each corridor, as well as the statistical test results. The result of the likelihood ratio test statistic shows a rejection of the null hypothesis that the parameters in the local model and the parameters in the modified transferred model (LOS case) before or after updating are equal. However, in comparing the modified approach and the non-modified approach, the modified approach provides a lower value of the likelihood ratio test statistic. Hence, the modified approach is a better method for transferring models.

Table 6.8

Transferability Test of the Modified Jeddah-Riyadh Model Before and After Updating Coefficients; (the Specific LOS Ratio Case)

Variable Name	Estimated Variable Coefficients		
	JED-DHA-LOS Model	DHA Model	JED-LOS-UP Model
ASC-AIR	-0.73 (-0.19)	40.34 (3.88)	2.13 (0.58)
ASC-BUS	6.56 (7.95)	5.33 (6.45)	6.04 (8.26)
OPTC	-0.02 (-7.48)	- 0.03 (-6.17)	-0.02 (-8.00)
$IVTT_{B,C}$	-1.09 (-2.97)	- 0.56 (-1.04)	-0.92 (-2.63)
$IVTT_A$	-4.29 (-1.16)	-43.46 (-4.21)	-6.87 (-1.96)
COMFORT	0.41 (3.81)	0.67 (4.50)	0.45 (4.44)
SAFETY	0.44 (3.79)	0.49 (3.30)	0.39 (1.25)
$MHINC_A$	0.52 (3.30)	0.39 (2.05)	0.62 (1.62)
$MHINC_B$	-1.61 (-6.68)	-0.72 (-5.54)	-1.21 (-6.64)
DUR_A	3.27 (2.72)	2.08 (3.10)	3.41 (3.86)
p^2	0.341	0.746	0.439
L(0)	-395.5	-395.5	-395.5
$LL_D(ß^*_D)$	---	-100.2	---
$LL_D(ß^*_J)$	-260.8	---	-221.8
$TTS_D(ß^*_J)$	320.9	---	243.3
Critical $X^2_{.05,10}$	18.3	18.3	18.3

where

(**)	t-statistic
$TTS_D(ß^*_D)$	Transferability test statistic
$LL_D(ß^*_J)$	The log likelihood of the behavior observed in Dhahran-Riyadh corridor generated by the model estimated in Jeddah-Riyadh corridor
$LL_D(ß^*_D)$	The log likelihood for the model estimated in Dhahran-Riyadh corridor
p^2	Goodness of fit measure

Table 6.9

Transferability Test of the Modified Dhahran-Riyadh Model Before and After Updating Coefficients; (the Specific LOS Ratio Case)

Variable Name	Estimated Variable Coefficients: JED Model	DHA-JED-LOS Model	DHA-LOS-UP Model
ASC-AIR	-0.55 (-0.15)	38.49 (3.47)	6.96 (1.19)
ASC-BUS	7.69 (7.80)	2.95 (2.89)	3.74 (3.99)
OPTC	-0.01 (-7.43)	- 0.01 (-4.17)	-0.01 (-5.57)
$IVTT_{B,C}$	-0.43 (-3.05)	- 0.12 (-0.72)	-0.22 (-1.42)
$IVTT_A$	-2.80 (-1.14)	-28.07 (-3.78)	-6.06 (-1.70)
COMFORT	0.42 (3.88)	0.65 (5.65)	0.54 (5.20)
SAFETY	0.43 (3.77)	0.41 (3.54)	0.45 (4.11)
$MHINC_A$	0.53 (3.36)	0.39 (2.26)	0.39 (2.50)
$MHINC_B$	-1.65 (-6.79)	- 0.70 (-6.29)	-0.74 (-6.80)
DUR_A	3.30 (2.69)	1.86 (2.97)	1.90 (3.09)
p^2	0.645	0.392	0.558
L(0)	-395.5	-395.5	-395.5
$LL_J(\beta^*_J)$	-140.3	---	---
$LL_J(\beta^*_D)$	---	-240.4	-174.9
$TTS_J(\beta^*_D)$	---	200.1	69.2
Critical $X^2_{.05,10}$	18.3	18.3	18.3

where

(***)	t-statistic
$TTS_J(\beta^*_J)$	Transferability test statistic
$LL_J(\beta^*_D)$	The log likelihood of the behavior observed in Jeddah-Riyadh corridor generated by the model estimated in Dhahran-Riyadh corridor
$LL_J(\beta^*_J)$	The log likelihood for the model estimated in Jeddah-Riyadh corridor.
p^2	Goodness of fit measure

The comparison in goodness of fit measure (p^2) between the original model and the modified transfer model before and after updating shows a difference (e.g., p^2 for the DHA model is 0.746 and p^2 for the JED-DHA-LOS; JED-LOS-UP are 0.341, and 0.439, respectively). However, the calibrated model for the modified Dhahran-Riyadh corridor data set after updating yields a lower value for the TTS test and a higher p^2 than transferring the model in its original form. In other words, the updated modified approach provides a better model than either transferring the original model as it is or updating it with a small sample.

The second modified approach was to divide IVTT and OPTC by the respective distance in each corridor. Then the recalibrated models were tested for transferability.

Tables 6.10, and 6.11 show the parameter before and after updating for each corridor as well as the statistical result of the test. The result of the Likelihood Ratio Test statistic shows a rejection of the null hypothesis that the parameters in the Jeddah-Riyadh distance model and the parameters in the Dhahran-Riyadh distance model before or after updating are equal, and vice-versa.

The comparison in goodness of fit measure (p^2) between the original and the transfer model (before or after updating) shows a very large difference (e.g., p^2 for the DHA model (calibrated model) is 0.746 and p^2 for the JED-UP-DIS (updated transferred model) is 0.146). The calibrated model for the Jeddah-Riyadh corridor yields a higher value of TTS and a lower p^2 after updating than does transferring the model in its original form. The Dhahran-Riyadh model exhibited just the opposite effect.

The same observation of the mix of significance and non-significance using the level-of-service variables and the socioeconomic variables can be seen in Tables 6.12 and 6.13.

In summary, transferring the Jeddah-Riyadh model (after updating) to the Dhahran-Riyadh corridor yields a very low goodness of fit. The Dhahran-Riyadh model (modified by distance), when transferred to the Jeddah-Riyadh corridor, yields an acceptable goodness of fit. Hence, the prediction power of the transfer model improved for the Dhahran-Riyadh model after updating, and deteriorated for the Jeddah-Riyadh corridor after updating. Hence, the DHA-DIS model is an acceptable model after updating for transferability, while the JED-DIS model is not.

Table 6.10

Transferability Test of the Modified Jeddah-Riyadh Model Before and After Updating Coefficients; (the distance case)

Variable Name	Estimated Variable Coefficients		
	JED-DHA-DIS Model	DHA-DIS Model	JED-DIS-UP Model
ASC-AIR	-0.55 (-0.15)	40.34 (3.88)	2.15 (0.60)
ASC-BUS	7.69 (7.80)	5.33 (6.45)	6.69 (8.00)
OPTC	-0.01 (-7.43)	- 0.02 (-6.17)	-0.01 (-7.80)
$IVTT_{B,C}$	-0.45 (-3.05)	- 0.26 (-1.04)	-0.40 (-2.76)
$IVTT_A$	-2.96 (-1.14)	-20.28 (-4.21)	-5.20 (-2.28)
COMFORT	0.42 (3.88)	0.67 (4.50)	0.46 (4.50)
SAFETY	0.43 (3.77)	0.49 (3.30)	0.43 (3.97)
$MHINC_A$	0.53 (3.36)	0.39 (2.05)	0.54 (3.72)
$MHINC_B$	-1.65 (-6.79)	-0.72 (-5.54)	-1.23 (-6.69)
DUR_A	3.30 (2.69)	2.09 (3.10)	3.43 (3.84)
p^2	0.25	0.746	0.146
L(0)	-395.5	-395.5	-395.5
$LL_D(\beta^*_D)$	---	-100.2	---
$LL_D(\beta^*_J)$	-298.3	---	-338.0
$TTS_D(\beta^*_J)$	395.6	---	476.1
Critical $X^2_{.05,10}$	18.3	18.3	18.3

where

(**)	t-statistic
$TTS_D(\beta^*_J)$	Transferability test statistic
$LL_D(\beta^*_J)$	The log likelihood of the behavior observed in Dhahran-Riyadh corridor generated by the model estimated in Jeddah-Riyadh corridor
$LL_D(\beta^*_D)$	The log likelihood for the model estimated in Dhahran-Riyadh corridor
p^2	Goodness of fit measure

Table 6.11

Transferability Test of the Modified Dhahran-Riyadh Corridor and After Updating Coefficients; (the distance case)

Variable Name	Estimated Variable Coefficients JED-DIS Model	DHA-JED-DIS Model	DHA-DIS-UP Model
ASC-AIR	-0.55 (-0.15)	40.34 (3.88)	8.63 (1.51)
ASC-BUS	7.69 (7.80)	5.33 (6.45)	5.62 (7.20)
OPTC	-0.01 (-7.43)	- 0.02 (-6.17)	-0.02 (-7.21)
$IVTT_{B,C}$	-0.43 (-3.05)	- 0.26 (-1.04)	-0.38 (-1.83)
$IVTT_A$	-2.96 (-1.14)	-20.28 (-4.21)	-8.71 (-2.71)
COMFORT	0.42 (3.88)	0.67 (4.50)	0.50 (3.99)
SAFETY	0.43 (3.77)	0.49 (3.30)	0.53 (3.98)
$MHINC_A$	0.53 (3.36)	0.39 (2.05)	0.39 (2.31)
$MHINC_B$	-1.65 (-6.79)	-0.72 (-5.54)	-0.77 (-6.12)
DUR_A	3.30 (2.69)	2.09 (3.10)	2.09 (16.14)
p^2	0.645	-4.91	0.544
L(0)	-395.5	-395.5	-395.5
$LL_J(\beta^*_J)$	-140.3	---	---
$LL_J(\beta^*_D)$	---	-2348	-180.5
$TTS_J(\beta^*_D)$	---	4417	80.3
Critical $X^2_{.05,10}$	18.3	18.3	18.3

where
(***) t-statistic

$TTS_J(\beta^*_D)$	Transferability test statistic
$LL_J(\beta^*_D)$	The log likelihood of the behavior observed in Jeddah-Riyadh corridor generated by the model estimated in Dhahran-Riyadh corridor
$LL_J(\beta^*_J)$	The log likelihood for the model estimated in Jeddah-Riyadh corridor.
p^2	Goodness of fit measure.

Table 6.12

Comparison Between the Calibrated Dhahran-Riyadh Model and the Updated Modified Jeddah-Riyadh Model (Distance Case)

	JED-UP-DIS Model		DHA-DIS Model		t-Stat
	Coefficients	Standard Error	Coefficients	Standard Error	
ASC-AIR	2.15	3.59	40.35	10.41	-3.47
ASC-BUS	6.69	0.84	5.33	0.83	1.16
$IVTT_{C,B}$	-0.39	0.14	-0.56	0.54	0.30
$IVTT_A$	-5.19	2.32	-43.46	10.33	3.61
OPTC	-0.01	0.00	-0.03	0.01	4.19
$MHINC_A$	0.54	0.15	0.39	0.19	0.64
$MHINC_B$	-1.23	0.18	-0.72	0.13	-2.29
COMFORT	0.46	0.10	0.67	0.15	-1.19
SAFETY	0.43	0.11	0.49	0.15	-0.36
DUR_A	3.43	0.89	2.09	0.13	1.49
p^2	0.146		0.746		
L(0)	-395.5		-395.5		
$LL_D(\beta_D)$	---		-100.2		
$LL_D(\beta_J)$	-338		---		
$TTS_D(\beta_J)$	476.1		---		
Critical $\chi^2_{.05,10}$	18.3		18.3		

where

(**)	t-statistic
$TTS_D(\beta^*_J)$	Transferability test statistic
$LL_D(\beta^*_J)$	The log likelihood of the behavior observed in Dhahran-Riyadh corridor generated by the model estimated in Jeddah-Riyadh corridor
$LL_D(\beta^*_D)$	The log likelihood for the model estimated in Dhahran-Riyadh corridor
p^2	Goodness of fit measure

Table 6.13

Comparison Between the Calibrated Jeddah-Riyadh Model and the Updated Modified Dhahran-Riyadh Model (Distance Case)

	JED-DIS Model		DHA-DIS-UP Model		
	Coefficients	Standard Error	Coefficients	Standard Error	t-Stat
ASC-AIR	-0.55	3.75	8.63	5.73	-1.34
ASC-BUS	7.69	0.99	5.62	0.78	1.65
$IVTTB_{B,C}$	-0.45	0.15	-0.38	0.20	-0.30
$IVTT_A$	-2.96	2.59	-8.71	3.22	1.39
OPTC	-0.01	0.00	-0.01	0.00	2.19
$MHINC_A$	0.53	0.16	0.39	0.17	0.63
$MHINC_B$	-1.65	0.24	-0.77	0.13	-3.21
COMFORT	0.42	0.11	0.50	0.13	-0.52
SAFETY	0.43	0.11	0.53	0.13	-0.58
DUR_A	3.30	1.23	2.09	0.13	0.98
p^2	0.645		0.544		
L(0)	-395.5		-395.5		
$LL_J(\beta_J)$	-140.3		---		
$LL_J(\beta_D)$	---		-180.5		
$TTS_J(\beta_D)$	---		80.3		
Critical $\chi^2_{.05,10}$	18.3		18.3		

where

(***)	t-statistic
$TTS_J(\beta_D)$	Transferability test statistic
$LL_J(\beta_D)$	The log likelihood of the behavior observed in Jeddah-Riyadh corridor generated by the model estimated in Dhahran-Riyadh corridor
$LL_J(\beta_J)$	The log likelihood for the model estimated in Jeddah-Riyadh corridor.
p^2	Goodness of fit measure

The last approach used was to calibrate general models by using both the data set for the Dhahran-Riyadh corridor and the data set for the Jeddah-Riyadh corridor. A second model, having the same specification except the level-of-service variable is divided by distance, was also tested. The following additional identification convention will be used:

GENERAL The calibrated model using both the Jeddah-Riyadh and Dhahran-Riyadh data (without dividing IVTT and OPTC by the distance).

GENERAL-DIS The calibrated model using both the Jeddah-Riyadh and Dhahran-Riyadh data (dividing IVTT and OPTC by the distance).

