WORLD EMPLOYMENT PROGRAMME RESEARCH

Working Papers

International Labour Office, Geneva

WEP 2-23/WP. 109
WEP 2-22/WP. 89

WORLD EMPLOYMENT PROGRAMME RESEARCH

Working Paper

TECHNOLOGY AND EMPLOYMENT PROGRAMME
INCOME DISTRIBUTION AND EMPLOYMENT PROGRAMME

PASSENGER TRANSPORT IN KARACHI: A NESTED LOGIT MODEL

by

Mateen Thobani

December 1981

ISBN 92-2-102989-1

PREFACE

This working paper is the ninth study completed in the context of a research project on technology, products and income distribution. This is a research project being carried out jointly by the Technology and Employment Programme and the Income Distribution and Employment Programme of the ILO's World Employment Programme. Some 8 to 10 country case studies, prepared under this project, are planned to be published in a single volume towards the end of 1982.

The central objective of the project is to determine the extent to which an improvement in income distribution (including, inter alia, the alleviation of poverty in the rural areas of developing countries) is likely to be consistent with the consumption of goods and services produced using labour-intensive technologies, thereby generating employment. Such consistency between the consumption and production sides of the economy has been a crucial assumption in the formulation of employment-oriented development strategies, although it has not yet been rigorously tested. After the completion of all the case studies, it is anticipated that it may be possible to formulate recommendations regarding policy in respect of the improvement and expansion of marketing channels for appropriate products (i.e. products that satisfy basic needs) and how consumers can be induced to buy these products which, given their income, satisfy their basic needs most efficiently.

This paper is the result of the author's graduate work at Yale University. It provides an analysis which demonstrates that the addition of buses would be cost effective. Further, the model simulates the impact of the increased bus service on the demand for other modes of transport - a useful result for planners. The household survey conducted for this study shows that a smaller percentage of the poorest income group has a bus available to it as compared to the middle income groups. This suggests that there is a frustrated demand for buses. Simulations of the model support this result by showing that about 18% more trips by bus would have been undertaken had the bus been available to everyone in the sample.

A. Bhalla F. Paukert

ACKNOWLEDGEMENTS

The study was begun while I was a Visiting Economist at the Applied Economics Research Centre, Karachi University. Having been brought up in Karachi, I tended to look upon Karachi's problems through jaded eyes. Credit for bringing the problem to my attention goes to James Knowles, who, as Visiting Professor to the Centre, was only too aware of the inadequate transport system in Karachi. He impressed upon me the need for developing an economic framework within which to analyse the problem and the importance of a household survey towards this end. I would also like to thank him for his guidance in designing the study and implementing the survey.

I am grateful to the Applied Economics Research Centre, particularly to Hafiz Pasha, for use of the Centre's facilities and for reducing the demands on my time so that I could devote my efforts towards the study. I would like to thank all my colleagues, research assistants and the support staff of the Centre for their helpful advice and for bearing with my demands. I suspect that for many of them the transport problems were very close to heart. At the risk of omitting the names of others who put in much work on the study, I would like to give special thanks to three research assistants: Sabihuddin Butt, Shaista Usmani and Arif Zaman, all of whom went beyond their call of duty.

Foremost among the individuals and agencies who helped in the data gathering effort is Mohiyudin Siddiqui of the Master Plan Office. In addition to all current material he made available to me all past material that had not mysteriously disappeared or had been eaten by white ants. Other institutions to whom I am grateful for their help and use of data are the Sind Regional Planning Office, the Karachi Urban Transport Corporation, the Karachi Bus Owners' Association and Pakistan National Motors.

At Yale, I would like to thank Herbert Scarf who, while not playing an active role in this study, steered me in the right direction and gave me encouragement when it was most needed. John Quigley served as my mentor and guide in a field that was new to me - urban economics. I am extremely grateful to him for the help that he managed to give despite his many commitments.

I would furthermore like to thank T.N. Srinivasan who, during the last stages of the study served as my main source of advice and feed-back and made himself very accessible to me. Richard Levin, who was kind enough to read the manuscript at short notice, made several insightful comments and suggestions. Others from whom I have benefitted from conversations are Kim Peck, Randy Olsen and John Beggs on the Yale faculty. Amongst my peers I have had useful discussions with Paul Pfleiderer and Mark Grinblatt.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

THE PROBLEM

A. Introduction

From a fishing town of less than a half million inhabitants in 1947, Karachi has grown to a thriving metropolis of six million. The six percent average annual growth rate of population during the last two decades has resulted in increasing problems in city services, particularly passenger transport. This paper identifies some of the major problems besetting Karachi's transportation system and, based on an analysis of household data, suggests some remedies to ease the situation.

Most people in Karachi will be quick to point out that Karachi has an acute transportation problem. The major problem is one of a shortage of public transportation as demonstrated by overcrowded buses and throngs of people seen every morning waiting for some means of transportation. Other problems include the total unavailability of public transport (especially buses) in some areas, the dangers involved in using public transport, the lack of clear sidewalks, and the congestion along certain roads during peak hours. A detailed description of the Karachi transport sector follows in the next section.

The main objective of this study is to make suggestions on how to improve the transport situation in Karachi. While there is no dearth of such suggestions from Karachi residents, it is necessary to provide a framework within which the consequences of the recommendations may be evaluated. Do the benefits to residents from the suggested changes outweigh the costs? What is the effect of the policy change on the demand for each mode? In order to answer these questions, the paper estimates a joint choice probabilistic model of mode ownership and mode to work.

The advantages to such a model will become clear later. One of the advantages that is worth pointing out at this stage is that the model may be estimated using a relatively small sample.

A 400 household survey was conducted for the purpose of this study. In addition to questions on income and expenditure, there were detailed questions regarding the travel behavior of each member of the household. The sample was stratified by categories of income and distance to the center of city.

Concern in Karachi's transport system is not new. Several studies[1] have made recommendations to reduce the problems, the most notable being those by the Master Plan Office (MPO) of the Karachi Development Authority. Evolved out of a United Nations Development Program grant to the city, the MPO has published many reports on Karachi's transport system. Most of these studies were done jointly with experts

---

1 See, for example, Esesjay (1975).

from the United Nations and two international consulting firms, PADCO and TERPLAN. Many of the recommendations made in this paper are similar to their proposals. This study strengthens some of the conclusions reached by other studies. However, it goes one step further in that it measures the effects of carrying out the proposals on the pattern of demand for various modes, and conducts a cost benefit analysis of one of the major recommendations.

Outside the developed countries, few studies have attempted to measure such parameters as the value of time or demand elasticities of various modes which are useful in evaluating policy changes. To my knowledge, none of the studies used probabilistic models which are best suited to infer the value of time. This is the first study of its kind to allow one to compare travel demand behavior in a developing country with those in developed countries. It also makes a contribution to the small but growing literature on multimodal probabilistic models and the yet smaller field of joint choice probabilistic models.

B. The Transport Sector in Karachi

Buses, with their regulated fares of 25 paisa to Rs. 1.00 (100 paisa = Rs. 1.00 = 10c US), are by far the most important mode of transportation for the majority of the residents. Yet this is precisely the mode of transport where the supply has lagged behind its demand over the years.

Table 1 shows the growth of various motorized vehicles in Karachi. The data on buses, in addition to private and public city buses, includes buses belonging to various organizations and businesses, inter-city buses, and contract carriers. The latter are private buses typically hired by a community where commuters pay a fixed sum of money per month and are guaranteed a seat. In 1979, of the total of 7530 buses, only 1760 were available for public transportation within the city (Table 2). While the total number of registered buses has been growing fairly rapidly, the number of city buses available for public transit has shown little growth. Bus capacity has been increasing somewhat with the introduction of the newer Fiat buses. However, the Bedford buses are still by far the most popular.

TABLE 1

REGISTERED MOTOR VEHICLES BY TYPE

Year	Cars	Motor Cycles	Taxis	Motor Rickshaws	Buses	Trucks	Others	Total
1971	27432	15609	3366	6458	1296	3714	1157	59032
1972	32109	21634	3772	6458	1174	4022	2110	71279
1973	34339	25913	3956	6561	1215	4400	2034	78418
1974	38495	31214	4331	6855	1595	5158	3292	90940
1975*	33143	31766	3334	6404	1472	3955	3293	83367
1976	37200	41140	2836	6532	2853	4304	5103	99968
1977	61321	61139	5481	6266	4133	5431	4569	148340
1978	73668	82037	6154	6466	4853	6245	8109	187532
1979**	133134	116030	11858	13860	7530	13784	16832	313028

Source: Motor Vehicles Registry Data

* the decline is due to the discontinuance of registering very old cars.

** the increase is partly due to stricter enforcement of registration.

About two-thirds of the city buses are privately owned (Table 2). In absolute terms, the number of private city buses decreased from 1200 in 1955 to 800 (of which 700 were on the road) in 1971. By 1979, of the 1163 privately registered city buses, about 800 were on the road. The decline in private buses since 1955 despite rapid population growth is primarily caused by the fare structure which has been kept very low due to political reasons. At a fare of US one cent for a three mile bus trip in December 1974, a World Bank study found Karachi fares to be the lowest in the world. In 1956, bus fares were reduced from an average of four paisa per passenger mile to two and a half paisa per passenger mile. In June 1979, fares averaged about five paisa per passenger mile. Presently they stand at about eight paisa per passenger mile[2].

In the public sector, only 350 of the 600 buses owned by the public sector were on the road in September 1979. Others were unoperational for lack of spare parts or other repairs. While a marked improvement from the early 70s when less than 200 of a total fleet of 800 public sector buses were typically on the road, it is not surprising to find the private sector better able to maintain its buses despite low fares. Of the 350 public buses on the road in 1979, 100 were used exclusively by students at a fare of 25 paisa regardless of distance.

----

2 Per capita income in Pakistan is $ 245 per year.

TABLE 2

COMPOSITION OF REGISTERED VEHICLES
(1979)

PUBLIC TRANSPORT	
1) Buses	1760
a) private	1163
b) public	597
2) Minibuses	2908
3) Taxis	11858
4) Motor Rickshaws	13860
Sub-total	30386
PRIVATE TRANSPORT	
1) Cars and jeeps	133134
2) Motor cycles	116030
Sub-total	249164
CARGO AND OTHERS	
1) Trucks	13784
2) Vans and Pickups	13924
3) Other buses	5770
Sub-total	33478
TOTAL MOTORIZED VEHICLES	313028
ANIMAL DRIVEN VEHICLES	
1) Donkey carts	1530
2) Tongas	180
3) Victoria	142
4) Camel carts	100
TOTAL	1952

Source: MPO (1979).

Bus frequencies are generally good. Most routes have a headway of less than half an hour. Based on household interviews conducted for this study in the summer of 1979, the average waiting time for a trip to work by bus was 8.5 minutes for areas within three miles of the center of city, 10.4 minutes for areas between three and five miles, and 13.7 minutes for areas further than five miles. However, these may underestimate the waiting time since some potential passengers may have chosen other transport modes after waiting for some time.

There is considerable variation in bus intervals even on the same route. In a study conducted by the MPO[3] in 1971, the interval between buses was often twice the mean interval for the sample. This was not due to congestion but rather the practice of waiting for the bus to fill up before leaving. Average speeds ranged from 10 to 14 m.p.h. with little variation throughout the day. (The effect of increased congestion during peak hours was compensated for by the decreased need of waiting at stops to pick up additional passengers.) In the sample for this study, the average speed for trips to work by bus was just over 12 m.p.h.