Table 6.14 shows the result of this approach. The general model with LOS divided by the distance provided a slightly better fit than the one where distance is not considered. Yet the GENERAL-DIS model is not recommended to be the general model for the two corridors because it has an unreasonable sign for the IVTT variable specific to car and bus.

Tables 6.15, and 6.16 show the general parameters and the specific parameters for each corridor as well as the statistical result. The result of the Likelihood Ratio Test statistic is a rejection of the null hypothesis that the parameters in the general model and the parameters in the specific Dhahran-Riyadh model or Jeddah-Riyadh model are equal. Yet, the comparison in goodness of fit measure (p^2) between the original model and the general model shows a slight difference (e.g. p^2, for the DHA model (specific model) is 0.746 and p^2 for the general model is 0.575).

The chi-square test was used to test if there is a difference in prediction accuracy between the original model for each corridor and the general model. Tables 6.17 and 6.18 show that the hypothesis that the number of tripmakers correctly predicted by the specific model and the general one are equal cannot by rejected at the 95% significance level. The percentage right for each mode in each corridor for the general model and the specific model are approximately the same.

In summary, the most encouraging result of this phase of the study was the ability of the general model to reasonably explain the behavior of the tripmaker in both corridors. The different approaches used to transfer models between corridors without modification was not encouraging. Yet, the modified approach (LOS case) gives an acceptable goodness of fit. Furthermore, by using Bayesian updating method the goodness of fit measure improved in both corridors. In other words, the transferred model after updating using the modified approach (LOS case) yields a lower value for the TTS test and a higher p^2 than transferring the model in its original form. Hence, the prediction power of the transfer model improved after updating. So, it is recommended to use the modified approach (LOS case) after updating to transfer the specific model from one corridor to another. In other words, the updated modified approach (LOS case) provides a better model than either transferring the original model as it is or updating it with a small sample.

The ability to transfer the intercity mode choice model between the corridors under study can significantly reduce the data requirements, calibration time, cost, and detailed analytical expertise required by planners to perform modal split analysis in Saudi Arabia.

Table 6.14

Test of the General model for the Two Corridors.

Variable Name	Estimated Variable Coefficients General Model	General DIS Model
ASC-AIR	4.54 (5.08)	9.51 (6.02)
ASC-BUS	6.18 (13.63)	4.59 (13.63)
OPTC	-0.01 (- 8.82)	-0.01 (-11.27)
$IVTT_{B,C}$	-0.70 (-10.00)	0.25 (2.61)
$IVTT_{A}$	-8.24 (- 7.87)	-4.34 (- 8.15)
COMFORT	0.65 (8.68)	0.66 (8.60)
SAFETY	0.36 (5.17)	0.42 (5.70)
$MHINC_{A}$	0.27 (3.34)	0.44 (4.76)
$MHINC_{B}$	-1.01 (- 9.71)	-0.95 (- 8.73)
DUR_{A}	1.23 (3.75)	2.38 (6.33)
p^2	0.568	0.596
L(0)	-790.9	-790.9
$LL_G(\beta^*_G)$	-341.7	-319.9

where

(**) t-statistic

$LL_G(\beta^*_G)$ The log likelihood for the general model estimated from the data set for both corridors.

p^2 Goodness of fit measure

Table 6.15

The General Model versus the Specific Jeddah-Riyadh Model

Variable Name	Estimated Variable Coefficients General Model	Specific JED Model
ASC-AIR	4.54 (5.08)	-0.55 (-0.15)
ASC-BUS	6.18 (13.63)	7.69 (7.80)
OPTC	-0.01 (- 8.82)	-0.01 (-7.43)
$IVTT_{B,C}$	-0.70 (-10.00)	-0.43 (3.05)
$IVTT_A$	-8.24 (- 7.87)	-2.80 (-1.14)
COMFORT	0.65 (8.68)	0.42 (3.88)
SAFETY	0.36 (5.17)	0.43 (3.77)
$MHINC_A$	0.27 (3.34)	0.53 (3.36)
$MHINC_B$	-1.01 (- 9.71)	-1.65 (-6.79)
DUR_A	1.23 (3.75)	3.30 (2.69)
p^2	0.56	0.645
L(0)	-395.5	-395.5
$LL_J(\beta^*_J)$	---	-140.3
$LL_J(\beta^*_G)$	-173.8	---
$TTS_J(\beta^*_G)$	67.0	---
Critical $x^2_{.05,10}$	18.3	18.3

where

(**)	t-statistic
$TTS_J(\beta^*_G)$	Transferability test statistic
$LL_J(\beta^*_G)$	The log likelihood of the behavior observed in Jeddah-Riyadh corridor generated by the general model
$LL_J(\beta^* J_J)$	The log likelihood for the specific model estimated in Jeddah-Riyadh
p^2	Goodness of fit measure

Table 6.16

The General Model Versus the Specific Dhahran-Riyadh Model

Variable Name	Estimated Variable Coefficients General Model	Specific DHA Model
ASC-AIR	4.54 (5.08)	40.34 (3.88)
ASC-BUS	6.18 (13.63)	5.33 (6.45)
OPTC	-0.01 (- 8.82)	- 0.03 (-6.17)
$IVTT_{B,C}$	-0.70 (-10.00)	- 0.56 (-1.04)
$IVTT_A$	-8.24 (- 7.87)	-43.46 (-4.21)
COMFORT	0.65 (8.68)	0.65 (4.50)
SAFETY	0.36 (5.17)	0.50 (3.30)
$MHINC_A$	0.27 (3.34)	0.39 (2.05)
$MHINC_B$	-1.01 (- 9.71)	-0.72 (-5.54)
DUR_A	1.23 (3.75)	2.08 (3.10)
p^2	0.575	0.746
L(0)	-395.5	-395.5
$LL_D(ß^*_D)$	---	-100.2
$LL_D(ß^*_G)$	-167.9	---
$TTS_D(ß^*_G)$	135.4	---
Critical $X^2_{.05,10}$	18.3	18.3

where

(**)	t-statistic
$TS_D(ß^*_G)$	Transferability test statistic
$LL_D(ß^*_G)$	The log likelihood of the behavior observed in Dhahran-Riyadh corridor generated by the general model
$LL_D(ß^*J_D)$	The log likelihood for the specific model estimated in Dhahran-Riyadh corridor.
p^2	Goodness of fit measure

Table 6.17

Comparison Between the Dhahran-Riyadh Model and the General Model

	ALTERNATIVES		
	AIR	BUS	CAR
Number of tripmakers correctly predicted by DHA-Model	108 (90)	108 (90)	104 (87)
Number of tripmakers correctly predicted by the General Model	110 (92)	104 (87)	87 (72)
x^2 = 2.96			

where

(***) % predicted right of each mode

Table 6.18

Comparison Between the Jeddah-Riyadh Model and the General Model

	ALTERNATIVES		
	AIR	BUS	CAR
Number of tripmakers correctly predicted by JED-Model	96 (80)	102 (85)	104 (87)
Number of tripmakers correctly predicted by the General Model	92 (77)	85 (71)	100 (83)
x^2 = 3.15			

where

(***) % predicted right of each mode

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

The main purpose of this study was to develop intercity disaggregate behavioral mode choice models for Saudi Arabia corridors and to test the transferability of these models within Saudi Arabia.

Data required to calibrate the models were collected by a survey using a questionnaire form. The collected data were divided into two data sets; one set was used for calibrating the models while the other was used for validation.

Different model specifications were tested in this research. Each model estimate is based on a different modal utility function. Three models were selected to be most reliable in explaining the variation of mode choice of the tripmakers in the corridors under study. Two of the models are specific to the Jeddah-Riyadh corridor and the Dhahran-Riyadh corridor, while the third one is a general model which was calibrated with data from both corridors. The goodness of fit measure rho-square (p^2) for the Jeddah-Riyadh corridor, the Dhahran-Riyadh corridor, and the general models is 0.645, 0.746, and 0.567, respectively. The p statistics for these model represent a very good fit.

The adjusted likelihood ratio index (rho-squared bar) for the Jeddah-Riyadh corridor and the Dhahran-Riyadh corridor models with and without the train mode is 0.641, 0.743 and 0.556 respectively.

The overall prediction ratio for the Jeddah model and Dhahran model is 84% and 89%, respectively. In other words, the selected mode of eighty four percent of tripmakers in the Jeddah-Riyadh corridor sample were correctly predicted by the model.

To determine the transferability of intercity mode choice models, several approaches were tested. The first approach was to use the calibrated model for the Riyadh-Jeddah corridor to explain the behavior of the tripmaker in the Dhahran-Riyadh corridor, and vice-versa. The second approach used a Bayesian method to update the coefficients and constants of the Jeddah-Riyadh model with sample data from the Dhahran-Riyadh corridor. Third, the specification of the Jeddah-Riyadh model and the Dhahran-Riyadh model was assumed to be similar, and new coefficients were determined for each corridor. Finally a modified approach was used. This modified approach consisted of two forms. One form of the modified approach was to use a separate scaling factor for each variable, while the other form is to use the distance as the scaling factor.

Tables 7.1 and 7.2 show the results of the different approaches used to transfer models between the two corridors under study. The criterion used to compare alternative approaches is the rho-square (p^2) goodness of fit measure:

transfer $$p^2 = 1- \frac{L(\beta)}{L(0)}$$

in which:

L(ß)	=	Log likelihood for the vector of estimated coefficients
L(0)	=	The value of the log likelihood function when all the parameters are zero

The higher the goodness of fit, the better the model explains the behavior of the tripmaker in the new context. This measure achieves an upper limit of one when the transferred model predicts perfectly in the new situation, has a zero value when the model predicts as well as the market share model ($L(\beta) = L(0)$), and it may attain a negative value when the transferred model predicts worse than a model in which the alternatives are assumed to have equal probability of being chosen.

The results of the different approaches used to transfer models between corridors without modification was not encouraging. Yet, the modified approach (LOS case) gives an acceptable goodness of fit. Furthermore, by using the Bayesian updating method, the goodness of fit measure improved in both corridors. In other words, the transferred model after updating using the modified approach (LOS case) yields a higher ρ^2 than transferring the model in its original form, which is an indication that the prediction power of the transfer model improved after updating.

It is recommended that the modified approach (LOS case) after updating be used to transfer the specific model from one corridor to another. The updated modified approach (LOS case) provides a better model than either transferring the original model as it is or updating it with a small sample. Moreover, the general intercity disaggregate modal-split model calibrated with data from both corridors gives more accurate predictions than transferring a specific model from one corridor to another.

The ability of the intercity mode choice model to be transferable between the corridors under study using the recommended approach or by using the general model will significantly reduce the data requirements, calibration time, cost, and detailed analytical expertise required by planners to perform modal split analysis in Saudi Arabia.

Another conclusion of the study is that a universal specification of utility for modelling intercity mode choice in Saudi Arabia exists. This finding will help the government concentrate their data collection efforts in an efficient manner.

Knowledge of elasticities and cross-elasticities in Saudi Arabia intercity corridors was gained through the research. For example, it was determined that the elasticity of the air mode in the longer corridors is lower than that in the shorter corridors. Moreover, from the estimation of the elasticities of the in-vehicle travel time variable it can be expected that the Saudi Arabian Airlines can benefit more by decreasing in-vehicle travel time (IVTT) than by decreasing the cost, especially in the Dhahran-Riyadh corridor. It was also found that bus tripmakers are more sensitive to cost than in-vehicle travel time in the Dhahran-Riyadh corridor, while in the Jeddah-Riyadh corridor the bus tripmaker is more sensitive to in-vehicle travel time.

Table 7.1

RESULTS OF DIFFERENT APPROACHES USED TO TRANSFER DHAHRAN-RIYADH MODEL TO JEDDAH-RIYADH CORRIDOR

CRITERION	LOCAL MODEL	TRANSFER APPROACH							GENERAL MODEL
		AS IT IS	AFTER UPDATING	MODIFIED LOS CASE	MODIFIED LOS UPDATED	MODIFIED DISTANCE CASE	MODIFIED DISTANCE UPDATED		
p^2	0.645	-4.91	-0.235	0.392	0.558	-4.91	0.554		0.560

p^2 = GOODNESS OF FIT MEASURE.

Table 7.2

RESULTS OF DIFFERENT APPROACHES USED TO TRANSFER JEDDAH-RIYADH MODEL TO DHAHRAN-RIYADH CORRIDOR

CRITERION	LOCAL MODEL	TRANSFER APPROACH							GENERAL MODEL
		AS IT IS	AFTER UPDATING	MODIFIED LOS CASE	MODIFIED LOS UPDATED	MODIFIED DISTANCE CASE	MODIFIED DISTANCE UPDATED		
p^2	0.746	0.25	0.09	0.341	0.439	0.25	0.146		0.575

p^2 = GOODNESS OF FIT MEASURE.

In summary, the results of this study include the following:

1. A modal utility specification for intercity mode choice models in Saudi Arabia was developed.
2. A general model for estimating the intercity modal split in Saudi Arabia was developed.
3. A specific model for each of the two corridors under study was developed and evaluated.
4. Knowledge of elasticities and cross elasticities in Saudi Arabia intercity corridors was gained through the research.
5. Intercity disaggregate models without modification are not transferable within Saudi Arabia.
6. The modified (LOS case) updated intercity disaggregate model gives an acceptable goodness of fit measure.
7. Intercity disaggregate models after modification (LOS case) are transferable within Saudi Arabia.
8. The general intercity disaggregate modal split model gives more accurate predictions than transferring a specific model from one corridor to another.

Recommendations for Further Study

To complement and expand on the findings of this research, the following recommendations for further study are presented:

1. This research focused only on the Jeddah-Riyadh and the Dhahran-Riyadh corridors. It would be desirable to survey other corridors to make a comparison of the universal modal utility. Moreover, a comparison between the estimated coefficients of the variables in the Jeddah-Riyadh model and the Dhahran-Riyadh model and the estimated coefficients from another corridor is highly recommended.
2. Data should be collected for the same corridors over an entire year, and should be categorized by the season when it was collected. A comparison between these data should be performed to determine if the behavior of the tripmaker changes from one season to another.
3. Research similar to this should be done using two corridors of approximately the same length. This would help identify more common factors which have a major effect on selecting an intercity mode independent of length.

APPENDICES

APPENDIX A

Disaggregate Models

DISAGGREGATE MODELS

Disaggregate models are probablistic in nature. In other words, the probability of a tripmaker choosing a particular alternative is a function of the characteristics of the tripmaker; such as, income, age, and sex-and of the characteristics of the mode relative to alternative modes. So, the probability of choosing a mode among other different modes depends upon the socioeconomic characteristics of the individual and the level of service of the chosen mode and the unchosen modes.