According to the large household survey conducted by the MPO in 1971, the number of trips to work by personal motorized modes such as cars, motorcycles, taxis, and rickshaws was less than 10% of total trips to work. Walking and bicycle accounted for 39.7%, while buses, trams, rail, and launch (passenger ferry) comprised 50.7% (Table 3).

The average trip length was over five miles for the mass transportation and personal motorized mode categories (Table 4). Walking and bicycle trips tended to be very short. In terms of passenger miles, mass transportation accounts for 76.3% of all trips to work (Table 5). The main component

---

3 See MPO (1974).

TABLE 3

DAILY TRIPS BY MODE AND PURPOSE
(in thousands)

Purpose	walk/ cycle	bus,tram, rail,launch	car,taxi, rick,mbike	total
Work	732	933	177	1842
School	645	145	16	806
Business/Shop	1523	124	124	1771
Social/Recreat	1164	33	574	1771
Total	4064	1235	891	6190
Percent	65.7	19.9	14.4	100.0

Source: MPO (1974)

TABLE 4

AVERAGE TRIP LENGTH BY MODE AND PURPOSE
(in miles)

Purpose	walk/ cycle	bus,tram, rail,launch	car,taxi, rick,mbike	total
Work	1.05	5.82	5.19	3.86
School	0.60	4.05	3.81	1.29
Business/Shop	0.35	3.00	5.00	0.86
Social/Recreat	0.20	3.52	4.99	1.82
All trips	0.47	5.27	5.01	2.08

Source: MPO (1974).

(86.4%) of mass transportation is bus (Table 6).

Based on demand projections carried out by the MPO in 1971, the Office recommended an increase in the number of buses to 2580 by 1977 in addition to a recommendation to upgrade the tram or street car system. The trams have since been discontinued and yet the current bus fleet comes nowhere close to the figure projected for 1977. To some

TABLE 5

DAILY PASSENGER MILES BY MODE AND PURPOSE
(in thousands)

Purpose	walk/ cycle	bus, tram, rail, launch	car, taxi, rick, mbike	total
Work	768	5432	918	7118
School	388	587	61	1036
Business/Shop	534	372	620	1526
Social/Recreat	233	116	2867	3216
TOTAL	1923	6507	4466	12896
Percent	14.9	50.5	34.6	100.0

Source: MPO (1974).

TABLE 6

DAILY PASSENGER MILES BY MOTORIZED MODES
(in thousands)

Mode	Passenger miles per day	Percent
Bus	5623	51.2
Tram	62	0.6
Train	800	7.2
Launch	22	0.2
Sub-total	6507	59.3
Taxi	909	8.3
Motor rickshaw	1078	9.8
Sub-total	1987	18.1
Car	1905	17.4
Motorcycle	574	5.2
Sub-total	2479	22.6
TOTAL	10973	100.0

Source: MPO (1974).

extent the frustrated demand has been picked up by the unanticipated dramatic rise in minibuses. However, there seems to be a case for increasing bus service, particularly in view of the fact that most buses are completely full and have passengers hanging out of windows and precariously balanced in doorways.

Privately owned minibuses were first introduced in 1972 and meant to serve as 14 passenger wagons. However, by early 1979 they typically carried 18 or 19 passengers at regulated fares of Rs.0.75 to Rs.1.25 per person. Known as yellow devils or yellow deathtraps depending on whether one dodges them or rides them, they have helped fill a gap between overcrowded buses on the one hand and expensive rickshaws and taxis on the other.

As of September 1979, there were about 3000 minibuses registered in Karachi, of which about 12% were out of service. While almost all minibuses up to early 1979 were 14 passenger Ford vans, the last two years have seen a huge increase in the number of diesel powered 26 passenger Mazda minibuses. Because of the import duty structure and the cheaper cost of diesel, both the purchase cost and operating cost of the Mazda is lower. The increased capacity also makes it much more desirable. With the exception of routes to areas further than five miles from the center of town, the average waiting time for minibuses in the sample for this study were a little higher than for buses. This may reflect the fact that minibuses are more likely than buses to get full as they get closer to town, so that one has to wait longer near the center of town. Average speeds for minibuses are about 25% faster than buses. They are significantly more comfortable than buses if one has a seat, but the comfort advantage is doubtful if one has to crouch standing.

Although the number of taxis has doubled over the last decade, the number of motor rickshaws (3 wheeled motorcycles meant to carry two passengers in addition to the driver) remained constant up to the end of 1978. While fares for both modes remained low (Rs.0.70 and Rs.1.00 per mile in early 1979) up to 1979, it is not clear why taxis have grown relative to motor rickshaws. Part of the reason may be the growth of minibuses which has detracted more from rickshaw than taxi demand. Due to the high level of noise and smoke pollution coupled with a high risk of accidents, additional rickshaws may not be desirable. In 1979, due to an increase in their fares, the number of both rickshaws and taxis increased dramatically. By early 1981, taxi fares stood at Rs. 2.00/mile while rickshaw fares were Rs. 1.20/mile.

Almost all the taxi fleet is composed of small Japanese cars with an engine size of less than 1300 cc. Due to a significant import duty reduction, a large proportion are reconditioned cars from the early 70s. It is common to find shared taxi rides during peak hours. These are often organized by the taxi driver who manages to obtain twice the metered fare by charging each of four customers half the metered fare. Taxi and rickshaw drivers often charge more than the metered fare even during non-peak hours. Depending on the whim of the driver, the appearance of the customer and his intended destination, they may charge 20% more as a rule, and may even charge ten times the amount to newly arrived foreigners. Comparing reported cost in the household survey for this study with the expected metered cost for distance travelled, it was found that rickshaw and taxi drivers charged about 20% over the expected fare.

Cars and motorcycles have exhibited a dramatic increase over the last decade. The congestion on some major roads due to this has led to the odd result of excluding buses and animal-drawn vehicles from these roads. Cars, however, are not used as inefficiently (in terms of utilization) as might be expected due to the presence of extended families and chauffeurs. Motorcycles also often serve as family transportation. It is not an uncommon sight to see a couple with three children on a motor scooter.

The motorcycle fleet is composed of either the Vespa scooters or light motorcycles in the 50 cc to 90 cc range. Duties (import duty plus sales tax) on motorcycles are 123%. Most cars are small Japanese cars mainly because of the escalating duty structure. Duties range from 127.5% on cars with an engine size of less than 1000 cc to 485% on cars over 1600 cc. Duties on spare parts are also high. Ninety octane petrol sells for about $2.23 per US gallon.

Bicycles are not used as much as one would expect in a relatively flat city with little rain, and where the locally manufactured bicycles are quite cheap. The use of bicycles is limited primarily to certain domestic or unskilled workers. This is due perhaps to the status consciousness of the white collar workers who would prefer to ride a crowded bus than be seen on a bicycle. Other reasons may be the strain of riding a bicycle in the hot Karachi sun and the danger of being knocked over by passing motorized vehicles. Traffic laws are flagrantly violated due to an ineffective police force and uneducated drivers[4].

Although a large number of trips are undertaken by foot and bicycle, the average trip length is just over one mile for trips to work, and one-fifth of a mile for social and recreational trips (Tables 3 and 4). To a large extent this is probably due to the non-availability of clear footpaths. Where they exist, footpaths are often encroached upon by pedlars, hawkers, small stalls and hand carts, leading the pedestrians to take their chances weaving between motorized and animal-drawn vehicular traffic, or choosing some other mode of travel.

There is circular railway running from a suburb of Karachi through the main industrial site to the center of the

----

4 The reader is referred to the Karachi Master Plan's 'Final Report on Transportation' for a more elaborate description of the demand and supply characteristics of Karachi transport during 1971 to 1973.

city. It carries over 100,000 passengers daily. While used heavily by residents of the suburb, relatively few passengers embark en route. This is probably due to its uncertain scheduling and the presence of alternative modes such as bus or minibus. According to a Master report,

'there is great scope for improvement in management and scheduling. The railway infrastructure is of good quality and the installed capacity can permit sizeable increases in traffic without further investment[5].'

Animal-drawn vehicles are on the decline in Karachi. From a total of 8000 animal-drawn vehicles in 1971, the current total stands at less than 2000. Table 2 gives a break down of the various kinds of animal-drawn vehicles. While tongas (small horse driven carts), donkey carts, and camel carts are used primarily as a substitute for trucks, victorias (large stately horse drawn carriages) are used exclusively for passenger transport.

C. Policy Questions and Choice of Model

In order to measure the impact of any policy changes on demand, the planner needs to know demand elasticities for public modes with respect to their fares and other attributes such as time taken. This is particularly important in Karachi where both fares and petrol prices are controlled by the government. Therefore, it is necessary to model the

---

[5] MPO (1979), page 46.

demand for a particular mode as a function of its own fare and other fares. Thus the model would predict not only the effect of a change in bus fare on the demand for buses but on the demand for minibuses and rickshaws too.

Another useful parameter for policy purposes is the commuter's value of travel time. The calculation of values of travel time and waiting time would be useful both for comparison purposes and in evaluating projects that result in a decrease in travel or waiting time for a mode.

In addition to the above questions of mode choice or modal split there are some other questions that may be of use to the policy maker -- those of mode ownership. What determines a household's decision to buy a car, motorcycle or bicycle? How does an increase in the maintenance cost of a car influence the decision to buy a car or motorcycle?

The questions raised in the first two paragraphs of this section suggest some sort of a modal split model. The more sophisticated of the earlier modal split models expresses the ratio of number of trips by car to the number of trips by public transport from one zone to another as a function of the time taken in each mode, the socio-economic characteristics of the origin zone, and the land use characteristics of the destination zone[6]. Although based on aggregated

---

6 See Fertal et. al. (1966) for descriptions of the conventional approaches to modelling urban modal split.

data, these models are behavioral and policy oriented. However, the choice of two modes in the aggregate modal split models appears to be restrictive and would have little relevence in a less developed country which typically has a rich variety of distinct modes. In addition, variables are sometimes aggregated in ways that lose policy implications of the model. For instance, the travel time attributes may not distinguish between the waiting time for a mode and the time spent in transit, so that a scheme to reduce only one of these could not be evaluated.

The newer probabilistic models remove these shortcomings. These models consider the probability of an individual making a certain choice (eg. the choice of mode to work) as a function of attributes of the choice and socio-economic characteristics of the individual. As such, they are behavioral, are based on disaggregated data and are policy oriented in that they are sensitive to changes in policy variables. In his summary paper, Stopher (1977) concludes that probabilistic models are best suited to infer the value of time.

Since the model includes such variables as value of time (as a function of income) and fare, the estimated model can yield demand elasticity estimates of these variables. The coefficients can then be used to see which would be the preferred mode for persons of various income groups given the characteristics of the trip and individual. A possible hypothesis is whether the bus is predicted to be the optimal mode for certain groups of people but is not used due to its unavailability. The probabilistic model would first be estimated under the assumption that an individual can choose a bus only if the bus is available to the person. The results of this model could then be compared with the unconstrained problem when the bus is available to all.

An important advantage of the probabilistic models is that under certain assumptions, they can be derived from a theory of stochastic utility maximization. Further the decision set may include several modes and allows for joint decisions such as the joint probability of buying a car and going to work in a bus. If the joint nature of a decision is ignored it may bias coefficient estimates. Decisions such as whether or not to make a trip or the time of day to make the trip can also be handled although they are usually either difficult to model or data are unavailable.