Most disaggregate models are based on the theory of "utility maximization." They assume that a person makes a particular choice from a set of different alternatives depending on the maximum benefit he receives. For example, a person may wish to minimize travel time and cost of the trip, and maximize comfort and convenience in selecting a mode from the available modes.

The utility of an alternative consists of two components, one systemic and the other random:

$U_{ik} = V_{ik} + \epsilon_{ik}$

where:

U_{ik} = the utility of alternative k to trip maker i

V_{ik} = the systematic component of U_{ik}

= (X_k, S_i)

X_k = a row vector of characteristics of alternative k

S_i = a row vector of socioeconomic characteristics of a tripmaker i

ϵ_{ik} = the random component of U_{ik}

The probability of a tripmaker choosing a specific alternative depends if the utility of that alternative is greater than the utility of the other alternatives available to him. Consequently the probability that a tripmaker (i) chose alternative k out of N alternatives can be expressed as follows:

$$P(k:N_i) = Pr(U_{ik} > U_{jk} \quad \forall j \text{ in } N, J \neq i)$$

$$= Pr(V_{ik} + \epsilon_{ik} > V_{jk} + \epsilon_{jk} \quad \forall j \text{ in } N, J \neq i)$$

$$= Pr(\epsilon_{jk} - \epsilon_{ik} < V_{ik} - V_{jk} \quad \forall j \text{ in } N, J \neq i)$$

Where:

$P(k:N_i)$ = the probability that tripmaker k will choose alternative i out of N alternative.

The most popular calibration techniques for the disaggregate models are probit and logit. The difference between these two techniques is the assumptions made concerning the distributions of the random elements of the utility function. The logit model assumed that the random component (ϵ_{ik}) of the choice utility function (U_{ik}) is independent and identically distributed with a Gumbel (double exponential) distribution function. The probit model is obtained by assuming that the random component (ϵ_{ik}) of the choice utility function (U_{ik} has a multivariate normal distribution.

Predictions of modal split from the probit model are similar to those obtained by the logit model. However, the probit model requires more complex computational procedure than the logit model. Furthermore, the logit model is the most functional form used in transportation demand model, and it is as follows:

$$P^i_k = \frac{\text{EXP } V_{ki}}{\sum\limits_j \text{EXP } V_{ji}}$$

Where:

P^i_k = probability of a tripmaker i choosing mode k out of j alternatives

V_{ki} = the systematic utility of alternative k to tripmaker i
= (X_k, S_i)

X_k = a row vector of characteristics of alternative k

S_i = a row vector of socioeconomic characteristics of a tripmaker i

The superior method for calibrating a logit model is the maximum likelihood procedure. The maximum likelihood procedure is usually used by transportation planners to estimate model parameters. The estimation package will iterate through the problem until the estimated coefficients reach a specific convergence criterion or the estimation completes a specified number of iterations. After iteration has been completed, the estimated model will provide the best fit to the observed pattern of choices in the calibration sample.

The maximum-likelihood estimation of the model produces goodness-of-fit statistic (p^2), t-statistics for coefficients and a X^2 statistic for assessing the entire model.

The goodness of fit measure is used in determining which specification is better in replicating the data. This measure is somewhat analogous to R^2 used in regression. Since the logit model is asymptotic to 0 and 1 probabilities in its tails, one can never precisely achieve a value equal to 1. A model with p^2 around 0.3 is consider to have a good fit. At the other extreme, if all the parameters in a logit model are 0, the model predicts that all the choices for any given individual are equally likely. In this case, the model does not explain choice variation. So in order to compare alternative models used to explain the variation of the new data, the rho-square (p^2) goodness of fit measure has been used:

$$p^2 = 1 - \frac{L(ß)}{L(0)}$$

in which

L(ß) = Log likelihood for the vector of estimated coefficients

L(0) = The value of the log likelihood function when all the parameters are zero

This measure is most useful in comparing two specifications developed from the identical data. Another goodness of fit measure is the adjusted rho-square. This measure is also used similar to R^2, and is as follows:

$$p^{-2} = 1 - \frac{(L(ß)-K)}{L(0)}$$

in which

K = Degrees of freedom; which is equal to the number of model parameters.

The model which has the higher goodness of fit is the better model for explaining the behavior of the tripmaker in the new context.

The likelihood ratio test statistic is used for assessing the entire model. This test is a X (chi-square) test (-2(L(0)-L(B)), which has a degree of freedom equal to the number of model parameters. This test is used to test the null hypothesis that all the parameters are zero ($ß_1 = ß_2 = ß_3 ... ß_k = 0$). Moreover the null hypothesis that all the coefficients, except the mode-specific constants, are zero is tested by

-2(L(C)-L(B))

with degree of freedom equal to **K-J+1**; where **K** is the number of model parameters, **J** is the number of alternatives in the universal choice set, and **L(C)** is the log likelihood for a model with only constants, and it is calculated as follows:

$$L(C) = \Sigma^{J}_{i=1} N_i \ln \frac{N_i}{N}$$

where N_i is the number of travellers selecting mode i and N is the total sample size.

Elasticities of Logit

Another property of the logit model is that it has uniform cross elasticities. That is, the cross elasticity of the choice probability of alternative i with respect to change in an attribute of alternative j is the same for all alternatives $i \neq j$.

This property can be considered a limitation of the logit model because equal substitutability isn't necessary logical in all cases.

Nested Logit

In a simultaneous model it is assumed that the tripmaker will make a decision considering all the travel choices at once. While a sequential (or nested) model assumes that a tripmaker decomposes his travel choices according to an order or hierarchy. It is more convenient to represent the nested logit as a tree. The choice hierarchy by nested logit consists of higher level and lower level decisions. The lower level decision (e.q. choice of travel mode) is conditional on the higher level decision (choice of destination). In other words, the tripmaker chooses an alternative at level one of the tree and then, conditional on this choice, chooses an alternative at level 2 from the alternatives connected to the level 1 choice by a branch of the tree. So the probability that a tripmaker chose mode i, given that he select a destination first, can be expressed as a product of marginal and conditional choice probabilities. More illustration of nested logit can be found in reference (8).

APPENDIX B

Questionnaires

بسم الله الرحمن الرحيم

Ministry of Higher Education

King Fahd University of Petroleum & Minerals

وزارة التعليم العالي

جامعة الملك فهد للبترول والمعادن

Questionnaire Form for Auto Tripmakers.

Dear Sir:

The Department of Civil Engineering at King Fahd University of Petroleum and Minerals is conducting a survey about passenger travel from city to city by private car. Your answers will help us determine how people choose one mode of transportation over another. With a better idea of people's travel habits and needs, we hope to be able to assist in planning transportation systems which would be more satisfactory and convenient for everyone. Your participation is requested, and your responses will be kept strictly confidential.

Please return the completed questionnaire to the person who gave it to you. If you have any questions, please feel free to ask the person who gave you the questionnaire. There are no "right" or " wrong" answers- just give your best estimate.

Your effort is very much appreciated. Thank you very much for your cooperation.

Sincerely yours,

Hasan M. Al-Ahmadi

King Fahd University of Petroleum and Minerals

PART I. The following general questions are about this city-to-city trip by private car

1. Where did you begin this trip? City ________________

2. What is your destination? City ____________

3. What is your place of residence? City ____________

For the following questions, please mark the one most appropriate answer.

4. What is the purpose of your trip?
    ____ 1- work/study ____ 4- Aumra
    ____ 2- personal business ____ 5- social/recreation
    ____ 3- business, related to work
    _____ 6- other (specify) _____

5. How long are you planning to stay at your destination?
    ____ one day ___ 2-7 days ____ more than 7 days

6. For this trip, about how long will it take you to reach your destination (door-to-door)?
    ____ hours _____ minutes

7. Please give your travel time in the following categories:

Total (door-to-door) travel time: ___ hours ____ minutes
Total in-vehicle travel time: ___ hours ____ minutes
Estimated time spend at the rest area:___ hours ____ minutes

8. Please give your travel costs in the following categories: (only fill in those that are appropriate):

Costs are round-trip ___ or one way____

Total cost SR.______________
Gas, oil SR.______________
Other (specify) ______________ SR.______________

9. Who pay for this trip?

____ 1. Yourself _____ 2. The Government
____ 3. The company _____ 4. others (specify) _____

PART II. **The questions below ask YOU to evaluate car, bus, plane, and train with respect to different characteristics.**

Please circle one number in each row; in each question 1 represent very good and 5 represent very poor level.

You can select only one number from 1 to 5 in each question to indicate how your feeling about different characteristics of different means of transportation.

10. Evaluate the following means of transportation with respect to **comfort.**

	very good				very poor
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

11. Evaluate the following means of transportation with respect to **privacy**

	very private				no privacy
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

12. Evaluate the following means of transportation with respect to **safety.**

	very safe				not safe at all
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

13. Evaluate the following means of transportation with respect to **expenses.**

	very cheap				very expensive
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

For the following questions, please mark the most appropriate answer.

---

14. What is your personal and household monthly income?

personal income

____ 1- less than 1000 SR.
____ 2- 1000-2000 SR.
____ 3- 2000-4000 SR.
____ 4- 4000-5000 SR.
____ 5- 5000-7000 SR.
____ 6- 7000-9000 SR.
____ 7- more than 9000 SR.

household income

____ 1- less than 1000 SR.
____ 2- 1000-2000 SR.
____ 3- 2000-4000 SR.
____ 4- 4000-5000 SR.
____ 5- 5000-7000 SR.
____ 6- 7000-9000 SR.
____ 7- more than 9000 SR.

15. Did you consider other means of transportation for the present trip?

—— yes —— no

If your answer is <u>**no**, go to question 16</u>.
If your answer is **yes**, what were your second and third preferences? (please indicate your choices as 1, 2, etc.)

—— plane —— train —— bus
—— car(with others) —— taxi —— other (specify) ——

16. For this trip, are you traveling alone? ——yes —— no
If your answer is <u>**yes**, go to question 19</u>.

17. If your answer is **no**, how many people are traveling with you (please do not count your self)

—— people

18. Are the people traveling with you from your household?

—— yes —— no

The next few questions will complete the questionnaires. Thank you for your time and effort spent in answering our questions.

---

19. What is your age? ——————

20. How many cars are there in your household? ————

21. Do you have a driver's license? —— yes —— no

22. How many other people in your household have a driver's license? ———

23. Are you employed? ——— yes ——— no

24. Are you a student? ——— yes ——— no

25. How many other people in your household are employed?——

26. What is your nationality? —— Saudi —— non Saudi
If non Saudi specify ————

27. Do you have a permanent residence in Saudi Arabia?

—— yes —— no

28. Why are you traveling by car?

Again, thank you for your cooperation.
Please return the questionnaire to the person who distributed the questionnaire.

بسم الله الرحمن الرحيم

Ministry of Higher Education

King Fahd University of Petroleum & Minerals

وزارة التعليم العالي

جامعة الملك فهد للبترول والمعادن

Questionnaire Form for Train Tripmakers.

Dear Sir:

The Department of Civil Engineering at King Fahd University of Petroleum and Minerals is conducting a survey about passenger travel from city to city by train. Your answers will help us determine how people choose one mode of transportation over another. With a better idea of people's travel habits and needs, we hope to be able to assist in planning transportation systems which would be more satisfactory and convenient for everyone. Your participation is requested, and your responses will be kept strictly confidential.

Please return the completed questionnaire to the person who gave it to you. If you have any questions, please feel free to ask the person who gave you the questionnaire. There are no "right" or " wrong" answers- just give your best estimate.

Your effort is very much appreciated. Thank you very much for your cooperation.

Sincerely yours,

Hasan M. Al-Ahmadi

King Fahd University of Petroleum and Minerals

PART I. The following general questions are about this city-to-city trip by Train

1. Where did you begin this trip? City ________

2. What is your destination? City ________

3. What is your place of residence? City ________

For the following questions, please mark the one most appropriate answer.

4. What is the purpose of your trip?
   ___ 1- work/study ___ 4- Aumra
   ___ 2- personal business ___ 5- social/recreation
   ___ 3- business, related to work
   ___ 6- other (specify) ___

5. How long are you planning to stay at your destination?
   ___ one day ___ 2-7 days ___ more than 7 days

6. For this trip, about how long will it take you to reach your destination (door-to-door)?
   ___ hours ___ minutes

7. Please give your travel time in the following categories:

Total (door-to-door) travel time: ___ hours ___ minutes
Time to get to the train station: ___ hours ___ minutes
Time spent waiting at the train station: ___ hours ___ minutes
Total in-vehicle travel time: ___ hours ___ minutes
Estimated time from train station to final destination: ___ hours ___ minutes

8. Please give your travel costs in the following categories: (only fill in those that are appropriate):

Costs are round-trip ___ or one way___

Total cost SR.________
Ticket(fare) SR.________
Taxi SR.________
limousine SR.________
Other (specify) ________ SR.________

9. Who pay for this trip?

___ 1. Yourself ___ 2. The Government
___ 3. The company ___ 4. others (specify) ___

PART II. **The questions below ask YOU to evaluate car, bus, plane, and train with respect to different characteristics.**

Please circle one number in each row; in each question 1 represent very good and 5 represent very poor level.

You can select only one number from 1 to 5 in each question to indicate how your feeling about different characteristics of different means of transportation.

10. Evaluate the following means of transportation with respect to **comfort.**

	very good				very poor
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

11. Evaluate the following means of transportation with respect to **privacy**

	very private				no privacy
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

12. Evaluate the following means of transportation with respect to **safety.**

	very safe				not safe at all
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

13. Evaluate the following means of transportation with respect to **expenses.**

	very cheap				very expensive
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

For the following questions, please mark the most appropriate answer.

---

14. What is your personal and household monthly income?

personal income

____ 1- less than 1000 SR.
____ 2- 1000-2000 SR.
____ 3- 2000-4000 SR.
____ 4- 4000-5000 SR.
____ 5- 5000-7000 SR.
____ 6- 7000-9000 SR.
____ 7- more than 9000 SR.

household income

____ 1- less than 1000 SR.
____ 2- 1000-2000 SR.
____ 3- 2000-4000 SR.
____ 4- 4000-5000 SR.
____ 5- 5000-7000 SR.
____ 6- 7000-9000 SR.
____ 7- more than 9000 SR.