While the probabilistic models are often laid out within a general framework which allows for elaborate joint decisions, few studies actually estimate the joint decisions. Among these are Adler and Ben Akiva's (1977) study on shopping trips and Lerman's (1977) study on choice of residential location, type of housing, automobile ownership, and mode to work. More recently Train (1980) estimated a joint choice model of mode ownership and mode to work based on a sample of households in the San Francisco area. Using

Train's approach, this paper estimates a joint choice model of mode ownership and mode to work based on household data in Karachi.

There are several reasons for selecting to model this set of joint decisions. The trip to work is a large percentage of total trips made by the household (36.9% of all non-home trips in our stratified sample). The primary use of public transport is for the trip to work. The trip to work is made to a fixed destination at a relatively fixed time of day and its demand is inelastic. This allows us to ignore the effect of a change in price on the decision either to go to an alternate location or decide not to make the trip at all.

One would expect that the decision to buy a car or motorcycle is determined simultaneously with the decision to choose a particular mode to work. If this were indeed the case and the simultaneity ignored, coefficient estimates may be biased. In addition, by modelling the joint decision it would be possible to see the effect of an increase in petrol price not only on the demand for a mode to work, but also on the demand for car ownership. Using income and expenditures on maintenance and depreciation as independent variables, the mode ownership issues raised in the second paragraph of this section could also be handled.

The next chapter first develops a general framework for problems of discrete choice involving time and derives an indirect utility function which is later used in the logit specification. It then shows how the joint choice model can be derived from a theory of stochastic utility maximization. Finally it explains how the model can be broken into its components without losing the structure of the model and at the same time allowing us to test the hypothesis that the decisions are indeed jointly made. This breakup is necessary to make the problem computationally tractable.

CHAPTER 2

METHODOLOGY

A. A General Framework

Conventional utility maximizing models fail to capture the demand for travel modes because they do not explicitly treat the time spent in travelling. Several studies[7] have attempted to overcome this either by explicitly entering the time spent in each mode directly in the utility function (eg. Blackburn (1970), DeSerpa(1971), De Donnea (1972), Bruzelius (1979)), or indirectly by recognizing that certain activities take time and have different productive uses (eg. Becker (1970)).

In order to highlight some interpretations on the value of time, an extension of the DeSerpa model (leisure has been added to his utility function) is first considered. Later this model is modified to treat the special case of the mode to work journey. The conclusions of the latter framework serve as a basis for the nested logit model described in the following section. The modified DeSerpa model is outlined below:

(1.0) Max $U(X_1,...,X_n,L,T_1,...,T_n)$

(1.1) subject to $\sum_{i=1}^{n} P_i X_i \leq Y$

---

[7] See Bruzelius (1979) for a survey.

(1.2) $T_i \geq a_i X_i \qquad i=1,\ldots n$

(1.3) $\sum_{i=1}^{n} T_i + L = T^o$

(1.4) $X_i,\ L,\ T_i \geq 0 \qquad i=1,\ldots n$

where X_i is the consumption of good i,

L the leisure time,

T_i the time spent in activity i,

P_i the price of good i,

a_i the minimum time required to consume one unit of good i (set by physical or institutional constraints -- a person may take more than the minimum time if he enjoys the activity),

and T^o the total time available for consuming goods and leisure (the work decision is assumed to have been made already).

The Lagrangian associated with the problem is

(2.0) $$U(X_1,\ldots,X_n,L,T_1,\ldots,T_n) + \lambda(Y - \sum_{i=1}^{n} P_i X_i) + \mu(T^o - L - \sum_{i=1}^{n} T_i) + \sum_{i=1}^{n} \delta_i (T_i - a_i X_i)$$

First order conditions for a maximum are:

(2.1) $\partial U/\partial X_i - \lambda p_i - \delta_i a_i = 0 \qquad i=1,\ldots n$

(2.2) $\partial U/\partial L - \mu = 0$

(2.3) $\partial U/\partial T_i - \mu - \delta_i = 0 \qquad i=1,\ldots n$

together with (1.2), (1.4), (1.5) and the complementary slackness conditions:

(2.4) $\delta_i (T_i - a_i X_i) = 0 \qquad i=1,\ldots n$

Thus λ is seen to be the marginal utility of income and μ the marginal utility of relaxing the total time constraint by one unit or the marginal utility of time as a resource. From (2.2) the latter equals the marginal utility of leisure. The marginal rate of substitution of time as a resource for income is μ/λ and is the value of time.

From (2.3) and (2.4), $\delta_i = 0$ for goods whose marginal utility of time equals the marginal utility of leisure (hence they are leisure goods) and the time spent on them exceeds their minimum time requirement. δ_i is the marginal utility of increasing the constraint $T_i - a_i X_i = 0$ by one unit, which is equivalent to decreasing the minimum time requirement a_i. It is the marginal utility of decreasing commuting time by one unit -- the marginal utility of time savings.

Dividing (2.3) by λ and rearranging terms:

$$\frac{\delta_i}{\lambda} = \frac{\mu}{\lambda} - \frac{\partial U/\partial T_i}{\lambda}$$

Thus the value of time savings in a particular activity (mode) is the difference between the value of time as a resource and the value of time spent in the activity (mode). Since $\partial U/\partial T_i$ will typically be negative for commuting time, the value of time savings will exceed the value of time as a resource. Hence it is quite plausible to expect different values of time savings for different activities and for these values to exceed the value of leisure time.

An individual's choice of mode to work does not readily fit into the above framework for two reasons. First, the individual only wants to make a fixed number of trips to work per unit of time (one per day), and second, the number of trips per period of time in a given mode must be an integer (0 or 1). To handle this and to be able to include other attributes of the mode to work such as waiting time, in-transit time and comfort which form a part of the utility function, the following framework is proposed:

(3.0) $\quad \text{Max} \quad U(X_1,\ldots,X_n,X_{n+1},L,Z_1,\ldots,Z_m)$

(3.1) $\quad \text{subject to} \quad \sum_{i=1}^{n} P_i X_i + X_{n+1} \leq Y$

(3.2) $\quad Z_j \geq \sum_{i=1}^{n} a_{ji} X_i \qquad j=1,\ldots m$

(3.3) $\quad \sum_{j=1}^{q} Z_j + L = T^{o}$

(3.4) $\quad \sum_{i=1}^{n} X_i = 1 \qquad X_1,\ldots X_n$ integers

(3.5) $\quad X_i,\ L,\ Z_i \geq 0$

where $X_i,\ldots X_n$ are the n possible modes to work,

X_{n+1} the composite commodity (the numeraire good),

Z_j the j th attribute of the transport mode (eg. waiting time),

a_{ji} the amount of the j th attribute in one unit of mode i, and the other terms are as defined earlier.

Of the m attributes, q are ones that take time (waiting time, in-transit time) and explicitly enter the total time constraint.

Given a feasible vector $(X_1,....X_n)$, from (3.1) it is possible to calculate X_{n+1} as a function of Y and $P_1,...P_n$. The Z_js are directly obtained from (3.2) as functions of $a_{j1},...a_{jn}$ (j=1,...m). Using the Z_js thus obtained, L is obtained as a function of T^o from (3.3). Therefore, given a solution vector $(X_1,...X_n)$, the indirect utility function is found as listed below:

(3.9) $V(P_1,...P_n,Y,a_{11},...a_{ji},...a_{mn},T^o)$

However, from (3.4), the only feasible solutions are of the kind X =(0,...0,1,0,...0) where the 1 is in the i th column. Taking a feasible solution to be $X_i = 1$, $X_k = 0$ for all $k \neq i$,

$$X_{n+1} = Y - P_i$$

$$Z_j = a_{ji} \qquad j=1,...m$$

and $L = T^o - \sum_{j=1}^{q} a_{ji}$.

Therefore the indirect utility function associated with a feasible solution $X_i = 1$, $X_k = 0$ for all $k \neq i$ is

$$V_i(P_1,Y,a_{1i},...a_{mi},T^o)$$

and is seen to a function only of the price and attributes of the chosen mode. To solve the problem (3.0) then, all that has to be done is evaluate the utility function for each of the n feasible solutions and choose the one that yields the highest utility. This is precisely the logit approach.

B. The Nested Logit Model

The nested logit model is a generalized version of the multinomial logit model[8]. An outline of the model as it applies to the problem at hand is given below:

The consumer is assumed to face a joint decision of choice of mode ownership indexed $c = 1,...C$ and mode to work indexed $n = 1,...N_c$[9]. The consumer derives utility U_{cn} for alternative cn which is a function of the attributes of the alternative. The attributes may be variables relating to the consumer such as family size and household income, to the choice of mode ownership c such as maintenance cost and depreciation, to the choice of mode to work such as commuting time, or interaction variables such as wage times the commuting time. The consumer then chooses the alternative that gives him the highest utility. All consumers are assumed to have the same stochastic utility function U_{cn}.

Not all attributes of the utility function are observed. The unobserved variables will have some probability distri-

---

8 See Domencich and McFadden (1975) and McFadden (1977).
9 The set N_c will vary according to c since it is assumed that a person cannot decide not to own a car or motorcycle but go to work in one.

bution conditioned on the values of the observed variables. If the observer knows the form of the utility function and the probability distribution of the unobserved variables he can make a probabilistic statement of the expected choice, namely

(4) $Pr_{cn} = Prob[U_{cn} \geq U_{bm} \text{ for } bm \neq cn]$

where Pr_{cn} denotes the probability of choosing cn.

Decompose U_{cn} into two components V_{cn} which is a function of the observed variables, and γ_{cn} which is a function of the unobserved variables:

(5) $U_{cn} = V_{cn} + \gamma_{cn}$

From (4) and (5)

(6) $Pr_{cn} = prob[V_{cn} + \gamma_{cn} \geq V_{bm} + \gamma_{bm} \text{ for } bm \neq cn]$

It can be shown that if the unobserved variables are independently and identically distributed and if the

$$Prob[\ \gamma_{cn} \leq \gamma\ ] = exp[-e^{-\gamma}]$$

(ie. if they have a Wiebull or extreme value distribution[10]), then the difference between the errors $(\gamma_{cn} - \gamma_{bm})$ has a logistic distribution and the choice model is multinomial logit[11]:

(7) $Pr_{cn} = exp(V_{cn}) \ / \ \sum_{b=1}^{C} \sum_{m=1}^{N_b} exp(V_{bm})$

---

10 The Wiebull distribution is similar to the normal distribution but is slightly skewed and has fatter tails.

11 See McFadden (1975) for a proof of this proposition.

An important implication of the above result is what is called the independence of irrelevent alternatives (IIA) which says that the odds of choosing one alternative over another are independent of the availability or non-availability of other unchosen alternatives. To see that this is implied by the above result, note that

$$\log(Pr_{cn} / Pr_{bm}) = V_{cn} - V_{bm}$$

and hence the odds of choosing alternative cn over bm is a function of only the attributes of cn and bm.

The main advantage of the result is that new alternatives may be introduced without reestimating the model once the form of the utility function is established. This is possible because the addition of a new alternative does not alter the relative odds with which the previous alternatives are selected.