15. Did you consider other means of transportation for the present trip?

___ yes ___ no

If your answer is **no, go to question 16**.
If your answer is **yes**, what were your second and third preferences? (please indicate your choices as 1, 2, etc.)

___ plane ___ train ___ bus
___ car(with others) ___ taxi ___ other (specify) ___

16. For this trip, are you traveling alone? ___yes ___ no
If your answer is **yes, go to question 19**.

17. If your answer is **no**, how many people are traveling with you (please do not count your self)

___ people

18. Are the people traveling with you from your household?

___ yes ___ no

19. How did you get to the train station?
___ walk ___ bus ___ car ___ taxi
___ dropped off. ___other (specify) ___________

20. If you had to leave your car at the train station, what did it cost you to park? SR.________ For how long______

21. How long did it take you to reach the check-in counter from the parking lot? ________ minutes

22. How early or late did the train depart the train station?
___ minutes early ___ minutes late ___ on time

23. How are you planning to get to your final destination from the train station?
___ walk ___ bus ___ limousine ___ rental car
___ private car ___ other (specify) ___________
___ someone will pick you up

24. What class did you travel?
___ first class ___ economy ___ reduced economy fare
___ other (specify) ___________

The next few questions will complete the questionnaires. Thank you for your time and effort spent in answering our questions.

25. What is your age? ____________

26. How many cars are there in your household? _________

27. Do you have a driver's license? ____ yes ____ no

28. How many other people in your household have a driver's license? ______

29. Are you employed? ______ yes _____ no

30. Are you a student? ______ yes _____ no

31. How many other people in your household are employed?____

32. What is your nationality? ____ Saudi ____ non Saudi
    If non Saudi specify _________

33. Do you have a permanent residence in Saudi Arabia?

    ___ yes ___ no

34. Why are you traveling by train?

____

____

Again, thank you for your cooperation.
Please return the questionnaire to the person who distributed the questionnaire.

بسم الله الرحمن الرحيم

Ministry of Higher Education

King Fahd University of Petroleum & Minerals

وزارة التعليم العالي

جامعة الملك فهد للبترول و المعادن

Questionnaire Form for Bus Tripmakers.

Dear Sir:

The Department of Civil Engineering at King Fahd University of Petroleum and Minerals is conducting a survey about passenger travel from city to city by bus. Your answers will help us determine how people choose one mode of transportation over another. With a better idea of people's travel habits and needs, we hope to be able to assist in planning transportation systems which would be more satisfactory and convenient for everyone. Your participation is requested, and your responses will be kept strictly confidential.

Please return the completed questionnaire to the person who gave it to you. If you have any questions, please feel free to ask the person who gave you the questionnaire. There are no "right" or " wrong" answers- just give your best estimate.

Your effort is very much appreciated. Thank you very much for your cooperation.

Sincerely yours,

Hasan M. Al-Ahmadi

King Fahd University of Petroleum and Minerals

PART I. The following general questions are about this city-to-city trip by Bus

1. Where did you begin this trip? City ________________

2. What is your destination? City ____________

3. What is your place of residence? City ____________

For the following questions, please mark the one most appropriate answer.

4. What is the purpose of your trip?
   ____ 1- work/study ____ 4- Aumra
   ____ 2- personal business ____ 5- social/recreation
   ____ 3- business, related to work
   _____ 6- other (specify) _____

5. How long are you planning to stay at your destination?
   ____ one day ___ 2-7 days ____ more than 7 days

6. For this trip, about how long will it take you to reach your destination (door-to-door)?
   ____ hours _____ minutes

7. Please give your travel time in the following categories:

Total (door-to-door) travel time: ___ hours ___ minutes
Time to get to the bus station: ___ hours ___ minutes
Time spent waiting at the bus station: ___ hours ___ minutes
Total in-vehicle travel time: ___ hours ___ minutes
Estimated time from bus station to final destination:
to final destination: ___ hours ___ minutes

8. Please give your travel costs in the following categories: (only fill in those that are appropriate):

Costs are round-trip ___ or one way____

Total cost SR.______________
Ticket(fare) SR.______________
Taxi SR.______________
limousine SR.______________
Other (specify) ______________ SR.______________

9. Who pay for this trip?

____ 1. Yourself _____ 2. The Government
____ 3. The company _____ 4. others (specify) _______

PART II. **The questions below ask YOU to evaluate car, bus, plane, and train with respect to different characteristics.**

Please circle one number in each row; in each question 1 represent very good and 5 represent very poor level.

You can select only one number from 1 to 5 in each question to indicate how your feeling about different characteristics of different means of transportation.

10. Evaluate the following means of transportation with respect to comfort.

	very good				very poor
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

11. Evaluate the following means of transportation with respect to privacy

	very private				no privacy
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

12. Evaluate the following means of transportation with respect to **safety.**

	very safe				not safe at all
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

13. Evaluate the following means of transportation with respect to **expenses.**

	very cheap				very expensive
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

For the following questions, please mark the most appropriate answer.

---

14. What is your personal and household monthly income?

personal income

____ 1- less than 1000 SR.
____ 2- 1000-2000 SR.
____ 3- 2000-4000 SR.
____ 4- 4000-5000 SR.
____ 5- 5000-7000 SR.
____ 6- 7000-9000 SR.
____ 7- more than 9000 SR.

household income

____ 1- less than 1000 SR.
____ 2- 1000-2000 SR.
____ 3- 2000-4000 SR.
____ 4- 4000-5000 SR.
____ 5- 5000-7000 SR.
____ 6- 7000-9000 SR.
____ 7- more than 9000 SR.

15. Did you consider other means of transportation for the present trip?

___ yes ___ no

If your answer is no, go to question 16.
If your answer is **yes**, what were your second and third preferences? (please indicate your choices as 1, 2, etc.)

___ plane ___ train ___ bus
___ car(with others) ___ taxi ___ other (specify) ___

16. For this trip, are you traveling alone? ___yes ___ no
If your answer is yes, go to question 19.

17. If your answer is **no**, how many people are traveling with you (please do not count your self)

___ people

18. Are the people traveling with you from your household?

___ yes ___ no

19. How did you get to the bus station?
___ walk ___ bus ___ car ___ taxi
___ dropped off. ___ other (specify) ___

20. If you had to leave your car at the bus station, what did it cost you to park?
SR.___ For how long___

21. How long did it take you to reach the check-in counter from the parking lot? ___ minutes

22. How early or late did the bus depart the bus station?
___ minutes early ___ minutes late ___ on time

23. How are you planning to get to your final destination from the bus station?
___ walk ___ bus ___ limousine ___ rental car
___ private car ___ other (specify) ___
___ someone will pick you up

The next few questions will complete the questionnaires. Thank you for your time and effort spent in answering our questions.

24. What is your age? ________

25. How many cars are there in your household? ________

26. Do you have a driver's license? ____ yes ____ no

27. How many other people in your household have a driver's license? ______

28. Are you employed? ______ yes _____ no

29. Are you a student? ______ yes _____ no

30. How many other people in your household are employed?____

31. What is your nationality? ____ Saudi ____ non Saudi
    If non Saudi specify ________

32. Do you have a permanent residence in Saudi Arabia?

    ___ yes ___ no

33. Why are you traveling by bus?

____

____

Again, thank you for your cooperation.
Please return the questionnaire to the person who distributed the questionnaire.

بسم الله الرحمن الرحيم

Ministry of Higher Education

King Fahd University of Petroleum & Minerals

وزارة التعليم العالي

جامعة الملك فهد للبترول و المعادن

Questionnaire Form for Plane Tripmakers.

Dear Sir:

The Department of Civil Engineering at King Fahd University of Petroleum and Minerals is conducting a survey about passenger travel from city to city by plane. Your answers will help us determine how people choose one mode of transportation over another. With a better idea of people's travel habits and needs, we hope to be able to assist in planning transportation systems which would be more satisfactory and convenient for everyone. Your participation is requested, and your responses will be kept strictly confidential.

Please return the completed questionnaire to the person who gave it to you. If you have any questions, please feel free to ask the person who gave you the questionnaire. There are no "right" or " wrong" answers- just give your best estimate.

Your effort is very much appreciated. Thank you very much for your cooperation.

Sincerely yours,

Hasan M. Al-Ahmadi

King Fahd University of Petroleum and Minerals

PART I. The following general questions are about this city-to-city trip by plane

1. Where did you begin this trip? City ____________

2. What is your destination? City ____________

3. What is your place of residence? City ____________

For the following questions, please mark the _one_ most appropriate answer.

4. What is the purpose of your trip?
   ___ 1- work/study ___ 4- Aumra
   ___ 2- personal business ___ 5- social/recreation
   ___ 3- business, related to work
   ___ 6- other (specify) ______

5. How long are you planning to stay at your destination?
   ___ one day ___ 2-7 days ___ more than 7 days

6. For this trip, about how long will it take you to reach your destination (door-to-door)?
   ___ hours ___ minutes

7. Please give your travel time in the following categories:

Total (door-to-door) travel time:	___hours	___minutes
Time to get to the airport:	___hours	___minutes
Time spent waiting at the airport:	___hours	___minutes
Total in-vehicle travel time:	___hours	___ minutes
Estimated time from plane terminal to final destination:	___hours	___minutes

8. Please give your travel costs in the following categories: (only fill in those that are appropriate):

Costs are round-trip ___ or one way___

Total cost SR.____________
Ticket(fare) SR.____________
Taxi SR.____________
limousine SR.____________
Other (specify) ____________ SR.____________

9. Who pay for this trip?

___ 1. Yourself ___ 2. The Government
___ 3. The company ___ 4. others (specify) ______

<u>PART</u> <u>II</u>. The questions below ask YOU to evaluate car, bus, plane, and train with respect to different characteristics.

Please circle one number in each row; in each question 1 represent very good and 5 represent very poor level.

You can select only one number from 1 to 5 in each question to indicate how your feeling about different characteristics of different means of transportation.

---

10. Evaluate the following means of transportation with respect to **<u>comfort.</u>**

	very good				very poor
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

11. Evaluate the following means of transportation with respect to **<u>privacy</u>**

	very private				no privacy
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

12. Evaluate the following means of transportation with respect to **safety.**

	very safe				not safe at all
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

13. Evaluate the following means of transportation with respect to **expenses.**

	very cheap				very expensive
BUS	1	2	3	4	5
PRIVATE CAR	1	2	3	4	5
PLANE	1	2	3	4	5
TRAIN	1	2	3	4	5

For the following questions, please mark the most appropriate answer.

---

14. What is your personal and household monthly income?

personal income

____ 1- less than 1000 SR.
____ 2- 1000-2000 SR.
____ 3- 2000-4000 SR.
____ 4- 4000-5000 SR.
____ 5- 5000-7000 SR.
____ 6- 7000-9000 SR.
____ 7- more than 9000 SR.

household income

____ 1- less than 1000 SR.
____ 2- 1000-2000 SR.
____ 3- 2000-4000 SR.
____ 4- 4000-5000 SR.
____ 5- 5000-7000 SR.
____ 6- 7000-9000 SR.
____ 7- more than 9000 SR.

15. Did you consider other means of transportation for the present trip?

—— yes —— no

If your answer is <u>**no**, go to question 16</u>.
If your answer is **yes**, what were your second and third preferences? (please indicate your choices as 1, 2, etc.)

—— plane —— train —— bus
—— car(with others) —— taxi —— other (specify) ——

16. For this trip, are you traveling alone? —yes — no
If your answer is <u>yes, go to question 19</u>.

17. If your answer is **no**, how many people are traveling with you (please do not count your self)

—— people

18. Are the people traveling with you from your household?

—— yes —— no

19. How did you get to the airport terminal?
—— walk —— bus —— car —— taxi
—— dropped off. ——other (specify) ——————

20. If you had to leave your car at the airport, what did it cost you to park? SR.———— For how long————

21. How long did it take you to reach the check-in counter from the parking lot? ———— minutes

22. How early or late did the plane depart the airport terminal?
—— minutes early —— minutes late —— on time

23. How are you planning to get to your final destination from the airport?

—— walk —— bus —— limousine —— rental car
—— private car —— other (specify) ——————
—— someone will pick you up

24. What class did you travel?
—— first class —— economy —— reduced economy fare
—— other (specify) ——————

The next few questions will complete the questionnaires. Thank you for your time and effort spent in answering our questions.

25. What is your age? ________

26. How many cars are there in your household? ________

27. Do you have a driver's license? ____ yes ____ no

28. How many other people in your household have a driver's license? ______

29. Are you employed? ______ yes _____ no

30. Are you a student? ______ yes _____ no

31. How many other people in your household are employed?_____

32. What is your nationality? ____ Saudi ____ non Saudi
If non Saudi specify ________

33. Do you have a permanent residence in Saudi Arabia?

___ yes ___ no

34. Why are you traveling by plane?

____

____

Again, thank you for your cooperation.
Please return the questionnaire to the person who distributed the questionnaire.

بسم الله الرحمن الرحيم

وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن
الظهران ٣١٢٦١ المملكة العربية السعودية

Ministry of Higher Education
King Fahd University of Petroleum & Minerals
DHAHRAN 31261, SAUDI ARABIA

أستفتاء للمسافرين بالسيارة الخاصة

عزيزي المسافر

السلام عليكم ورحمة الله وبركاته :

ان الهدف الرئيسي من هذا الاستفتاء هو التعرف على أسباب اختبار المسافر لوسيلة السفر من مدينة الى أخرى ، والتي أرجو أن تفيد الأشخاص والجهات ذوي العلاقة في المستقبل .

كما هو معروف لديكم أن المعرفة والالمام بطبائع ورغبات المسافرين سوف تساعد على تقييم وسائل المواصلات المستخدمة والتي تعود نتائجه على ارضاء وراحة المسافرين .

ان مساهمتك سوف يكون لها كل التقدير والتي تتطلب اقتطاع قدر من وقتكم الثمين ، هذا وسوف تحلل نتائج هذا الاستفتاء باستخدام الحاسب الآلي .

ارجو الالتزام بالدقة لتعبئة هذه الاستفتاء حيث تعتبر هذه المعلومات أساسية في أطروحة الدكتوراة التي أقوم باجراءها في هندسة المواصلات .

أرجو أن تستمتعوا بتعبئة هذا الاستبيان متمنيا لكم رحلة سعيدة .