The IIA property is a major weakness in that it requires all alternatives to be distinct so that no two alternatives are close substitutes. If they are not distinct then a 'red bus-blue bus' problem occurs. Suppose a population faces two alternatives, a red bus and a car and chooses a car with probability 2/3. Now suppose a blue bus is introduced which is exactly like the red bus except for the color. One would expect that consumers would continue to use the car with probability 2/3 and be equally likely to take the blue or red bus. However IIA predicts that the odds of choosing a car over a red bus remain at 2 to 1 thus predicting that the new probabilities of choosing a car, red bus and blue bus are 1/2, 1/4, and 1/4 respectively. This counter-intuitive result is due to the fact that blue buses and red buses are lumped together as one alternative rather than treated as two independent alternatives. (The error terms γ_{bm} are identical, yet they are assumed to be independent.) The implication of the red bus-blue bus problem is that care be exercised in making sure that alternatives really are regarded as distinct by the consumer. As will be explained later, the nested logit model avoids the problem somewhat since it no longer requires the joint choice model to be multinomial logit.

In order to obtain an econometric model from (7) it is necessary to specify a functional form for the systematic component of the utility function V_{cn}. We shall assume V_{cn} is additively separable and linear in parameters, but not necessarily in variables:

$$V_{cn} = \lambda' t_{cn}$$

where t_{cn} is a column vector of attributes and λ a vector of coefficients of t_{cn}.

Thus

$$(8) \quad Pr_{cn} = \exp(\lambda' t_{cn}) \;/\; \sum_{b=1}^{C} \sum_{m=1}^{N_b} \exp(\lambda' t_{bm})$$

and λ can be estimated by maximum likelihood techniques. McFadden (1973) has shown that the log likelihood function from (8) is concave and has a unique maximum.

An alternate way to estimate λ is to break up the joint decision into two sequential decisions. First consider the choice of mode to work conditional upon mode ownership and then the marginal probability of mode ownership:

$$(9) \qquad Pr_{cn} = Pr_{n|c} \cdot Pr_c .$$

Let

$$(10) \qquad V_{cn} = \beta' x_n + \alpha' y_c$$

where x_n is a vector of observed attributes which vary with mode attributes of the work trip[12] (eg. in-transit time), and y_c is a vector of observed attributes which vary only with mode ownership (eg. depreciation cost). From (7) and (10):

$$(11) \qquad Pr_{n|c} = \exp(V_{cn}) \Big/ \sum_{m=1}^{N_c} \exp(V_{cm})$$

$$= \exp(\beta' x_n) \Big/ \sum_{m=1}^{N_c} \exp(\beta' x_m), \text{ and}$$

$$(12) \qquad Pr_c = \sum_{m=1}^{N} \exp(V_{cm}) \Big/ \sum_{b=1}^{C} \sum_{m=1}^{N_b} \exp(V_{bm})$$

$$= \exp(\alpha' y_c) \left[\sum_{m=1}^{N_c} \exp(\beta' x_m)\right] \Big/ \sum_{b=1}^{C} \exp(\alpha' y_b) \left[\sum_{m=1}^{N_b} \exp(\beta' x_m)\right]$$

---

12 The general model allows for x_n to vary with both mode ownership and mode attributes. However in this model $x_{cn}=x_n$ since the variables such as in-transit time are independent of mode ownership.

Define an inclusive value

$$I_c = \log[\sum_{n=1}^{N_c} \exp(\beta' x_n)], \quad \text{then}$$

(13) $$Pr_{n|c} = \exp(\beta' x_n)/\exp(I_c) \quad \text{and}$$

(14) $$Pr_c = \exp(\alpha' y_c + I_c) \;/\; \sum_{b=1}^{C} \exp(\alpha' y_b + I_b)$$

A more intuitive interpretation of inclusive value in this model is that it is the aggregate (summed over all available modes) utility from the trip to work in each of the mode ownership categories. It is the 'utility' from each of the available public modes and walking, plus the 'utility' from taking the owned mode to work. By estimating (13) and (14) sequentially, one could economize on both the number of parameters being estimated and the number of alternatives at each stage. This results in computational savings. Equation (13) is first estimated and the estimates substituted in equation (14) to obtain α. The gain in computational ease comes at the expense of some loss of efficiency relative to direct estimation of the joint model.

An empirical generalization of the multinomial logit model due to McFadden (1977) is to allow the inclusive value in (13) to have a coefficient other than one:

(15) $$Pr_c = \exp(\alpha' y_c + (1-\sigma)I_c) \;/\; \sum_{b=1}^{C} \exp(\alpha' y_b + (1-\sigma)I_b)$$

where σ is a parameter. The model is only consistent with stochastic utility maximization for $0 \leq \sigma \leq 1$. If the coefficient of I_c is 1 (ie. $\sigma=0$) then we have the multinomial logit case. $0<\sigma<1$ and significantly different from zero gives us the case when the joint choice model is valid. In this case, σ is an estimate of the unobserved errors in the first stage of the model. $\sigma=1$ implies that the two decisions are in fact independent -- that the mode to work decision is independent of the mode ownership decision.

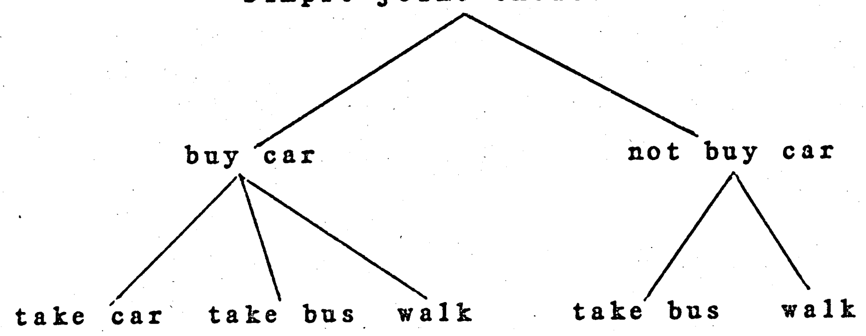
The best way to proceed is to first estimate (11) and calculate I_c. Using these estimates of I_c estimate (15) and test for the coefficient of I_c being different from one. If not different from 1 then we are in the multinomial logit world ($\sigma=0$). If between 0 and 1 we have a nested logit model which is consistent with stochastic utility maximization. Other values of the coefficient lead us to reject the joint choice model.

To illustrate the model consider a simple case where a person makes the joint decision of whether or not to own a car, and whether to go to work by car, bus or walking. If this person is not allowed to decide not to buy a car but go to work in one, he has five choices available to him as shown in the lowest level of the tree in Figure (i).

Under the assumptions of the multinomial logit model described earlier, one could now estimate the five alternative model directly. Note that the IIA property requires all alternatives to be distinct. However the alternative walk given he owns a car and walk given he does not own a

Figure (i)

Simple joint choice model



car are likely to be close substitutes, thus violating the one of the assumptions of the multinomial logit model. By breaking up the decision into the conditional probability of choosing a mode to work given the decision to buy a car, and the marginal probability of buying a car, the five alternative model is broken up into a two step estimation procedure. The first step is a multinomial logit model of three alternatives and the second a binomial logit model. The logit structure is only imposed on the two smaller models. In the first step one only requires the three modes car, bus and walking to be distinct, while the second stage requires the alternative not to own a car to be distinct from owning a car. Direct estimation of the five alternative model is a special case of the two stage procedure. The two stage procedure allows one to calculate the degree of similarity σ amongst the conditional sets of modes to work. With $\sigma=0$ the alternatives walk given car and walk given no car are indeed distinct and the five alternative model is multinomial logit. Further the two stage procedure results in computational savings since there are fewer numbers of alternatives and parameters estimated at each stage.

At this stage it is worth commenting on why it was necessary to select a relatively complex estimation technique. Using ordinary least squares (OLS) is not suitable for such a probabilistic model for several reasons. Since the dependent variable is a probability it is bounded by 0 and 1 whereas OLS predictions could well lie beyond these bounds. A simple solution of regarding all predictions greater than 1 as 1 and those less than 0 as 0 generates bias. A more sophisticated approach would be to use OLS subject to the restriction that the dependent variable lie between 0 and 1. However the procedure requires non-linear estimation which is particularly difficult with the presence of hetroskedasticity. Further, if one is willing to use a non-linear estimation technique it is worthwhile to use a better statistical technique at the same time. OLS error terms are hetroskedastic in this model since observations where the probability is close to one-half have large variance whereas observations at the extremes of the distributions have small variance.

C. Econometric Properties of the Logit Model

As an aid to understanding the results in Chapter 4, this section interprets coefficient estimates, discusses some statistics used in the logit model, and derives elasticity expressions.

The variables used in the first step of the nested logit model all vary across the alternatives. By having only one coefficient for a variable, for instance waiting time, the restriction that one minute of waiting for a bus is as onerous as one minute of waiting for a rickshaw is implicitly imposed on the model. ($\partial V/\partial a_{ji} = \partial V/\partial a_{jk}$.) The interpretation of the coefficient in this case is straightforward. It is the disutility from an additional minute of waiting. (Recall that $V_{cn} = \beta' x_n + \alpha' y_c$.)

The value of one unit of an attribute is the marginal rate of substitution between the attribute and income. Therefore the value of one unit of an attribute j is $\partial V/\partial a_{ji}$ (the coefficient of the attribute term) divided by $\partial V/\partial P_i$ (the coefficient of the price term).

The derivation of elasticity expressions is important to this analysis. How does a 10% increase in the waiting time of a bus affect the demand for buses and minibuses? In this model, the change in demand of a mode can be interpreted as a change in the probability of choosing the mode (summed over all individuals[13]).

From (10),

(16) $Pr_{n|c} = f(V_{c1},\ldots,V_{cN})$[14]

Diffrentiating (16) with respect to x_m,

$$\partial Pr_{n|c}/\partial x_m = (\partial f/\partial V_{c1})(\partial V_{c1}/\partial x_m) + \ldots + (\partial f/\partial V_{cN})(\partial V_{cN}/\partial x_m)$$

Since x_m (eg. waiting time for a bus) does not enter the utility function V_{cj} for $j \neq m$,

(17) $$\begin{aligned} \partial Pr_{n|c}/\partial x_m &= (\partial f/\partial V_{cm})(\partial V_{cm}/\partial x_m) \\ &= Pr_{n|c}(1-Pr_{n|c})\beta_m \qquad \text{for } m = n \\ &= -\, Pr_{m|c}Pr_{n|c}\beta_m \qquad \text{for } m \neq n \end{aligned}$$

by diffrentiating (11) and (10) with respect to V_{cm} and x_m. Elasticities can be readily obtained from the above expressions by multiplying through by $x_m/Pr_{n|c}$ and summing over all individuals.

In the second step (top level of figure (i)) of the model, most of the explanatory variables (eg. household size) are ones that vary across households and not among mode ownership alternatives. The effect of these variables on utility cannot be the same for all alternatives ($\partial V/\partial a_{ji} \neq \partial V/\partial a_{jk}$ for some $i \neq k$).

Defining $V_c = \alpha' y_c + I_c$,

(18) $P_c = g(V_1,\ldots,V_C)$ from (14).

---

13 This implicitly assumes that all individuals make the same number of trips.

14 For convenience, when there is no ambiguity, the subscript c of N_c will be dropped.

Diffrentiating (18) with respect to y_j,

$$\partial P_c/\partial y_j = (\partial g/\partial V_1)(\partial V_1/\partial y_j) + \ldots + (\partial g/\partial V_C)(\partial V_C/\partial y_j)$$
$$= \alpha_{jc}(1-Pr_c)Pr_c - \sum_{k\neq c}\alpha_{jk}Pr_k Pr_c \qquad \ldots(19)$$

by diffrentiating (12) and (14). Multiplying the above expression by y_j/Pr_c the relevent elasticities are obtained.