المهندس
حسن مساعد الأحمدي

١ - ماهي المدينة التي بدأت منها سفرك ؟ مدينة المغادرة ______________

٢ - ماهي وجهة سفرك ؟ مدينة الوصـــول ______________

٣ - أين مكان اقامتك الدائم ؟ مدينة ______________

الرجاء اختيار الجواب المناسب لكل سؤال

٤ - ماهو هدفك من هذا السفر ؟

١ - للعمل أو الدراســـة ________

٢ - انهاء أعمال خاصــــة ________

٣ - انهاء أعمال متعلقة بالعمل ________

٤ - للعمـــرة ________

٥ - لزيارة الأهل والأصدقــاء ________

٦ - للسياحــة ________

٧ - غيــر ذلك ________

٥ - كم من الزمن سوف تمكث في المدينة التي أنت ذاهب اليها ؟

___ يوم واحد ___ ٢ الى ٧ أيام ___ أكثر من ٧ أيـــام

٦ - ماهي المدة الزمنية التي تعتقد أنها كافية لهذه الرحلة منذ خروجك من منزلك حتى وصولك الى هدفك أو بالعكس ؟

___ دقائق ___ ساعـــات

٧ – الرجاء وضع تقسيم الفترة الزمنية لهذه الرحلة ؟

دقائق	ساعات	
____	____	زمن الرحلة الاجمالي (مثلا من منزلك الى هدفك)
____	____	الفترة الزمنية للاستراحة .
____	____	الفترة الزمنية التي تقضيها في السيارة .

٨ – الرجاء تعبئة الفراغات المناسبة فقط

أ – ١ – التكلفة الاجمالية ________ ريال

٢ – تكاليف الوقود ________ ريال

٣ – تكاليف أخرى ________ ريال وضح ماهي من فضلك ____________

ب – هل التكاليف تشمل الرحلة ذهابا وايابا ______ أو لاتجاه واحد ______

٩ – من دفع تكاليف هذه الرحلة ؟

١ – أنت (على حسابك الخاص) __________

٢ – الحكومة __________

٣ – الشركة أو المؤسسة التي تعمل بها __________

عزيزي المسافر : الأسئلة التالية تتطلب منك مقارنة وسائل السفر المختلفة . وفضلا ضع دائرة واحدة في كل سطر حول الاجابة المناسبة لك (يلاحظ أن رقم واحد هو للأفضل ورقم خمسة هو للأسوء) .

١٠ – فضلا قارن بين وسائل المواصلات التالية من حيث :

<u>الراحة في السفر :</u>

	الأفضل			الأسوء
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١١ – <u>الخصوصية</u> (ويقصد بها الحرية بالتملك والتصرف خلال الرحلة)

	الأفضل				الاسوء
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١٢ – <u>السلامة</u> :

	الأفضل من حيث السلامة				الاسوء من حيث السلامة
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١٣ – <u>التكلفة الاجمالية :</u>

	أقل تكلفة				أكثر تكلفة
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

<u>الرجاء اختيار جواب واحد فقط لكل سؤال</u>

١٤ – كم هو دخلك الشخصي ؟ وكم هو دخل الأسرة ؟

الدخل الشخصي (الشهري)	دخل الأسرة (بما فيهم أنت) (الشهري)
١ – أقل من ١٠٠٠ ريال	١ – أقل من ١٠٠٠ ريال
٢ – ١٠٠٠ ريال – ٢٠٠٠ ريال	٢ – ١٠٠٠ ريال – ٢٠٠٠ ريال
٣ – ٢٠٠٠ ريال – ٤٠٠٠ ريال	٣ – ٢٠٠٠ ريال – ٤٠٠٠ ريال
٤ – ٤٠٠٠ ريال – ٥٠٠٠ ريال	٤ – ٤٠٠٠ ريال – ٥٠٠٠ ريال
٥ – ٥٠٠٠ ريال – ٧٠٠٠ ريال	٥ – ٥٠٠٠ ريال – ٧٠٠٠ ريال
٦ – ٧٠٠٠ ريال – ٩٠٠٠ ريال	٦ – ٧٠٠٠ ريال – ٩٠٠٠ ريال
٧ – أكثر من ٩٠٠٠ ريال	٧ – أكثر من ٩٠٠٠ ريال

١٥ – هل فكرت في وسيلة أخرى للسفر ؟

___ نعم ___ لا

اذا كانت الاجابة بلا ، فضلا انتقل الى سؤال رقم (١٦) أما اذا كانت الاجابة بنعم فمن فضلك رتب وسائل المواصلات التالية (١،٢،٣،...) حسب الرغبة ؟

الحافلة (الباص) ________	السيارة الخاصة ________
الطائرة ________	القطار ________
سيارة الأجرة ________	غير ذلك ________

١٦ – هل أنت مسافر بمفردك ؟

___ نعم ___ لا

١٧ – اذا كانت اجابتك بـ (نعم) فرجاء انتقل الى السؤال رقم (١٩) أما اذا كانت اجابتك بـ (لا) فكم عدد المسافرين معك ؟

___ ذكور ___ اناث

١٨ – هل المسافرون معك من العائلة ؟

___ نعم ___ لا

١٨ – هل الأشخاص المسافرون معك على حسابك الخاص ؟
___ نعم ___ لا

١٩ – كم عمرك؟ ________________

٢٠ – كم عدد السيارات التي تملكها أسرتك ؟ __________

٢١ – هل لديك رخصة قيادة ؟ ___ نعم ___ لا

٢٢ – كم عدد الموجودين في منزلك لديهم رخصة قيادة ؟ ______________

٢٣ – هل أنت موظف ؟ ___ نعم ___ لا

٢٤ – هل أنت طالب ؟ ___ نعم ___ لا

٢٥ – كم عدد الموظفين في العائلة (تشمل الأشخاص الذين تعولهم)؟ __________

٢٦ – ماهي جنسيتك ؟
___ سعودي ___ غير سعودي

٢٧ – هل تقيم في المملكة ؟
___ نعم ___ لا

٢٨ – لماذا أخترت السيارة للسفر ؟

____

____

وفي نهاية هذا الاستفتاء أود أن أتقدم اليك بالشكر الجزيل على مشاركتك راجيا لك التوفيق في حلك وترحالك .

فضلا لاتنس أن ترد هذا الأستفتاء للشخص الذي تسلمته منه .

بسم الله الرحمن الرحيم

Ministry of Higher Education
King Fahd University of Petroleum & Minerals
DHAHRAN 31261, SAUDI ARABIA

وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن
الظهران ٣١٢٦١ المملكة العربية السعودية

أستفتاء للمسافرين بالطائرة

عزيزي المسافر

السلام عليكم ورحمة الله وبركاته :

ان الهدف الرئيسي من هذا الاستفتاء هو التعرف على أسباب اختبار المسافر لوسيلة السفر من مدينة الى أخرى ، والتي أرجو أن تفيد الأشخاص والجهات ذوي العلاقة في المستقبل .

كما هو معروف لديكم أن المعرفة والالمام بطباع ورغبات المسافرين سوف تساعد على تقييم وسائل المواصلات المستخدمة والتي تعود نتائجه على ارضاء وراحة المسافرين .

ان مساهمتك سوف يكون لها كل التقدير والتي تتطلب اقتطاع قدر من وقتكم الثمين ، هذا وسوف تحلل نتائج هذا الاستفتاء باستخدام الحاسب الآلي .

ارجو الالتزام بالدقة لتعبئة هذه الاستفتاء حيث تعتبر هذه المعلومات أساسية في أطروحة الدكتوراة التي أقوم باجراءها في هندسة المواصلات .

أرجو أن تستمتعوا بتعبئة هذا الاستبيان متمنيا لكم رحلة سعيدة .

المهندس
حسن مساعد الأحمدي

١ - ماهي المدينة التي بدأت منها سفرك ؟ مدينة المغادرة ______________

٢ - ماهي وجهة سفرك ؟ مدينة الوصول ______________

٣ - أين مكان اقامتك الدائم ؟ مدينة ______________

الرجاء اختيار الجواب المناسب لكل سؤال

٤ - ماهو هدفك من هذا السفر ؟

١ - للعمل أو الدراسة ______________

٢ - انهاء أعمال خاصة ______________

٣ - انهاء أعمال متعلقة بالعمل ______________

٤ - للعمرة ______________

٥ - لزيارة الأهل والأصدقاء ______________

٦ - للسياحة ______________

٧ - غير ذلك ______________

٥ - كم من الزمن سوف تمكث في المدينة التي أنت ذاهب اليها ؟

___ يوم واحد ___ ٢ الى ٧ أيام ___ أكثر من ٧ أيام

٦ - ماهي المدة الزمنية التي تعتقد أنها كافية لهذه الرحلة منذ خروجك من منزلك حتى وصولك الى هدفك أو بالعكس ؟

___ دقائق ___ ساعات

٧ - الرجاء وضع تقسيم الفترة الزمنية لهذه الرحلة ؟

دقائق	ساعات	
____	____	زمن الرحلة الاجمالي (مثلا من منزلك الى هدفك)
____	____	الفترة الزمنية من مكان المغادرة (مثلا من المنزل أو المكتب) حتى وصولك الى المطار .
____	____	الفترة الزمنية المستغرقة في صالة الانتظار .
____	____	زمن الطيران الفعلي .
____	____	الفترة الزمنية من المطار حتى وصولك الى هدفك (مثلا المنزل , العمل)

٨ - الرجاء تعبئة الفراغات المناسبة

أ - ١ - التكلفة الاجمالية ________

٢ - قيمة التذاكر ________

٣ - تكلفة مواصلات من وجهتك حتى المطار ____________

٤ - التكلفة المتوقعة للمواصلات من المطار حتى وصولك الى هدفك ________

ب - هل التكاليف تشمل الرحلة ذهابا وايابا ______ أو لاتجاه واحد ________

٩ - من دفع تكاليف هذه الرحلة ؟

١ - أنت (على حسابك الخاص) __________

٢ - الحكومة __________

٣ - الشركة أو المؤسسة التي تعمل بها __________

٤ - غير ذلك __________ وضح من فضلك

عزيزي المسافر : الأسئلة التالية تتطلب منك مقارنة وسائل السفر المختلفة . وفضلا ضع دائرة واحدة في كل سطر حول الاجابة المناسبة لك (يلاحظ أن رقم واحد هو للأفضل ورقم خمسة هو للأسوء) .

١٠ – فضلا قارن بين وسائل المواصلات التالية من حيث :

<u>الراحة في السفر :</u>

	الأفضل				الأسوء
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١١ – <u>الخصوصية</u> (ويقصد بها الحرية بالتملك والتصرف خلال الرحلة)

	الأفضل				الاسوء
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١٢ – <u>السلامة</u> :

	الأفضل من حيث السلامة				الاسوء من حيث السلامة
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١٣ – <u>التكلفة الاجمالية :</u>

	أقل تكلفة				أكثر تكلفة
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

الرجاء اختيار جواب واحد فقط لكل سؤال

١٤ – كم هو دخلك الشخصي ؟ وكم هو دخل الأسرة ؟

الدخل الشخصي (الشهري)	دخل الأسرة (بما فيهم أنت) (الشهري)
١ – أقل من ١٠٠٠ ريال	١ – أقل من ١٠٠٠ ريال
٢ – ١٠٠٠ ريال – ٢٠٠٠ ريال	٢ – ١٠٠٠ ريال – ٢٠٠٠ ريال
٣ – ٢٠٠٠ ريال – ٤٠٠٠ ريال	٣ – ٢٠٠٠ ريال – ٤٠٠٠ ريال
٤ – ٤٠٠٠ ريال – ٥٠٠٠ ريال	٤ – ٤٠٠٠ ريال – ٥٠٠٠ ريال
٥ – ٥٠٠٠ ريال – ٧٠٠٠ ريال	٥ – ٥٠٠٠ ريال – ٧٠٠٠ ريال
٦ – ٧٠٠٠ ريال – ٩٠٠٠ ريال	٦ – ٧٠٠٠ ريال – ٩٠٠٠ ريال
٧ – أكثر من ٩٠٠٠ ريال	٧ – أكثر من ٩٠٠٠ ريال

١٥ – هل فكرت في وسيلة أخرى للسفر ؟

___ نعم ___ لا

اذا كانت الاجابة بلا ، فضلا انتقل الى سؤال رقم (١٦) أما اذا كانت الاجابة بنعم فمن فضلك رتب وسائل المواصلات التالية (١،٢،٣،...) حسب الرغبة ؟

الحافلة (الباص) ______	السيارة الخاصة ________
الطائرة ______	القطار ________
سيارة الأجرة ______	غير ذلك ________

١٦ – هل أنت مسافر بمفردك ؟

___ نعم ___ لا

١٧ – اذا كانت اجابتك بـ (نعم) فرجاء انتقل الى السؤال رقم (١٩) أما اذا كانت اجابتك بـ (لا) فكم عدد المسافرين معك ؟

___ ذكور ___ اناث

١٨ – هل المسافرون معك من العائله ؟

___ نعم ___ لا

١٩ – كيف وصلت الى المطار ؟

___ مشيا على الأقدام ___ بالحافلة (الباص) ___ بسيارة الأجرة
___ بالسيارة ___ شخص أوصلك للمحطة ___ غير ذلك

٢٠ – اذا كنت أوقفت سيارتك في موقف سيارات المطار , فكم تبلغ تكلفة ايقاف السيارة ؟
التكلفة __________ ريال لمدة : __________ أيام

٢١ – كم الزمن المستغرق من موقف السيارات حتى وصولك الى داخل مبنى المطار ؟ __________ دقائق

٢٢ – متى أقلعت الطائرة ؟
___ بعد الوقت المحدد بمدة ______ دقائق
___ في الوقت المحدد
___ قبل الوقت المحدد بمدة ______ دقائق.

٢٣ – ماهي الوسيلة المتوقع أن تنقلك من المطار الى هدفك ؟
___ سيارة الايجار بدون سائق، ___ سيارة أجرة ___ الحافلة (الباص)
___ سيارتك الخاصة ___ شخص سوف يستقبلك ___ غير ذلك

٢٤ – ماهي الدرجة التي سافرت عليها ؟
___ درجة أولى ___ سياحية ___ سياحية مخفضة
___ غير ذلك (وضح ______

٢٥ – كم عمرك؟ ________________

٢٦ – كم عدد السيارات التي تملكها أسرتك ؟ __________

٢٧ – هل لديك رخصة قيادة ؟ ___ نعم ___ لا

٢٨ – كم عدد الموجودين في منزلك لديهم رخصة قيادة ؟ ______________

٢٩ – هل أنت موظف ؟ ___ نعم ___ لا

٣٠ – هل أنت طالب ؟ ___ نعم ___ لا

٣١ – كم عدد الموظفين في العائلة (تشمل الأشخاص الذين تعولهم)؟ ________

٣٢ – ماهي جنسيتك ؟

___ سعودي ___ غير سعودي

٣٣ – هل تقيم في المملكة ؟

___ نعم ___ لا

٣٤ – لماذا أخترت الطائرة للسفر ؟

____

____

وفي نهاية هذا الاستفتاء أود أن أتقدم اليك بالشكر الجزيل على مشاركتك راجيا لك التوفيق في حلك وترحالك .