Since the α_{jc}s cannot be uniquely determined (it only makes sense to speak of the effect of household size on the probability of owning a car <u>relative</u> to owning no modes), some normalization on the coefficients $\alpha_{j1},\ldots,\alpha_{jC}$ has to be used. The normalization used in this paper is $\alpha_{j3} = 0$. ie. All coefficients are compared to the alternative of owning no modes.

The log likelihood function is one of the best indicators as regards an improvement in the model. Two goodness-of-fit measures are based on it. One such measure is the likelihood ratio statistic:

$$-2[L(\beta_0) - L(\tilde{\beta})]$$

which, under the null hypothesis that all parameters equal zero, is asymptotically distributed as a chi squared variate with k degrees of freedom, where k is the number of estimated parameters. $L(\beta)$ is the log likelihood evaluated alternatively at $\tilde{\beta}$, the maximum likelihood estimate of the parameter and at β_0, a vector of zeroes. If the statistic is large it leads us to reject the null hypothesis.

Another goodness-of-fit statistic is the likelihood ratio index defined as:

$$\rho^2 = 1 - [L(\beta)/L(\beta_0)].$$

The index is analogous to the OLS multiple correlation coefficient.

Another useful statistic is the percentage of choices correctly predicted. An alternative is correctly predicted if the predicted probability of the chosen alternative is greater than that of any other alternative.

CHAPTER 3

DESCRIPTION OF THE KARACHI MODEL

A. The Survey

Four hundred households throughout Karachi were interviewed for the purpose of this study. Of these, 349 had usable information and 330 included households where at least one member of the household made a trip to work. Since missing data information was included in the subsequent tables, the number of trips and households may differ between tables. A description of the sampling methodology is given below:

In order to ensure enough variation in mode choice, it was important to have sufficient observations within various income categories. Accordingly, each homogeneous income area in Karachi was assigned to one of five income categories based on their median household income[15].

Similarly, it was considered important to have sufficient observations on households that live near the centre of the city as well as those that live at a distance. Therefore these homogeneous income areas were further split into three distance categories -- zero to three miles, three to five

---

15 Such a study had previously been carried out by a UNDP mission to the MPO (1972). In addition to income, the groups were homogeneous with respect to level of literacy, water and sewerage connections, and percentage of brick or concrete ('pucca') houses.

miles, and five or more miles from the center of the city. Certain areas were then discarded for special reasons such as for being a red light district or for having moved significantly from its income group since the UNDP study. To decrease the probability that one of the chosen areas was not a representative member of the cell, two areas were randomly selected from the list of areas in each cell. Since random sampling within these relatively large areas was infeasible, a sample of about 50 households within each of the areas was chosen by the author after inspection to ensure that the block of houses selected was not atypical for the area. Interviewers were then sent out to interview at least 13 households in each of the 30 areas selected.

The richness of the data comes from information not only on the trips made the day earlier by each individual of the household, but also on demographic characteristics of the household, income, hours worked, expenditure by various categories, assets, availability of public modes, present and purchase prices for owned modes, and maintenance expenditures on these modes. The questions on trips made included origin and destination, purpose, mode used, in-transit and waiting time, distance covered, number of persons in mode, cost (if public mode), and trip frequency. The questionnaire is appended (Appendix I).

The survey shows that over one-fifth of the trips in the stratified sample are work trips (Table 7). Not surpris-

TABLE 7

CROSS TABULATION OF PURPOSE BY MODE USED

PURPOSE	MODE								
	CAR	MBIKE	BIKE	TAXI	RICK	MINI	WALK	BUS	TOTAL
WORK	124	44	12	9	17	41	56	138	441
SCHOOL	24	8	3	2	1	3	19	83	143
SOCIAL	91	23	6	7	14	10	32	39	222
RECREATION	16	3	1	0	0	2	5	15	42
SHOPPING	26	6	1	2	4	3	4	3	49
PERSONAL B	21	10	1	4	8	6	4	20	74
EMPLOYER B	5	5	1	0	1	0	3	8	23
SERV PASNG	35	7	1	0	0	0	0	3	46
HOME	269	76	19	24	33	69	134	257	881
CHNG MODE	9	0	0	0	1	20	35	77	142
OTHER	2	0	0	0	0	2	5	4	13
TOTAL	672	182	45	48	79	156	297	647	2076

ingly for Karachi, social trips to visit friends or relatives account for over 10% of total trips or 18.6% of all non-home trips. The home category is not very revealing as the cross tabulation does not distinguish between coming home from work and coming home from some other destination. The other category includes trips made for religious, tutorial, or training purposes. Due to the manner in which the sample was selected and because households with cars tend to make more trips, there were about equal numbers of trips by the two principal modes -- car and bus. Although a good proportion of the sample included persons in the below Rs.1600/month income category who were most likely to own bicycles, relatively few bicycle trips and still fewer bicycle owners were found in the sample. This seems to support the hypothesis advanced earlier that bicycles are under utilized. Unfortunately, the paucity of bicycle owners also makes statistical analysis of bicycle ownership extremely unreliable.

Table 8-A gives a distribution of household income categories while Table 8-B gives a percentage distribution of trips made in each mode for various income categories. The car is the predominant mode for the high income groups, while bus, walking and minibus are the principle transport for low income classes.

TABLE 8-A

DISTRIBUTION OF HOUSEHOLD INCOME

HOUSEHOLD INCOME	NUMBER OF HOUSEHOLDS	PERCENT
Rs.0-799/mth	54	17.1
Rs.800-1599	70	22.2
Rs.1600-2999	73	23.2
Rs.3000-4999	65	20.6
Over Rs.5000	53	16.8

The income cutoff points were chosen so as to get approximately equal numbers of households in each category and to roughly correspond to apriori expectations of income levels in the selected areas.

Table 3 indicates that buses and minibuses are on the average available to about three-quarters of all households. (A public mode of transportation was considered available if

TABLE 8-B

PERCENTAGE OF TRIPS MADE IN EACH MODE BY INCOME GROUP

MODE	INCOME RS.0-799	800-1599	1600-2999	3000-4999	OVER 5000
CAR	0.5	3.9	15.3	37.9	65.7
MBIKE	1.0	5.2	12.2	12.8	7.2
BICYCLE	3.5	3.6	2.3	1.6	1.5
TAXI	0.0	2.5	1.9	2.4	3.3
RICKSHAW	2.0	7.7	3.7	3.5	2.1
MINIBUS	13.6	10.5	11.6	4.7	2.8
WALKING	30.6	19.6	16.1	11.0	5.6
BUS	48.7	47.1	37.0	26.1	11.8

the individual answered affirmatively to the question 'Are the following modes readily available in your area?') The proportion is somewhat lower for the low and high income groups. However the situation is more serious for low income groups since they have no alternative modes of transportation. In other words, there is likely to be a frustrated demand for buses in the low income areas. The relatively high availability of minibuses in the low income areas is probably due to the unavailability of buses in that area.

Another feature of the Karachi transport system is the high number of persons that is transported in each trip. It is interesting to note, for example, that the frequency of trips with two persons on a motorcycle is almost as high as that of one person while there were more trips with two persons to a car than with one person to a car. The distribu-

TABLE 9

BUS AND MINIBUS AVAILABILITY BY INCOME GROUP
(PERCENTAGES)

INCOME GROUP (Rs)	AVAILABILITY OF BUSES	AVAILABILITY OF MINIBUSES
0-799	66.7	70.4
800-1599	74.3	72.9
1600-2999	89.0	79.5
3000-4999	73.9	69.2
OVER 5000	67.9	66.0
TOTAL	75.2	72.1

tion of number of persons in a minibus (not shown) for work trips reflects the scarcity of adequate public transportation in Karachi. Of the total of 39 work trips by minibus for which data on number of persons in vehicle existed, 35 trips had more than the seating capacity (14 persons). Nine persons responded that there were 20 persons in the vehicle.

TABLE 10

PERCENTAGE FREQUENCY OF NUMBER OF PERSONS IN EACH MODE

# OF PERSONS	MODE				
	CAR	MBIKE	BICYCLE	TAXI	RICKSHAW
ONE	29.2	55.1	70.7	25.0	29.5
TWO	31.8	44.9	24.4	27.1	57.7
THREE	13.7	0.0	4.9	10.4	9.0
FOUR	10.9	0.0	0.0	20.8	2.6
FIVE	3.6	0.0	0.0	16.7	0.0
SIX	5.3	0.0	0.0	0.0	1.3
> SIX	5.6	0.0	0.0	0.0	0.0

In order to observe the influence of non-monetary factors on travel demand behavior, an attitudinal survey was carried out which attempted to quantify individual preferences for comfort, danger, physical strain, privacy, and status. It is interesting to note some factors that emerged during the course of pretesting. It became apparent that interviewees could not understand an abstract concept such as 'willingness to pay' for additional comfort, etc. Therefore, the questions were rephrased in terms of more concrete situations of the sort 'how much would you be willing to pay a seated person to obtain his seat' or 'how much would someone have to pay you to give up your seat?'. There was violent opposition to these sorts of questions on grounds of 'what kind of a person do you think I am anyway?'. When the questions were reworded in the form of 'how much extra would you be willing to pay to be guaranteed a seat on the bus', they felt that the survey was a ploy to raise bus fares without a commensurate increase in service. Finally it was decided to pose questions based on hypothetical situations where an individual had to make a decision of trading minutes of leisure time with obtaining a seat on a minibus. The main conclusion to be drawn from the exercise was that the answers straddled the entire spectrum of responses. People appear to have widely dispersed preferences on travel modes.

B. The Alternatives and Variables

Although it would have been desirable to consider the C choices of mode ownership to be all possible combinations of buying a car, motorcycle or bicycle, this was not possible due to insufficient data. Because there were very few people in the sample who owned both a car and a motorcycle, these were dropped from the sample. Similarly, since there were only a few people who both owned a bicycle and rode it to work, it was decided to treat the bicycle like any public mode. Either it was available or not -- the consumer did not have the option to buy one. The bicycle was considered available if either the individual owned one, or rode to work in one. Hence the mode ownership decision was reduced to three alternatives -- own a car, own a motorcycle, or own no mode.

The N modes to work for a consumer include car, motorcycle, bicycle, taxi, motor rickshaw, minibus, walking and bus. The total number of choices being considered is therefore 24. However, in order to exclude the possibility of a person not owning a car or motorcycle but going to work in one, the choice set can be reduced to 20. It was assumed that a car is available to an individual for his work trip if the household owns a car but that a motorcycle or bicycle is available to the individual only if the individual is himself the owner. The distinction was necessary because many cars, which for all purposes are personal cars, are owned by the firm for tax purposes. Also it is likely that the person going on the work trip has priority on the car. On the other hand it is not realistic to expect that the earner will take his college going son's motorcycle to work. The choice set may be further reduced for some individuals as certain public modes may not be available in certain areas.

There are three types of variables in the model -- those that vary with mode choice to work such as in-transit time, those that vary with mode ownership such as depreciation cost, and those that vary with individuals such as income. Data are only observed for chosen alternatives. Data on attributes of alternate choices have to be generated from these observed data.

The dependent variable for the modal split analysis or first step of the estimation process, is the probability of the consumer choosing a certain mode given the availability of the mode. For the choice of ownership of mode, the dependent variable is the probability of owning a car, motorcycle, or no modes.

A description of the way by which the independent variables (x_i) for the modal split analysis (bottom level of figure (i)) were generated is given below. The description is followed by a table which gives the means of the variable.

(i) Value of waiting time (WWAIT): The traditional way to treat the value of waiting time, this variable equals the waiting time times the wage rate. The wage rate is defined in rupees per minute and the waiting time in minutes. The waiting time for a car, motorcycle, bicycle or walking was assumed to be zero while that for modes not selected was taken to be the average waiting time in minutes for each mode. This is likely to be an underestimate because of a sample selectivity problem -- the choice not to use a bus may be motivated by the excessive waiting time for buses in the consumer's area. For buses and minibuses, since there were enough observations, it was possible to take the average time in the three distance categories and so reduce the sample selectivity problem. It was not possible to take averages by each geographical region due to the many empty cells in a cross tabulation of area by mode to work. In addition, the fact that actual values are used for some alternatives while imputed values are used for others causes a measurement-like error. However, this is not likely to be serious, and in the case of waiting time at least, cannot be easily corrected.

(ii) Value of in-transit time (WTRAN): This variable is the product of in-transit time and the wage rate. The actual in-transit time in minutes was used when the alternative was selected.

In order to generate the in-transit time for the alternatives not selected, a simple regression of distance (in tenths of a mile) on in-transit time was carried out for work trips by each mode. It was necessary to suppress the constant term as trips of zero distance are expected to take zero minutes. Including the constant causes short trips to have large percentage errors. As can be seen by the results of the regressions of Table 11, the coefficient of distance was significant at the 1% level in each case. These coefficients were then used to generate the in-transit time.

TABLE 11
REGRESSION COEFFICIENTS FOR GENERATION OF IMPUTED VARIABLES

DEPENDENT VARIABLE	MODE	INDEPENDENT VARIABLES DISTANCE	T-STAT	CONSTANT	T-STAT
INTRAN	car	.292	19.63		
	mbike	.438	16.72		
	bike	.595	8.79		
	taxi	.437	6.72		
	rickshaw	.537	7.32		
	minibus	.429	11.26		
	walking	1.67	12.58		
	bus	.490	26.02		
COST	rickshaw	.845	3.63		
	minibus	.040	5.89	8.886	16.64
	bus	.044	10.39	2.912	10.93

(iii) Marginal monetary cost (COST): This refers to the fare if the mode is a public mode. For cars and motorcycles it is the petrol cost of the trip divided by the number of persons (excluding the chauffeur) in the car. This is not a bad assumption since parking is free virtually everywhere and the addition to depreciation and maintenance cost caused by the work trip is likely to be negligible as they tend to be related to time rather than mileage.

To generate data on per mile fares of public modes when the alternative was not selected, it was decided to resort to regression analysis rather than use official fares. The results are shown in Table 11. Not surprisingly, the regression of distance on rickshaw yielded a coefficient that was 20% higher than the official fare of Rs.0.70 per mile. Observations on taxi fares to work were too few to give good results and so a premium of 20% over the official fare was assumed. Bus and minibus coefficients were similarly generated with all coefficients being significant at the 1% level. Data on the cost of car trip to work when the car was owned was based on the interviewee's estimate of the mileage per gallon. When two or more modes were owned the information on the first was used.

(iv) Dummy for long walking trips (DWALK): Since walking is likely to be more onerous than other modes, a dummy for walking is constructed as a function of distance. It equals zero unless the trip is longer than one mile in which case it is one. Alternate specifications of DWALK (proportional to and exponential with distance) were also tried but were not as satisfactory.

(v) Dummy for car use (DHEAD): While everyone in the household is assumed to have a car available for the trip to work if anyone in the household has a car, the head of household is more likely to get the car. DHEAD, which is one when the car is available and the individual is the head of household, and zero otherwise, captures this effect.

(vi) Opportunity costs of time for near and distant households (NEARWW,FARWW,NEARWR,FARWR): If individuals have different values of time, then other things being equal, the ones with lower values would tend to locate further from the center of city. These variables allow one to test for this. FARWW and FARWR equal WWAIT and WTRAN, respectively, if the individual is located more than five miles from the center of city, and zero otherwise. Conversely, NEARWW and FARWR equal WWAIT and WTRAN when the individual lives within five miles of the center, and zero otherwise.

TABLE 12

MEANS OF INDEPENDENT VARIABLES -- MODAL SPLIT

VARIABLE	MODE							
	CAR	MBIK	BIKE	TAXI	RICK	MINI	WALK	BUS
WWAIT(Rs)	0	0	0	2.42	3.03	2.14	0	0.49
WTRAN(Rs)	6.83	4.62	2.16	4.36	4.33	5.04	18.6	5.50
COST(Rs)	2.02	0.80	0	5.67	3.83	1.08	0	0.49
DWALK	0	0	0	0	0	0	0.81	0
DHEAD	0.68	0	0	0	0	0	0	0
FARWW(Rs)	0	0	0	0.57	0.71	0.73	0	0.57
NEARWW(Rs)	0	0	0	1.85	2.32	1.41	0	1.17
FARWR(Rs)	1.21	1.14	1.05	1.31	1.30	1.41	5.10	1.30
NEARWR(Rs)	5.61	3.48	1.11	3.05	3.03	3.62	13.5	4.19

The variables (y_c) used in the mode ownership analysis are described below:

(i) Aggregate utility from the trip to work or inclusive value (INCLUS): For each individual, this variable reflects the aggregate utility from the trip to work in the three mode ownership categories. The definition of inclusive value is given on page 30.

(ii) Mode expenditures as function of income (EXPINC): The sum of maintenance expenditures and depreciation costs on a car or motorcycle is taken to be the cost of owning a mode. The actual values of yearly maintenance cost in thousands of rupees obtained from detailed questions on mode servicing, tuning, spare parts, labor, body work, tires, batteries, insurance and overhauling were used when the alternative was owned. Depreciation costs were calculated by taking the interviewee's estimate of the purchase value and present value of the vehicle discounted for inflation, and dividing by the number of years the vehicle had been in his possession. The actual values of average yearly depreciation in real thousands of rupees were used when available. Imputed values for the expenditure variable were simply taken to be the average values of maintenance and depreciation costs. In order to account for the decreasing marginal utility of money, the expenditure variable was divided by total household income from both earned and unearned sources in hundreds of rupees per month. The alternative way to account for the diminishing utility of income was to consider the logarithm of income as a separate variable. This approach proved not to be as satisfactory.

(iii) Dummies for living close to the center of city (NRCAR,NRBIKE): These variables test the hypothesis that individuals living close to the center of city obtain a lower utility from owning a car or motorcycle. NRCAR equals one if the alternative is car and the individual lives within three miles of the center, and zero otherwise. Similarly, NRBIKE equals one if the alternative is motorcycle and the individual lives within three miles of the center, and zero otherwise.

(iv) Dummies for being a nuclear family (NUKCAR and NUKBIK): The construction of these variables allows one to test the hypothesis that nuclear familiar families are less likely to own a car. NUKCAR equals one if the family is composed of only the head of household, spouse or children and the alternative is car, and zero otherwise. NUKBIK was constructed in a similar manner for the motorcycle alternative.

(v) Number of people in the household (NMEMCR and NMEMBK): NMEMCR equals the number of members in the household over five years of age if the alternative is car, and zero otherwise. Similarly, NMEMBK equals the number of members in the household if the alternative is motorcycle, and zero otherwise. The signs of these variables are expected to be negative because of the hypothesis that larger households would have less money left over to buy a car or motorcycle (assuming that the nuclear family dummies adequately capture the effect of extended families being able to use the mode more efficiently).

TABLE 13

MEANS OF INDEPENDENT VARIABLES -- MODE OWNERSHIP

VARIABLE	MODE		
	OWN CAR	OWN MBIKE	OWN NO MODE
INCLUS	-.266	-.111	-1.29
EXPINC	.701	.073	0
NRCAR	.419	0	0
NRBIKE	0	.419	0
NUKCAR	.451	0	0
NUKBIK	0	.451	0
NMEMCR	6.67	0	0
NMEMBK	0	6.67	0

CHAPTER 4

RESULTS

A. Modal Split Analysis

Several specifications of the model given by equation (13) were estimated. The estimation was carried out using a statistical package QUAIL, developed by Wills, Glanville, and McFadden at the University of California.

The coefficient estimates and other relevent statistics for four alternate specifications of the first step of the joint choice model are given in Table 14. The restriction that the value of time is proportional to the wage rate is implicitly imposed on each of the models. Model A considers only the time and cost attributes of each mode. In order to account for the additional disutility of walking long distances, Model B introduces a dummy DWALK[16]. In addition, Model B also uses a dummy DHEAD to test for the higher probability of the head of household having access to the family car. Model C employs two alternative specific dummies DMINI and DBUS to capture some of the negative attributes of non-personal modes. Finally, in order to test the hypothesis that people who locate further from the center of city have lower values of time, the variables FARWW, NEARWW, FARWR and NEARWR replace WWAIT and WTRAN of Model B.

---

16 See Chapter 3 for a detailed description of the variables used in the models.

TABLE 14

COEFFICIENT ESTIMATES -- MODAL SPLIT

Variable	Model A	Model B	Model C	Model D
WWAIT coeff	-1.163	-1.044	-.8026	
t-stat	-9.835	-7.341	-5.590	
WTRAN coeff	-.4994	-.1293	-.1034	
t-stat	-9.087	-6.184	-4.489	
COST coeff	-.3784	-.5763	-.6824	-.5200
t-stat	-5.783	-7.167	-7.398	-6.511
DWALK coeff		-3.729	-4.358	-4.322
t-stat		-8.234	-8.676	-7.415
DHEAD coeff		1.643	1.629	1.591
t-stat		3.016	2.946	2.901
DMINI coeff			-1.356	
t-stat			-4.918	
DBUS coeff			-.5540	
t-stat			-2.325	
FARWW coeff				-.7055
t-stat				-3.926
NEARWW coeff				-1.395
t-stat				-6.662
FARWR coeff				-.0955
t-stat				-1.690
NEARWR coeff				-.0445
t-stat				-.7977
$L(\beta_0)$	-507.6	-507.6	-507.6	-507.6
$L(\beta)$	-314.8	-253.1	-238.6	-247.7
Like'd ratio stat	385.7	509.1	538.1	519.9
Like'd ratio index	.3799	.5014	.5300	.5121
% predicted correct	70.22	79.49	81.46	79.49
degrees of freedom	1194	1192	1190	1190

With the exception of NEARWR and FARWR, all coefficients are significant at the 1% level. The likelihood ratio statistic which is distributed as chi square, leads one to reject the hypothesis that all coefficients are zero. Models B, C and D all predict about equally well, with Model C yielding the best fit as reflected in its higher likelihood ratio index. Of the observed trips by various modes, Model C correctly predicts 81.5%[17].

Since these coefficients are parameter estimates of a linear utility function, their ratio is the marginal rate of substitution. The ratio of the coefficients of WWAIT to WTRAN in Model A of 2.3 implies that the marginal disutility of waiting time is 2.3 times that of in-transit time.