فضلا لاتنس أن ترد هذا الأستفتاء للشخص الذي تسلمته منه .

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وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن
الظهران ٣١٢٦١ المملكة العربية السعودية

استفتاء للمسافرين بالقطار

عزيزي المسافر

السلام عليكم ورحمة الله وبركاته :

ان الهدف الرئيسي من هذا الاستفتاء هو التعرف على أسباب اختيار المسافر لوسيلة السفر من مدينة الى أخرى ، والتي أرجو أن تفيد الأشخاص والجهات ذوي العلاقة في المستقبل .

كما هو معروف لديكم أن المعرفة والالمام بطبائع ورغبات المسافرين سوف تساعد على تقييم وسائل المواصلات المستخدمة والتي تعود نتائجه على ارضاء وراحة المسافرين .

ان مساهمتك سوف يكون لها كل التقدير والتي تتطلب اقتطاع قدر من وقتكم الثمين ، هذا وسوف تحلل نتائج هذا الاستفتاء باستخدام الحاسب الآلي .

ارجو الالتزام بالدقة لتعبئة هذه الاستفتاء حيث تعتبر هذه المعلومات أساسية في أطروحة الدكتوراة التي أقوم باجرائها في هندسة المواصلات .

أرجو أن تستمتعوا بتعبئة هذا الاستبيان متمنيا لكم رحلة سعيدة .

المهندس
حسن مساعد الأحمدي

١ - ماهي المدينة التي بدأت منها سفرك ؟ مدينة المغادرة ____________

٢ - ماهي وجهة سفرك ؟ مدينة الوصـــول ____________

٣ - أين مكان اقامتك الدائم ؟ مدينة ________________

<u>الرجاء اختيار الجواب المناسب لكل سؤال</u>

٤ - ماهو هدفك من هذا السفر ؟

١ - للعمل أو الدراســـــة __________

٢ - انهاء أعمال خاصـــــة __________

٣ - انهاء أعمال متعلقة بالعمل __________

٤ - للعمـــرة __________

٥ - لزيارة الأهل والأصدقـــاء __________

٦ - للسياحـــة __________

٧ - غيـــر ذلك __________

٥ - كم من الزمن سوف تمكث في المدينة التي أنت ذاهب اليها ؟

___ يوم واحد ___ ٢ الى ٧ أيام ___ أكثر من ٧ أيـــام

٦ - ماهي المدة الزمنية التي تعتقد أنها كافية لهذه الرحلة منذ خروجك من منزلك حتى وصولك الى هدفك أو بالعكس ؟

___ دقائق ___ ساعـــات

٧ - الرجاء وضع تقسيم الفترة الزمنية لهذه الرحلة ؟

	ساعات	دقائق
زمن الرحلة الاجمالي (مثلا من منزلك الى هدفك)	____	____
الفترة الزمنية من مكان المغادرة (مثلا من المنزل أو المكتب) حتى وصولك الى محطة القطار	____	____
الفترة الزمنية المستغرقة في صالة الانتظار .	____	____
الزمن المتوقع امضاؤه في القطار	____	____
الفترة الزمنية من محطة القطار حتى وصولك الى هدفك (مثلا المنزل ، العمل)	____	____

٨ - الرجاء تعبئة الفراغات المناسبة

أ - ١ - التكلفة الاجمالية ________

٢ - قيمة التذاكر ________

٣ - تكلفة مواصلات من وجهتك حتى محطة القطار ____________

٤ - التكلفة المتوقعة للمواصلات من محطة القطار حتى وصولك الى هدفك ________

ب - هل التكاليف تشمل الرحلة ذهابا وايابا ______ أو لاتجاه واحد ______

٩ - من دفع تكاليف هذه الرحلة ؟

١ - أنت (على حسابك الخاص) __________

٢ - الحكومة __________

٣ - الشركة أو المؤسسة التي تعمل بها __________

٤ - غير ذلك __________ وضح من فضلك

عزيزي المسافر : الأسئلة التالية تتطلب منك مقارنة وسائل السفر المختلفة . وفضلا ضع دائرة واحدة في كل سطر حول الاجابة المناسبة لك (يلاحظ أن رقم واحد هو للأفضل ورقم خمسة هو للأسوء) .

١٠ – فضلا قارن بين وسائل المواصلات التالية من حيث :

<u>الراحة في السفر :</u>

	الأفضل			الأسوء
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١١ – **<u>الخصوصية</u>** (ويقصد بها الحرية بالتملك والتصرف خلال الرحلة)

	الأفضل				الاسوء
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١٢ – **<u>السلامة</u>** :

	الأفضل من حيث السلامة				الاسوء من حيث السلامة
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١٣ – **<u>التكلفة الاجمالية :</u>**

	أقل تكلفة				أكثر تكلفة
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

الرجاء اختيار جواب واحد فقط لكل سؤال

١٤ - كم هو دخلك الشخصي ؟ وكم هو دخل الأسرة ؟

دخل الأسرة (بما فيهم أنت) (الشهري)	الدخل الشخصي (الشهري)
١ - أقل من ١٠٠٠ ريال	١ - أقل من ١٠٠٠ ريال
٢ - ١٠٠٠ ريال - ٢٠٠٠ ريال	٢ - ١٠٠٠ ريال - ٢٠٠٠ ريال
٣ - ٢٠٠٠ ريال - ٤٠٠٠ ريال	٣ - ٢٠٠٠ ريال - ٤٠٠٠ ريال
٤ - ٤٠٠٠ ريال - ٥٠٠٠ ريال	٤ - ٤٠٠٠ ريال - ٥٠٠٠ ريال
٥ - ٥٠٠٠ ريال - ٧٠٠٠ ريال	٥ - ٥٠٠٠ ريال - ٧٠٠٠ ريال
٦ - ٧٠٠٠ ريال - ٩٠٠٠ ريال	٦ - ٧٠٠٠ ريال - ٩٠٠٠ ريال
٧ - أكثر من ٩٠٠٠ ريال	٧ - أكثر من ٩٠٠٠ ريال

١٥ - هل فكرت في وسيلة أخرى للسفر ؟

___ نعم ___ لا

اذا كانت الاجابة بلا ، فقلا انتقل الى سؤال رقم (١٦) أما اذا كانت الاجابة بنعم فمن فضلك رتب وسائل المواصلات التالية (١،٢،٣،...) حسب الرغبة ؟

الحافلة (الباص) ______	السيارة الخاصة ______
الطائرة ______	القطار ______
سيارة الأجرة ______	غير ذلك ______

١٦ - هل أنت مسافر بمفردك ؟

___ نعم ___ لا

١٧ - اذا كانت اجابتك بـ (نعم) فرجاء انتقل الى السؤال رقم (١٩) أما اذا كانت اجابتك بـ (لا) فكم عدد المسافرين معك ؟

___ ذكور ___ اناث

١٨ - هل المسافرون معك من العائلة ؟

___ نعم ___ لا

١٩ - كيف وصلت الى محطة القطار ؟

___ مشيا على الأقدام ___ بالحافلة (الباص) ___ بسيارة الأجرة
___ بالسيارة ___ شخص أوصلك للمحطة ___ غير ذلك

٢٠ - اذا كنت أوقفت سيارتك في محطة القطار فكم تبلغ تكلفة ايقاف السيارة؟
التكلفة __________ ريال لمدة : __________ أيام

٢١ - كم الزمن المستغرق من موقف السيارات حتى وصولك الى داخل مبنى المحطة ؟ __________ دقائق

٢٢ - متى غادر القطار المحطة ؟
___ بعد الوقت المحدد بمدة ______ دقائق
___ في الوقت المحدد
___ قبل الوقت المحدد بمدة ______ دقائق

٢٣ - ماهي الوسيلة المتوقع أن تنقلك من محطة القطار الى هدفك ؟
___ سيارة الايجار بدون سائق ___ سيارة أجرة ___ الحافلة (الباص)
___ سيارتك الخاصة ___ شخص سوف يستقبلك ___ غير ذلك

٢٤ - ماهي الدرجة التي سافرت عليها ؟
___ درجة أولى ___ سياحية ___ سياحية مخفضة
___ غير ذلك (وضح)

٢٥ - كم عمرك؟ __________________

٢٦ - كم عدد السيارات التي تملكها أسرتك ؟ ____________

٢٧ - هل لديك رخصة قيادة ؟ ___ نعم ___ لا

٢٨ - كم عدد الموجودين في منزلك لديهم رخصة قيادة ؟ ________________

٢٩ - هل أنت موظف ؟ ___ نعم ___ لا

٣٠ - هل أنت طالب ؟ ___ نعم ___ لا

٣١ - كم عدد الموظفين في العائلة (تشمل الأشخاص الذين تعولهم)؟ ____________

٣٢ - ماهي جنسيتك ؟
___ سعودي ___ غير سعودي

٣٣ – هل تقيم في المملكة ؟
___ نعم ___ لا

٣٤ – لماذا أخترت القطار للسفر ؟

____

____

وفي نهاية هذا الاستفتاء أود أن أتقدم اليك بالشكر الجزيل على مشاركتك راجيا لك التوفيق في حلك وترحالك .

فضلا لاتنسى أن ترد هذا الأستفتاء للشخص الذي تسلمته منه .

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وزارة التعليم العالي
جامعة الملك فهد للبترول والمعادن
الظهران ٣١٢٦١ المملكة العربية السعودية

أستفتاء للمسافرين بالنقل الجماعي

عزيزي المسافر

السلام عليكم ورحمة الله وبركاته :

ان الهدف الرئيسي من هذا الاستفتاء هو التعرف على أسباب اختيار المسافر لوسيلة السفر من مدينة الى أخرى , والتي أرجو أن تفيد الأشخاص والجهات ذوي العلاقة في المستقبل .

كما هو معروف لديكم أن المعرفة والالمام بطبائع ورغبات المسافرين سوف تساعد على تقييم وسائل المواصلات المستخدمة والتي تعود نتائجه على ارضاء وراحة المسافرين .

ان مساهمتك سوف يكون لها كل التقدير والتي تتطلب اقتطاع قدر من وقتكم الثمين , هذا وسوف تحلل نتائج هذا الاستفتاء باستخدام الحاسب الآلي .

ارجو الالتزام بالدقة لتعبئة هذه الاستفتاء حيث تعتبر هذه المعلومات أساسية في أطروحة الدكتوراة التي أقوم باجراءها في هندسة المواصلات .

أرجو أن تستمتعوا بتعبئة هذا الاستبيان متمنيا لكم رحلة سعيدة .

المهندس
حسن مساعد الأحمدي

١ - ماهي المدينة التي بدأت منها سفرك ؟ مدينة المغادرة ________________

٢ - ماهي وجهة سفرك ؟ مدينة الوصــول ________________

٣ - أين مكان اقامتك الدائم ؟ مدينة ____________________

<u>الرجاء اختيار الجواب المناسب لكل سؤال</u>

٤ - ماهو هدفك من هذا السفر ؟

١ - للعمل أو الدراســـــة ____________

٢ - انهاء أعمال خاصـــــة ____________

٣ - انهاء أعمال متعلقة بالعمل ____________

٤ - للعمـــرة ____________

٥ - لزيارة الأهل والأصدقـــاء ____________

٦ - للسياحـــة ____________

٧ - غيـــر ذلك ____________

٥ - كم من الزمن سوف تمكث في المدينة التي أنت ذاهب اليها ؟

___ يوم واحد ____ ٢ الى ٧ أيام ___ أكثر من ٧ أيـــام

٦ - ماهي المدة الزمنية التي تعتقد أنها كافية لهذه الرحلة منذ خروجك من منزلك حتى وصولك الى هدفك أو بالعكس ؟

___ دقائق ___ ساعـــات

٧ – الرجاء وضع تقسيم الفترة الزمنية لهذه الرحلة ؟

	ساعات	دقائق
زمن الرحلة الاجمالي (مثلا من منزلك الى هدفك)	____	____
الفترة الزمنية من مكان المغادرة (مثلا من المنزل أو المكتب) حتى وصولك الى محطة النقل الجماعي .	____	____
الفترة الزمنية المستغرقة في صالة الانتظار .	____	____
الزمن المتوقع امضاءه في الحافلة	____	____
الفترة الزمنية من محطة النقل الجماعي حتى وصولك الى هدفك (مثلا المنزل ، العمل)	____	____

٨ – الرجاء تعبئة الفراغات المناسبة

أ – ١ – التكلفة الاجمالية ________

٢ – قيمة التذاكر ________

٣ – تكلفة مواصلات من وجهتك حتى محطة النقل الجماعي ____________

٤ – التكلفة المتوقعة للمواصلات من محطة النقل الجماعي حتى وصولك الى هدفك ________

ب – هل التكاليف تشمل الرحلة ذهابا وايابا ______ أو لاتجاه واحد ________

٩ – من دفع تكاليف هذه الرحلة ؟

١ – أنت (على حسابك الخاص) __________

٢ – الحكومة __________

٣ – الشركة أو المؤسسة التي تعمل بها __________

٤ – غير ذلك __________ وضح من فضلك

عزيزي المسافر : الأسئلة التالية تتطلب منك مقارنة وسائل السفر المختلفة . وفضلا ضع دائرة واحدة في كل سطر حول الاجابة المناسبة لك (يلاحظ أن رقم واحد هو للأفضل ورقم خمسة هو للأسوء) .