In Models B and C, the variables WTRAN and DWALK are correlated since walking is the slowest mode. I suspect therefore, that the resulting collinearity attributes some of the disutility of WTRAN to DWALK leading to a low absolute value for WTRAN. On the other hand, since walking does not involve any cost or waiting time, the uncorrected correlation coefficient between COST and DWALK, and between WWAIT and DWALK, are zero. Thus, although Models B and C may not provide us with a good estimates of the coefficients of DWALK or the in-transit time variables, the other coefficients are likely to be reliable. The models have high prediction which make them useful in subsequent simulations. Note also that Models B and C are more general versions of

---

17 If all trips were equally likely, a random method would be expected to correctly predict 25.4%.

Model A, and the null hypothesis that the coefficients of DWALK and DHEAD are zero is rejected at the 1% level.

As explained in Chapter 2, the marginal rate of substitution between an attribute (eg. WWAIT) and income is the ratio of the coefficient of the attribute to the coefficient of price (COST). Therefore, the value of WWAIT is 3.07 (1.163/.3784) in Model A, and hence, the value of waiting time is 3.07 times the wage rate. (Recall that WWAIT equals the wage times the waiting time). Similarly, the value of in-transit time is 1.32 times the wage rate. This is higher than expected and could be due to the absence of some variables such as comfort and convenience which are negatively correlated with waiting time and in-transit time, and strain and danger which are positively correlated with the time variables[19].

The introduction of DWALK in Model B partially compensates for the above problem, decreasing the disutility of waiting time to 2.38 times the wage rate. Adding the alternative specific dummies for buses and minibuses (Model C) reduces the value of waiting time to 1.2 times the wage rate. Other alternate specific dummies were also tried but did not predict any better. It was considered best to stay with the simpler formulation since it was not clear exactly

---

19 Note that in this joint choice model the use of a dummy for car to capture the effects of comfort and convenience results in being a dummy for car ownership since non-car owners do not have the option to take a car.

which attributes (comfort, convenience, danger) these alternate specific dummies were picking up and how they were correlated with the other included variables.

In model D, the value of waiting time for people who live close to the center of city is revealed to be 2.68 times the wage, while for those who live far it is 1.36 times the wage. While coefficients for in-transit time are not significant for near and distant households, an appropriately constructed chi square test shows that the hypothesis of the coefficients of both NEARWR and FARWR being simultaneously zero is rejected at the 1% level. Thus the model finds that individuals with lower values of time tend to live further from the center of town.

In a competitive framework, if the only value of time is as a resource and there is no additional disutility from commuting time, individuals would tend to locate so that their marginal valuation of time would be equal to their wage (the coefficient of WWAIT would equal the coefficient of COST). However those living closer to town could have a higher value of time if, for instance, they could work fewer hours while those further from town could not. I suspect that the coefficients of WWAIT and COST in this model are not equal because individuals have a disutility of time as a commodity -- some individuals may hate to spend 15 minutes waiting for a bus while others earning the same wage are almost indifferent. The latter group would tend to locate further from town giving us the observed result. The other reason for not observing the competitive behavior result is that since the housing market in Karachi is notoriously imperfect, individuals no longer face an unconstrained optimization.

The results of this study are surprisingly similar to the study by Train (1980) which applied a very similar model to data from San Francisco residents. While the value of time was lower in Karachi as expected, the difference was not large. In Train's study, the value of waiting time[20] was revealed to be 3.27 times the wage rate while most specifications of the Karachi model found the number to lie between 1.2 and 2.4. Unlike Train's findings, this study did not reveal the value of in-transit time to be different for private and public modes. This result of the value of time being different depending on the proximity to the center of town was also borne out by Train. More specifically, Train rejected the hypothesis that urban and suburban dwellers have the same value of in-transit and walk time.

Tables 15-A and 15-B show a cross tabulation of observed versus predicted alternatives for Models A and B, respectively. A trip is predicted to be by a certain mode if the

----

20 Actually, Train's estimate was for walk time. In the Karachi sample, only the difference between the time the person left the house and the time he embarked on the mode was available. This number, which includes walk time, was called waiting time. Hence the two estimates are not strictly comparable.

TABLE 15-A

PREDICTION SUCCESS TABLE FOR FIRST LEVEL OF MODEL A

OBSERVED ALTERNATIVES	PREDICTED ALTERNATIVES								
	CAR	MBIK	BIKE	TAXI	RICK	MINI	WALK	BUS	TOTAL
CAR	97	0	0	0	0	0	2	1	100
MBIK	0	40	0	0	0	0	0	0	40
BIKE	0	0	10	0	0	0	2	0	12
TAXI	0	0	0	0	0	0	2	5	7
RICK	3	0	0	0	1	1	0	7	12
MINI	2	0	0	0	0	12	10	9	33
WALK	3	0	0	0	0	0	39	3	45
BUS	4	0	0	0	0	19	33	51	107
PB SUM	89.8	27.6	5.6	12.4	16.3	55.1	72.2	76.9	356

predicted probability of that mode is greater than that of each of the other modes. Correctly predicted trips occur along the diagonal. In Model A, most of the incorrect predictions occured among the minibus, walking, and bus categories (Table 15-A). Walking trips were overpredicted since there was no variable to capture the strain of walking long distances. The introduction of DWALK and DHEAD in Model B improved the predictions considerably (Table 15-B).

The last row of Tables 15-A and 15-B probably gives the best measure of the predictive ability of the model. The probability sum is the sum over all individuals of the predicted probabilities for each mode. The numbers in this row should be compared with the observed behavior of the last column.

TABLE 15-B

PREDICTION SUCCESS TABLE FOR FIRST LEVEL OF MODEL B

OBSERVED ALTERNATIVES	PREDICTED ALTERNATIVES								
	CAR	MBIK	BIKE	TAXI	RICK	MINI	WALK	BUS	TOTAL
CAR	98	0	0	0	0	0	1	1	100
MBIK	0	35	0	0	0	0	4	1	40
BIKE	0	0	10	0	0	0	2	0	12
TAXI	0	0	0	0	1	0	1	5	7
RICK	3	0	0	0	1	1	0	7	12
MINI	2	0	0	0	0	15	1	15	33
WALK	1	0	0	0	0	2	38	4	45
BUS	2	0	2	0	0	9	8	86	107
PB SUM	97.0	28.5	7.56	9.85	15.6	59.1	39.3	99.1	356

While the predicted probability of a taxi was never greater than those of all other modes, the weighted probability sum for the taxi alternative (9.85) was actually greater than the observed number of trips (7). The Prediction Success Tables for Models C and D were very similar to that of Model B.

In order to obtain demand elasticities for the modes with respect to the attributes it was decided to simulate the results rather than resort to equation (17) -- elasticities obtained from equation (17) are very sensitive to where they are evaluated. To evaluate the elasticity at the mean makes little sense when there is a wide variation in values. One could evaluate at the observed values for each individual and take the mean of the sum of individual elasticities. This would be the average point elasticity. For the purpose of this study which proposes studying the effect of discrete changes in the attributes, it makes more sense to evaluate the <u>arc</u> elasticity in the relevent range. The simulation of the model with the new values of the attribute evaluates the arc elasticity.

While Model C has the best fit, it is not used for simulating elasticities since it is not clear what factors are incorporated in the alternate specific dummies, and whether the dummies would be sensitive to the proposed changes. Therefore, it was decided to employ Model B which, with fewer variables, predicted almost as well as Model C.

The elasticities (Table 16) are based on a 10% change in the independent variables. For example, to obtain the demand elasticity of waiting time for a bus (WAIT(BUS)), the waiting time for each trip in the bus alternative was decreased by 10%. The new pattern of predicted demand (probability sum) was compared to the predicted demand before the change (last row of Table 15-B). The difference in the probability sums (divided by ten) yields the relevent elasticities. For convenience, only the absolute values of the elasticities are given. All elasticities have the expected sign.

Elasticities with respect to waiting time turn out to be much higher than those with respect to cost. All cross elasticities with respect to cost are less than .12 while all waiting time cross elasticities are more than .12.

Being fairly close substitutes, the cross elasticities between minibuses and buses were higher than between other modes.

The second to last row shows the effect of changing the waiting time of both buses and minibuses simultaneously. Decreasing waiting time for buses and minibuses has a significant effect on all but the car alternative. However, changing the cost of buses and minibuses simultaneously (last row) has a significant impact on car demand.

TABLE 16

ABSOLUTE VALUES OF SIMULATED ELASTICITIES
FOR SELECT VARIABLES -- FIRST STEP

	CAR	MBIK	BIKE	TAXI	RICK	MINI	WALK	BUS
WAIT(BUS)	.057	.161	.125	.231	.208	.297	.144	.401
WAIT(MINI)	.041	.079	.100	.369	.171	.673	.131	.215
COST(BUS)	.010	.036	.042	.061	.059	.103	.041	.117
COST(MINI)	.014	.032	.042	.117	.089	.362	.065	.134
COST(CAR)	.100	.006	.037	.047	.051	.046	.035	.039
COST(MBIK)	.001	.110	.000	.006	.006	.013	.004	.020
WAIT(MINI,BUS)	.096	.236	.222	.583	.369	.359	.281	.187
COST(MINI,BUS)	.243	.069	.110	.179	.167	.261	.107	.017

The implication of the higher waiting time elasticities suggests that more gains are likely to come as a result of decreasing waiting time for public modes (adding more minibuses or buses) than from making public transport cheaper. While changing waiting time for a bus or minibus has little impact on car demand, changing the cost of a bus or minibus has some impact. The costs and benefits to carrying out these recommendations is given in the next chapter.

TABLE 17

PERCENTAGE CHANGE IN DEMAND IF PUBLIC TRANSIT WERE AVAILABLE TO ALL

MODE	MODEL B			MODEL C		
	BUS	MINI	BOTH	BUS	MINI	BOTH
CAR	-3.45	-2.40	-4.77	-4.49	-3.24	-6.32
MBIK	-3.93	-4.56	-7.43	-4.14	-4.88	-7.76
BIKE	-1.70	-0.06	-1.76	-1.48	-0.01	-1.49
TAXI	-9.49	-5.70	-12.84	-9.65	-6.63	-14.49
RICK	-16.41	-11.16	-21.58	-16.03	-11.56	-21.78
MINI	-10.27	30.10	16.96	-9.45	32.44	19.45
WALK	-8.98	-5.81	-12.76	-9.15	-6.40	-13.50
BUS	17.83	-8.97	6.57	18.98	-9.71	7.46

Table 9 suggests that there are several households who do not use the bus or minibus because of its unavailability. In order to test for this, Model B was simulated under the assumption that the bus was available to all households. The resulting probability sum was compared with the original probability sum (last row of Table 15-B) where a person could only take a bus when it was available. The results (Table 17) suggest that in our sample of 356 trips, there is a 17.8% frustrated demand for buses or a 30.1% frustrated demand for minibuses predicted by Model B. If both minibuses and buses are available to all residents, the model predicts a 17% increase in minibus use and a 6.6% increase in bus use. Surprisingly, the increase in demand was distributed quite uniformly across the five income groups and the three distance categories.

To test the robustness of the result, Model C was also simulated under the same conditions. The results (Table 17) were similar to Model B, thus strengthening the case for increasing bus and minibus service.

B. Mode Ownership Analysis

The second step of the analysis is a multinomial logit analysis of the decision to buy a car, motorcycle, or no mode. One of the independent variables is inclusive value (INCLUS) which is the aggregate utility from the trip to work given that the individual owns a car, motorcycle, or no mode respectively. It is this variable which provides the link with the decision to choose a certain mode to work. As pointed out earlier (Chapter 2), the joint choice model is valid only if the coefficient of inclusive value lies between 0 and 1.