١٠ - فضلا قارن بين وسائل المواصلات التالية من حيث :

<u>الراحة في السفر :</u>

	الأفضل			الأسوء
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١١ - <u>الخصوصية</u> (ويقصد بها الحرية بالتملك والتصرف خلال الرحلة)

	الأفضل				الاسوء
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١٢ - <u>السلامة</u> :

	الأفضل من حيث السلامة				الاسوء من حيث السلامة
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

١٣ - <u>التكلفة الاجمالية :</u>

	أقل تكلفة				أكثر تكلفة
الحافلة (الباص)	١	٢	٣	٤	٥
السيارة الخاصة	١	٢	٣	٤	٥
الطائرة	١	٢	٣	٤	٥
القطار	١	٢	٣	٤	٥

الرجاء اختيار جواب واحد فقط لكل سؤال

١٤ – كم هو دخلك الشخصي ؟ وكم هو دخل الأسرة ؟

الدخل الشخصي (الشهري)	دخل الأسرة (بما فيهم أنت) (الشهري)
١ – أقل من ١٠٠٠ ريال	١ – أقل من ١٠٠٠ ريال
٢ – ١٠٠٠ ريال – ٢٠٠٠ ريال	٢ – ١٠٠٠ ريال – ٢٠٠٠ ريال
٣ – ٢٠٠٠ ريال – ٤٠٠٠ ريال	٣ – ٢٠٠٠ ريال – ٤٠٠٠ ريال
٤ – ٤٠٠٠ ريال – ٥٠٠٠ ريال	٤ – ٤٠٠٠ ريال – ٥٠٠٠ ريال
٥ – ٥٠٠٠ ريال – ٧٠٠٠ ريال	٥ – ٥٠٠٠ ريال – ٧٠٠٠ ريال
٦ – ٧٠٠٠ ريال – ٩٠٠٠ ريال	٦ – ٧٠٠٠ ريال – ٩٠٠٠ ريال
٧ – أكثر من ٩٠٠٠ ريال	٧ – أكثر من ٩٠٠٠ ريال

١٥ – هل فكرت في وسيلة أخرى للسفر ؟

___ نعم ___ لا

اذا كانت الاجابة بلا ، فضلا انتقل الى سؤال رقم (١٦) أما اذا كانت الاجابة بنعم فمن فضلك رتب وسائل المواصلات التالية (١،٢،٣،...) حسب الرغبة ؟

الحافلة (الباص) ______	السيارة الخاصة ________
الطائرة ______	القطار ________
سيارة الأجرة ______	غير ذلك ________

١٦ – هل أنت مسافر بمفردك ؟

___ نعم ___ لا

١٧ – اذا كانت اجابتك بـ (نعم) فرجاء انتقل الى السؤال رقم (١٩) أما اذا كانت اجابتك بـ (لا) فكم عدد المسافرين معك ؟

___ ذكور ___ اناث

١٨ – هل المسافرون معك من العائلة ؟

___ نعم ___ لا

١٩ - كيف وصلت الى محطة النقل الجماعي (محطة الحافلات) ؟

___ مشيا على الأقدام ___ بالحافلة (الباص) ___ بسيارة الأجرة
___ بالسيارة ___ شخص أوصلك للمحطة ___ غير ذلك

٢٠ - اذا كنت أوقفت سيارتك في محطة وسيلة السفر فكم تبلغ تكلفة ايقاف السيارة؟
التكلفة ________ ريال لمدة : ________ أيام

٢١ - كم الزمن المستغرق من موقف السيارات حتى وصولك الى داخل مبنى المحطة ؟ ________ دقائق

٢٢ - متى غادرت الحافلة المحطة ؟
___ بعد الوقت المحدد بمدة ______ دقائق.
___ في الوقت المحدد
___ قبل الوقت المحدد بمدة ______ دقائق.

٢٣ - ماهي الوسيلة المتوقع أن تنقلك من محطة الحافلات الى هدفك ؟
___ سيارة الايجار بدون سائق ___ سيارة أجرة ___ الحافلة (الباص)
___ سيارتك الخاصة ___ شخص سوف يستقبلك ___ غير ذلك

٢٤ - كم عمرك؟ ________________

٢٥ - كم عدد السيارات التي تملكها أسرتك ؟ ________

٢٦ - هل لديك رخصة قيادة ؟ ___ نعم ___ لا

٢٧ - كم عدد الموجودين في منزلك لديهم رخصة قيادة ؟ ____________

٢٨ - هل أنت موظف ؟ ___ نعم ___ لا

٢٩ - هل أنت طالب ؟ ___ نعم ___ لا

٣٠ - كم عدد الموظفين في العائلة (تشمل الأشخاص الذين تعولهم)؟ ________

٣١ - ماهي جنسيتك ؟
___ سعودي ___ غير سعودي.

٣٢ - هل تقيم في المملكة ؟
___ نعم ___ لا

٣٣ - لماذا أخترت الحافلة للسفر ؟

وفي نهاية هذا الاستفتاء أود أن أتقدم اليك بالشكر الجزيل على مشاركتك راجيا لك التوفيق في حلك وترحالك .

فضلا لاتنسى أن ترد هذا الأستفتاء للشخص الذي تسلمته منه .

APPENDIX C

Coding Manual for Intercity Mode Choice Models in Saudi Arabia

CODING MANUAL FOR INTERCITY MODE CHOICE MODELS IN SAUDI ARABIA
(for Plane and Train Questionnaire Forms)

FIELD	QUESTION NUMBER	VARIABLE NAME	INSTRUCTION
1-4	none	ID	coder assigned 4-digit number where **1st digit** is mode of travel; 1=auto, 2=bus, 3=train, 4=plane **2nd-4th** digits: start each sequence at 001 for mode e.g., first auto respondent =1001; second auto respondent = 1002;... first plane respondent = 4001;... **coder**: write ID number on survey; upper right-hand corner of first page
5	Q 1	city	code a one-digit number for the name origin city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
6	Q 2	city name	code a one-digit number for the destination city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
7	Q 3	city name	code a one-digit number for the residence city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
8	Q 4	trip purpose	1=work/study; 2=personal business; 3=business, related to work; 4=Aumra; 5=social/recreational; 6=other; 7=other.
9	Q 5	number of days	1=one day; 2=2-7days; 3=more than 7days
10-11	Q 6	time	code actual hours
12-13	Q 6		code actual minutes
14-15	Q 7		code actual # of hours.
16-17			code actual # of minutes
18-19			time to station, or airport # of hrs.
20-21			time to station, or airport # of min.

22-23			waiting time # of hrs.
24-25			waiting time # of min.
26-27			in-vehicle time # of hrs.
28-29			in-vehicle time # of min.
30-31			time from sta. to final destination, # of hrs.
32-33			time from stat. to final destination in minutes
34	Q 8	cost	1=one way; 2=round trip
35-38			total cost, code to the nearest SR.
39-41			ticket cost, code to the nearest SR.
42-43			taxi cost, code to the nearest SR.
44-45			limo. cost, code to the nearest SR.
46-47			other cost, code to the nearest SR.
48	Q 9		1=yourself; 2=government; 3=Company; 4=other
49	Q 10	comfort	put the scale value; for bus
50			private car
51			plane
52			train
53	Q 11	privacy	put the scale value; for bus
54			private car
55			plane
56			train
57	Q 12	safety	put the scale value; for bus
58			private car
59			plane
60			train
61	Q 13	expenses	put the scale value; for bus
62			private car
63			plane
64			train
65	Q 14	income person	1=<1000; 2= 1000-2000; 3=2000-4000; 4=4000-5000; 5=5000-7000; 6=7000-9000; 7=>9000

66	Q 14	income hhld	1=<1000; 2= 1000-2000; 3=2000-4000; 4=4000-5000; 5=5000-7000; 6=7000-9000; 7=>9000
67	Q 15		1=yes; 2=no
68-71	Q 15		coder rank them as the tripmaker, then write the hypothesized number respectively, e.g., tripmaker second and third preference are plane, and train respectively, so, in coding plane= 4 (see field 1-4) will be in column 68 and train=3 will be in column 69
72	Q 16		1=yes; 2=no
73-74	Q 17		code 1=alone, or the actual number if they are >1
75	Q 18		1=yes; 2=no
76	Q 19		1=walk; 2=bus; 3=car; 4= taxi; 5=dropped off; 6=other
77-78	Q 20		cost of parking
78-80			period of parking
81-82	Q 21		time in minutes to reach check-in counter
83-84	Q 22	early	code actual min. early
85-86		late	code actual min. late
87		one-time	zero minutes
88	Q 23	f mode	1=walk; 2=bus; 3=limo; 4=rental car; 5=private car; 6=other; 7=someone will pick you up
88		claQs 24	1=first; 2=economy; 3=reduced economy fare; 4=other
90-91	Q 25	age	code #
92	Q 26	cars	code # (9=9 or more)
93	Q 27	licen.	1=yes; 2=no
94	Q 28	others	code #
95	Q 29	empl.	1=yes; 2=no
96	Q 30	stud.	1=yes; 2=no
97	Q 31	others	code #
98	Q 32	nat.	1=Saudi; 2=non Saudi
99	Q 33	res.	1=yes; 2=no

CODING MANUAL FOR INTERCITY MODE CHOICE MODELS IN SAUDI ARABIA (for Bus Questionnaire Form)

FIELD	QUESTION NUMBER	VARIABLE NAME	INSTRUCTION
1-4	none	ID	coder assigned 4-digit number where **1st digit** is mode of travel; 1=auto, 2=bus, 3=train, 4=plane **2nd-4th** digits: start each sequence at 001 for mode e.g., first auto respondent =1001; second auto respondent = 1002;... first plane respondent = 4001;... **coder**: write ID number on survey; upper right-hand corner of first page
5	Q 1	city	code a one-digit number for the name origin city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
6	Q 2	city name	code a one-digit number for the destination city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
7	Q 3	city name	code a one-digit number for the residence city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
8	Q 4	trip purpose	1=work/study; 2=personal business; 3=business, related to work; 4=Aumra; 5=social/recreational; 6=other; 7=other.
9	Q 5	number of days	1=one day; 2=2-7days; 3=more than 7days
10-11	Q 6	time	code actual hours
12-13	Q 6		code actual minutes
14-15	Q 7		code actual # of hours.
16-17			code actual # of minutes
18-19			time to station, or airport # of hrs.
20-21			time to station, or airport # of min.

22-23			waiting time # of hrs.
24-25			waiting time # of min.
26-27			in-vehicle time # of hrs.
28-29			in-vehicle time # of min.
30-31			time from sta. to final destination, # of hrs.
32-33			time from stat. to final destination in minutes
34	Q 8	cost	1=one way; 2=round trip
35-38			total cost, code to the nearest SR.
39-41			ticket cost, code to the nearest SR.
42-43			taxi cost, code to the nearest SR.
44-45			limo. cost, code to the nearest SR.
46-47			other cost, code to the nearest SR.
48	Q 9		1=yourself; 2=government; 3=Company; 4=other
49	Q 10	comfort	put the scale value; for bus
50			private car
51			plane
52			train
53	Q 11	privacy	put the scale value; for bus
54			private car
55			plane
56			train
57	Q 12	safety	put the scale value; for bus
58			private car
59			plane
60			train
61	Q 13	expenses	put the scale value; for bus
62			private car
63			plane
64			train
65	Q 14	income person	1=<1000; 2= 1000-2000; 3=2000-4000; 4=4000-5000; 5=5000-7000; 6=7000-9000; 7=>9000

66	Q 14	income hhld	1=<1000; 2= 1000-2000; 3=2000-4000; 4=4000-5000; 5=5000-7000; 6=7000-9000; 7=>9000
67	Q 15		1=yes; 2=no
68-71	Q 15		coder rank them as the tripmaker, then write the hypothesized number respectively, e.g., tripmaker second and third preference are plane, and train respectively, so, in coding plane= 4 (see field 1-4) will be in column 68 and train=3 will be in column 69
72	Q 16		1=yes; 2=no
73-74	Q 17		code 1=alone, or the actual number if they are >1
75	Q 18		1=yes; 2=no
76	Q 19		1=walk; 2=bus; 3=car; 4= taxi; 5=dropped off; 6=other
77-78	Q 20		cost of parking
78-80			period of parking
81-82	Q 21		time in minutes to reach check-in counter
83-84	Q 22	early	code actual min. early
85-86		late	code actual min. late
87		one-time	zero minutes
88	Q 23	f mode	1=walk; 2=bus; 3=limo; 4=rental car; 5=private car; 6=other; 7=someone will pick you up
90-91	Q 24	age	code #
92	Q 25	cars	code # (9=9 or more)
93	Q 26	licen.	1=yes; 2=no
94	Q 27	others	code #
95	Q 28	empl.	1=yes; 2=no
96	Q 29	stud.	1=yes; 2=no
97	Q 30	others	code #
98	Q 31	nat.	1=Saudi; 2=non Saudi
99	Q 32	res.	1=yes; 2=no

CODING MANUAL FOR INTERCITY MODE CHOICE MODELS IN SAUDI ARABIA
(for Auto Questionnaire Form)

FIELD	QUESTION NUMBER	VARIABLE NAME	INSTRUCTION
1-4	none	ID	coder assigned 4-digit number where **1st digit** is mode of travel; 1=auto, 2=bus, 3=train, 4=plane **2nd-4th** digits: start each sequence at 001 for mode e.g., first auto respondent =1001; second auto respondent = 1002;... first plane respondent = 4001;... **coder:** write ID number on survey; upper right-hand corner of first page
5	Q 1	city	code a one-digit number for the name origin city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
6	Q 2	city name	code a one-digit number for the destination city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
7	Q 3	city name	code a one-digit number for the residence city; **coder** set 1= Riyadh, 2= Jeddah, 3=eastern province
8	Q 4	trip purpose	1=work/study; 2=personal business; 3=business, related to work; 4=Aumra; 5=social/recreational; 6=other; 7=other.
9	Q 5	number of days	1=one day; 2=2-7days; 3=more than 7days
10-11	Q 6	time	code actual hours
12-13	Q 6		code actual minutes

14-15	Q 7		code actual # of hours.
16-17			code actual # of minutes
18-19			time spent at the rest area # of hrs.
20-21			time spent at the rest area # of min.
22-23			in-vehicle time # of hrs.
24-25			in-vehicle time # of min.
26	Q 8	cost	1=round-trip; 2=one way
27-29			total cost, code to the nearest SR.
30-32			oil cost, code to the nearest SR.
33-35			other cost, code to the nearest SR.
36	Q 9		1=yourself; 2=government; 3=Company; 4=other
37	Q 10	comfort	put the scale value; for bus
38			private car
39			plane
40			train
41	Q 11	privacy	put the scale value; for bus
42			private car
43			plane
44			train
45	Q 12	safety	put the scale value; for bus
46			private car
47			plane
48			train
48	Q 13	expenses	put the scale value; for bus
50			private car
51			plane
52			train
53	Q 14	income person	1=<1000; 2= 1000-2000; 3=2000-4000; 4=4000-5000; 5=5000-7000; 6=7000-9000; 7=>9000
54	Q 14	income hhld	1=<1000; 2= 1000-2000; 3=2000-4000; 4=4000-5000; 5=5000-7000; 6=7000-9000; 7=>9000

55	Q 15		1=yes; 2=no
56-59	Q 15		coder rank them as the tripmaker, then write the hypothesized number respectively, e.g., tripmaker second and third preference are plane, and train respectively, so, in coding plane= 4 (see field 1-4) will be in column 53 and train=3 will be in column 54
60	Q 16		1=yes; 2=no
61-62	Q 17		code 1=alone, or the actual number if they are >1
63	Q 18		1=yes; 2=no
64-65	Q 19	age	code #
66	Q 20	cars	code # (9=9 or more)
67	Q 21	licen.	1=yes; 2=no
68	Q 22	others	code #
69	Q 23	empl.	1=yes; 2=no
70	Q 24	stud.	1=yes; 2=no
71	Q 25	others	code #
72	Q 26	nat.	1=Saudi; 2=non Saudi
73	Q 27	res.	1=yes; 2=no

Appendix D

FORTRAN PROGRAM

```
C*****************************************************************
C*****************************************************************
C*****************************************************************
C
C      PROGRAM VALIDATE
C
C      ***********************************************************
C      TO  READ THE FIL MADE FOR B LOGIT AND CALCULATE THE AGGREGATE
C      PREDICTION FOR EACH MODE IN THE DHAHRAN-RIYADH CORRIDOR
C      ***********************************************************
         DIMENSION F(30,30,30),S(10,10,10),E(10,10,10)
         DIMENSION X(10,10),Z(10),P(10),V(10)
         DIMENSION INDEX(10),PRED(10),IND(10),QC(10)
       OPEN (1,FILE -'VALD.LOL',STATUS-'OLD')
       OPEN (9,FILE -'VAL.DHA')
         NDIM-3
         NT-3
         KK-10
C       KK-NUMBER OF PARAMETERS
C       NT-NUMBER OF ALTERNATIVE
C       NN-NUMBER OF OBSERVATIONS
C       INITIALIZE F-MATRIX AND Z-VECTOR
         DO 10 I-1,NT
         DO 10 J-1,KK
         DO 10 K-1,NT
  10    F(I,K,J)-0.0
         DO 15 K-1,NT
         QC(K)-0.0
         IND(K)-0
   15    Z(K)-0.0
              WRITE(9,314)
 314  FORMAT(1H1,9X,'ALT.',5X,'ALT.'/8X,'CHOSEN',3X,'PREDICTED',6X,'CHOI
     1CE     PROBABILITIES OF ALTERNATIVES')
         NN-189
      DO 1 ICO-1,NN
C************************************************
      READ  (1,30)RNDA,TTHA,TTSA,
     *THWA,VHA,TFSA,TTCTA,TKCA,
     *QUAL3,QUAL7,
     *QUAL11,QUAL15,
     *RINCA,RINHHA,RNPA,CPAKA,
     *RLICA,AGEA,CARA,STUDA,
     *ATA,FREA
30    FORMAT(F2.0,5F5.2,F5.0,F4.0,6F2.0
     *,F3.0,2F4.0,F3.0,3F2.0,F5.2)
C*****************************************************************
      IF (RNDA .LE. 1.)THEN
      DUR-1.
      ELSE
      DUR-0.0
      ENDIF
```

```
C******************************************************************
      READ  (1,40)TTHB,TTSB,
     *THWB,VHB,TFSB,TTCAB,TKCB,
     *QUAL1,QUAL5,QUAL9,QUAL13,
     *RLATEB,FREB,
     *TTHT,TTST,
     *THWT,VHT,TFST,TTCT,TKCT,
     *QUAL4,QUAL8,QUAL12,QUAL16,
     *RLATET,
     *FRET,TTHC,
     *THWC,VHC,TTCAC,OIL,
     *QUAL2,QUAL6,QUAL10,QUAL14,FREC,IPLA,IBUS,ITRA,ICAR
      IF (IPLA .EQ. 1) THEN
      LPK=1
      IND(1)=IND(1)+1
      ENDIF
      IF (IBUS .EQ. 1) THEN
      IND(2)=IND(2)+1
      LPK=2
      ENDIF
      IF (ICAR .EQ. 1) THEN
      IND(3)=IND(3)+1
      LPK=3
      ENDIF
40    FORMAT(5F5.2,F5.0,F4.0,4F2.0,F4.0,F5.2,
     *5F5.2,/,F5.0,F4.0,4F2.0,F4.0,
     *F5.2,3F5.2,F5.0,F4.0,4F2.0,F5.2,2X,4I2)
C***********************************************************************
C     CALCULATION OF UTILITY
      UTIA=40.34-43.46*VHA-.032*TTCTA+.39*RINHHA
     *+.670*QUAL3+.492*QUAL11+2.1*DUR
C***********************************************************************
      UTIB=5.33-.560*VHB-.032*TTCAB-.717*RINHHA
     *+.670*QUAL1+.492*QUAL9
C***********************************************************************
      UTIC=-.560*VHC-.032*TTCAC
     *+.670*QUAL2+.492*QUAL10
C***********************************************************************
C     WRITE (9,*)VHA,TTCTA,RINHHA,QUAL3,QUAL11
      PROBA=0.0
      PROBB=0.0
      PROBT=0.0
      PROBC=0.0
      SUMT=0.0
C     CALCULATION OF LOG SUM
      ROSA=EXP(UTIA)
      ROSB=EXP(UTIB)
      ROSC=EXP(UTIC)
C     CALCULATION OF PROBABILITIES
      SUMT=SUMT+ROSA+ROSB+ROSC
C     WRITE (9,*)ICO,ROSA,ROSB,ROSC,SUMT
      PROBA=ROSA/SUMT
```

```
      PROBB-ROSB/SUMT
      PROBC-ROSC/SUMT
      P(1)-PROBA
      P(2)-PROBB
      P(3)-PROBC
C*****************************************************************
       PMAX-AMAX1(P(1),P(2),P(3))
C*****************************************************************
C*****************************************************************
C
C
C      KK- K
         WRITE(9,313)(LL,LL-1,NT)
 313   FORMAT(1H0,27X,10I8/)
         DO 900 IRK-1,NT
 900  INDEX(IRK)-0
       IF(P(LPK).EQ.PMAX)QC(LPK)-QC(LPK)+1.
C       WRITE (9,*)QC(LPK),P(LPK)
         DO 316 LL-1,NT
         IF(PMAX.EQ.P(LL))IMAX-LL
 316   CONTINUE
         WRITE(9,315)ICO,LPK,IMAX,(P(LL),LL-1,NT)
 315  FORMAT(3X,I4,3X,I2,6X,I2,9X,10F8.4)
      P(1)-0.0
      P(2)-0.0
      P(3)-0.0
      P(4)-0.0
      P(5)-0.0
      P(6)-0.0
      P(7)-0.0
      P(8)-0.0
      P(9)-0.0
      P(10)-0.0
1     CONTINUE
C     OUTPUT OF PREDICTION RATIO
         SUM-0.0
         DO 600 K-1,NT
         PRED(K)-QC(K)/IND(K)
 600   SUM-SUM+QC(K)
         TOT-SUM/FLOAT(NN)
         WRITE(9,610)TOT
 610  FORMAT(//////,'  RATIO OF CHOICES PREDICTED CORRECTLY-',F6.4/)
         DO 615 K-1,NT
 615   WRITE(9,630)K,IND(K),QC(K),PRED(K)
 630  FORMAT(/,/,'ALTERNATIVE',I3, ' CHOSEN  ',I5, ' TIMES',/,/
     1,'PREDICTED CORRECTLY',F5.0,' TIMES',/,'PREDICTION RATIO - ',F6.4)
      STOP
      END
```

```
C*****************************************************************
C*****************************************************************
C*****************************************************************
C
C     PROGRAM VALIDATE
C
C     ************************************************************
C     TO  READ THE FIL MADE FOR B LOGIT AND CALCULATE THE AGGREGATE
C     PREDICTION FOR EACH MODE IN THE JEDDAH-RIYADH CORRIDOR
C     ************************************************************
        DIMENSION F(30,30,30),S(10,10,10),E(10,10,10)
        DIMENSION X(10,10),Z(10),P(10),V(10)
        DIMENSION INDEX(10),PRED(10),IND(10),QC(10)
      OPEN (1,FILE ='VALJ.LOL',STATUS='OLD')
      OPEN (9,FILE ='VAL.JED')
        NDIM=3
        NT=3
        KK=10
C     KK=NUMBER OF PARAMETERS
C     NT=NUMBER OF ALTERNATIVE
C     NN=NUMBER OF OBSERVATIONS
C     INITIALIZE F-MATRIX AND Z-VECTOR
        DO 10 I=1,NT
        DO 10 J=1,KK
        DO 10 K=1,NT
  10   F(I,K,J)=0.0
        DO 15 K=1,NT
        QC(K)=0.0
        IND(K)=0
   15   Z(K)=0.0
             WRITE(9,314)
 314 FORMAT(1H1,9X,'ALT.',5X,'ALT.'/8X,'CHOSEN',3X,'PREDICTED',6X,'CHOI
    1CE     PROBABILITIES OF ALTERNATIVES')
        NN=244
      DO 1 ICO=1,NN
C**************************************************
      READ  (1,30)RNDA,TTHA,TTSA,
     *THWA,VHA,TFSA,TTCTA,TKCA,
     *QUAL3,QUAL7,
     *QUAL11,QUAL15,
     *RINCA,RINHHA,RNPA,CPAKA,
     *RLICA,AGEA,CARA,STUDA,
     *ATA,FREA
30    FORMAT(F2.0,5F5.2,F5.0,F4.0,6F2.0
     *,F3.0,2F4.0,F3.0,3F2.0,F5.2)
C*****************************************************************
      IF (RNDA .LE. 1.)THEN
      DUR=1.
      ELSE
      DUR=0.0
      ENDIF
C*****************************************************************
```

```
       READ  (1,40)TTHB,TTSB,
      *THWB,VHB,TFSB,TTCAB,TKCB,
      *QUAL1,QUAL5,QUAL9,QUAL13,
      *RLATEB,FREB,
      *TTHT,TTST,
      *THWT,VHT,TFST,TTCT,TKCT,
      *QUAL4,QUAL8,QUAL12,QUAL16,
      *RLATET,
      *FRET,TTHC,
      *THWC,VHC,TTCAC,OIL,
      *QUAL2,QUAL6,QUAL10,QUAL14,FREC,IPLA,IBUS,ITRA,ICAR
       IF (IPLA .EQ. 1) THEN
       LPK=1
       IND(1)=IND(1)+1
       ENDIF
       IF (IBUS .EQ. 1) THEN
       IND(2)=IND(2)+1
       LPK=2
       ENDIF
       IF (ICAR .EQ. 1) THEN
       IND(3)=IND(3)+1
       LPK=3
       ENDIF
40     FORMAT(5F5.2,F5.0,F4.0,4F2.0,F4.0,F5.2,
      *5F5.2,/,F5.0,F4.0,4F2.0,F4.0,
      *F5.2,3F5.2,F5.0,F4.0,4F2.0,F5.2,2X,4I2)
C*********************************************************************
C      CALCULATION OF UTILITY
       UTIA=-0.55-2.795*VHA-.009*TTCTA+.53*RINHHA
      *+.416*QUAL3+.43*QUAL11+3.3*DUR
C*********************************************************************
       UTIB=7.69-.426*VHB-.009*TTCAB-1.65*RINHHA
      *+.416*QUAL1+.43*QUAL9
C*********************************************************************
       UTIC=-.426*VHC-.009*TTCAC
      *+.416*QUAL2+.43*QUAL10
C*********************************************************************
C      WRITE (9,*)VHA,TTCTA,RINHHA,QUAL3,QUAL11
       PROBA=0.0
       PROBB=0.0
       PROBT=0.0
       PROBC=0.0
       SUMT=0.0
C      CALCULATION OF LOG SUM
       ROSA=EXP(UTIA)
       ROSB=EXP(UTIB)
       ROSC=EXP(UTIC)
C      CALCULATION OF PROBABILITIES
       SUMT=SUMT+ROSA+ROSB+ROSC
C      WRITE (9,*)ICO,ROSA,ROSB,ROSC,SUMT
       PROBA=ROSA/SUMT
       PROBB=ROSB/SUMT
```

```
      PROBC=ROSC/SUMT
      P(1)=PROBA
      P(2)=PROBB
      P(3)=PROBC
C*****************************************************************
        PMAX=AMAX1(P(1),P(2),P(3))
C*****************************************************************
C*****************************************************************
C
C
C       KK= K
          WRITE(9,313)(LL,LL=1,NT)
 313    FORMAT(1H0,27X,10I8/)
          DO 900 IRK=1,NT
 900  INDEX(IRK)=0
        IF(P(LPK).EQ.PMAX)QC(LPK)=QC(LPK)+1.
C        WRITE (9,*)QC(LPK),P(LPK)
          DO 316 LL=1,NT
          IF(PMAX.EQ.P(LL))IMAX=LL
 316    CONTINUE
          WRITE(9,315)ICO,LPK,IMAX,(P(LL),LL=1,NT)
 315  FORMAT(3X,I4,3X,I2,6X,I2,9X,10F8.4)
      P(1)=0.0
      P(2)=0.0
      P(3)=0.0
      P(4)=0.0
      P(5)=0.0
      P(6)=0.0
      P(7)=0.0
      P(8)=0.0
      P(9)=0.0
      P(10)=0.0
1     CONTINUE
C     OUTPUT OF PREDICTION RATIO
         SUM=0.0
         DO 600 K=1,NT
         PRED(K)=QC(K)/IND(K)
 600    SUM=SUM+QC(K)
         TOT=SUM/FLOAT(NN)
         WRITE(9,610)TOT
 610  FORMAT(//////,'  RATIO OF CHOICES PREDICTED CORRECTLY=',F6.4/)
         DO 615 K=1,NT
 615    WRITE(9,630)K,IND(K),QC(K),PRED(K)
 630  FORMAT(/,/,'ALTERNATIVE',I3, ' CHOSEN   ',I5, ' TIMES',/,/
     1,'PREDICTED CORRECTLY',F5.0,' TIMES',/,'PREDICTION RATIO = ',F6.4)
      STOP
      END
```

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