In order to test for the sensitivity of the coefficients, the model was estimated for two specifications of the first step, Models B and D (Table 18). All goodness of fit statistics support the model structure. In each case the coefficient of inclusive value lay between 0 and 1 indicating that the decision to choose a mode to work and the decision to buy a mode are indeed made simultaneously.

Since the coefficient of inclusive value is different from 1 ($\sigma \neq 0$), it suggests that the structure of the joint

TABLE 18

COEFFICIENT ESTIMATES -- MODE OWNERSHIP

VARIABLE		MODEL B	MODEL D	MODEL Z
INCLUS	coeff	.5194	.6521	
	t-stat	4.985	5.097	
NRCAR	coeff	-1.407	-1.177	-.9175
	t-stat	-3.232	-2.777	-2.546
NRBIKE	coeff	-.7635	-.5346	-.4184
	t-stat	-1.601	-1.141	-1.104
NUKCAR	coeff	-.3237	-3259	-.2669
	t-stat	-.8085	-.8106	-.7808
NUKBIK	coeff	-1.662	-1.725	-1.617
	t-stat	-3.561	-3.683	-3.551
EXPINC	coeff	-3.027	-3.035	-2.798
	t-stat	-4.473	-4.423	-5.052
NMEMCR	coeff	-.0523	-.0714	.0141
	t-stat	-1.311	-1.732	.4309
NMEMBK	coeff	-.2738	-.2916	-.2036
	t-stat	-6.227	-6.484	-5.305
$L(\beta_0)$		-338.4	-338.4	-369.1
$L(\hat{\beta})$		-163.9	-162.7	-202.5
Like'd ratio stat		349.0	351.3	333.3
Lik'd ratio index		.5146	.5192	.4515
% predicted correct		84.4	84.1	77.4
Degrees of freedom		608	608	665

choice model is not multinomial logit. The degree of dependence (σ) between the error terms of the model is .48 in Model B and .35 in Model D. Since the coefficient of inclusive value is not zero, estimation of the mode ownership decision without the inclusive value variable would have yielded biased coefficients. In order to see the degree of bias, the second step of the model was reestimated without the inclusive value term. The results (Model Z) show that while all coefficients are biased upwards, the magnitude of the bias is small. Predicted probability shares from Model Z were also similar to those from Model B.

The mode ownership analysis reveals that along with the costs of owning a mode, household location and demographic features play an important role. The negative coefficients for NRCAR and NRBIKE indicate that a person who lives within 3 miles of the city center derives less utility from owning a car or motorcycle than a person who lives further than 3 miles. The hypothesis that nuclear families are less likely to buy a car or motorcycle is supported by the negative coefficients of NUKCAR and NUKBIK. One of the most robust, the coefficient of EXPINC indicates that the disutility of expenditures on a car or motorcycle is a significant factor in the decision to buy a mode. The negative coefficients of NMEMCR and NMEMBK suggest that larger families have less left over from their income to afford a car or motorcycle.

The prediction success table for Model B (Table 19) shows that while only one motorcycle owner was correctly predicted, the predicted probability sum was not very far off the mark. Because of the structure of the logit model, the result of a relatively infrequently chosen alternative seldom being 'correctly' predicted is not uncommon. The success table for Model D (not shown) was quite similar to Model B.

TABLE 19

PREDICTION SUCCESS TABLE FOR SECOND LEVEL

OBSERVED ALTERNATIVES	PREDICTED ALTERNATIVES			
	OWN CAR	OWN MBIKE	OWN NO MODE	TOTAL
OWN CAR	22	2	20	44
OWN MBIKE	0	1	20	21
OWN NO MODE	5	1	237	243
PB SUM	43.6	28.6	235.8	308

TABLE 20

SIMULATED ELASTICITIES FOR SELECT VARIABLES -- SECOND STEP

	OWN CAR	OWN MBIKE	OWN NO MODE
HHSIZE	-0.05	-1.11	0.14
INCOME	0.68	-0.02	-0.12
EXPCAR	-0.62	0.16	0.10
EXPMBIK	0.01	-0.15	0.02

Elasticities of mode ownership with respect to household size, household income, and expenditures on cars and motorcycles were simulated using the coefficients of Model B. The results (Table 20) suggest that income elasticity of demand for car ownership is high while that for motorcycle ownership is low. Similarly, an increase in depreciation and maintenance expenditures affects car ownership significantly but barely affects motorcycle ownership. The size of the family does not affect car ownership much but has great impact on motorcycle ownership.

CHAPTER 5

POLICY ANALYSIS AND CONCLUSIONS

A. Policy Analysis of Expanding Bus Service

In interviews, both consumers and transport authorities voiced the need for expanding bus service. There is much evidence which suggests a shortage of bus service -- over-crowded buses, a relatively high elasticity of demand for buses with respect to waiting time, a high value of waiting time, the fact that many people in poor areas do not have a bus available to them, and simulations of the model which reveal a frustrated demand for buses at current fares and frequencies. Some obvious recommendations to improve bus service include reducing the turnaround time of buses in the workshop and allocating routes more efficiently by means of a new origin and destination survey. However, given the present state of efficiency, would a scheme to increase the number of buses be cost effective?

This section attempts to answer the above question by conducting a cost-benefit analysis for a project which calls for increasing the number of buses in Karachi by 10%. Due to a paucity of data on short term costs and benefits, only long term steady-state streams of costs and benefits will be compared, rather than undertake a traditional cost-benefit analysis in a time framework. The exercise shows how one might be able to address the above question using a small sample and limited cost data.

The major benefit to consumers from an increase in the number of buses is the savings from decreased waiting time for a bus. Here it is assumed that buses are allocated to routes in proportion to their frequency. Hence, a 10% increase in buses results in a 10% decrease in waiting time along each route. Since the long waiting times for trips to work often occur because buses are too crowded to board, the 10% increase in bus service may reduce waiting time for a bus during peak hours by more than 10%. Note also that the 10% figure implicitly assumes that the same proportion of the additional buses will be off the road for repairs.

The actual gains will be greater if buses are allocated to routes where they are most needed. Additional benefits include an increase in comfort and, in the long run, decreased congestion as people switch from other modes to buses[21]. Because of the difficulty in measuring the latter two forms of benefits, it was decided to use only the gain from decreased waiting time.

The benefit to a person from the decreased waiting time clearly is zero if he never takes the bus, and equals the

---

21 For the same road space, buses carry passengers more efficiently. Since the introduction of buses would typically affect travel times in all modes, it is not clear what the end result will be. However, it is likely that the first order effect of buses being more efficient in carrying passengers will outweigh any second order effects.

value of his waiting time if he always takes the bus. What if the model predicts that a person takes the bus with probability one-half? The logical way to evaluate his gain from the decreased waiting time is to use one-half the value of his waiting time. This approach is followed here.

The benefit thus calculated is an underestimate since the individual was not allowed to reoptimize with the new magnitude of waiting time for the bus. With decreased waiting time for a bus, the bus will now be predicted with greater probability. Appendix II describes a method of evaluating the benefit which utilizes the new predicted probabilities. While this is closer to a general equilibrium approach, a better approach would take into account the change in travel times for all modes as a result of the increased number of buses. Since this was not possible and since the expression from Appendix II is unwieldy and difficult to evaluate, it was decided to stay with the simpler computational method.

Using this method and parameter estimates from Model B, the rupee benefits (weighted by initial probabilities) were calculated for each work trip, and the sample sum for the five income group categories was obtained (Table 21). A figure for total trips to work in 1971 was obtained from the Master Plan survey[22]. Under the assumption that trips to work are proportional to population and based on income dis-

---

22 MPO (1974).

tribution data and population growth to 1979, estimates for the total number of trips to work in 1979 were obtained for each income group. The rupee benefit per trip for each income group was multiplied by the total trips made per day by each income group, to obtain the total rupee benefit to consumers. This figure was multiplied by 25 (Karachi has a 6 day work week) to obtain the total monthly benefit to consumers of Rs 3.2 million.

TABLE 21

DAILY GAIN TO CONSUMERS CAUSED BY DECREASING WAITING TIME FOR A BUS BY 10%

	INCOME GROUP					
	I	II	III	IV	V	TOTAL
Sample gain (Rs)	1.132	3.316	4.984	3.363	2.633	15.43
Trips in sample	54	70	73	65	53	315
Gain/trip (Rs)	.0210	.0474	.0683	.0517	.0497	.0489
Tot trips(000/day)	604	1618	293	253	132	2900
Total gain(Rs/day)	12950	76650	20000	13090	6560	129250

The above figure only reflects the gains from trips to work. There will be additional gains from non-work trips. Since the additional buses would be used primarily during peak hours, and since estimates for the value of time for non-work trips were not available, only gains for trips to work have been calculated.

Detailed operating cost figures for a bus were not available from the public sector. In a publication of the Karachi Bus Owners' Association dated December 31, 1978, a breakdown of operating expenditures (excluding depreciation) for an 8 year old bus were estimated to be Rs 12,855. Strangely enough the same publication describes the life of a bus as 5 years. Since the primary purpose of the publication was to make a case for increasing bus fares by 60%, the costs are likely to be overestimated. To place an upper bound on total costs, the average cost of depreciation (assuming a bus life of 10 years) was added to the high operating cost of an 8 year old bus. This yielded a total cost figure of Rs. 15,000 per bus per month.

The other source on bus operating costs was obtained from a study by a consulting firm (Esesjay (1975)) which conducted a financial analysis of expanding bus service in Karachi and other districts of Sind. The Karachi project called for the public sector to increase their bus holdings by about 1200, of which 1000 would be on the road. The project, to be started in 1975, was to have by 1979 an average monthly expenditure (including depreciation) per bus of 8,400 in 1975 rupees or 12,200 in 1979 rupees.

Based on 1760 registered buses in 1979, this implies adding 176 buses at a total monthly expenditure of Rs 2.1 million or Rs. 2.6 million depending on whether one uses the lower or higher cost figure. With a monthly benefit of Rs 3.2 million to consumers, this analysis indicates that the project is worthwhile. It is equivalent to saying that an individual lump-sum tax-subsidy scheme could be devised to finance the expenditure on buses which would lead to a pareto-superior position.

With more reliable and detailed cost data, a more sophisticated cost-benefit analysis could have been attempted -- one that would weight the benefits to various income groups and consider the marginal social costs of each component of cost in terms of a common yardstick (eg., rupees of public income). Given the incomplete data and the problems involved in weighting different income groups and obtaining the various parameters, it was decided to stay with comparing rupees of consumer income with private operating costs of a bus.

As an alternative to the public sector supplying the additional buses, it was considered worthwhile to seek a self-financing scheme which would provide a net benefit to consumers. For instance, would a 20% bus fare increase coupled with a 10% decrease in waiting time leave the consumers better off? Would the 20% bus fare increase call forth at least 10% more buses from the private sector? In short, would a 20% fare increase be privately profitable to result in at least 10% more buses, as well as be socially preferable to consumers who gain 10% decreased waiting time at the expense of the higher fare?

The answer to the second question is uncertain. However, based on past responsiveness of the private sector to changes in fare, and the zeal with which private bus owners are clamoring for a fare increase, it is likely that the required 176 buses would be available. To see the plight of the consumers after the suggested scheme was implemented, the change in utility for each consumer is weighted by the initial probability, and multiplied by the marginal utilility of income. Sample sums for the five income group categories reveal that only the poorest group suffer a loss in utility (Table 22). The loss is very small as compared to the gain by the other groups. A loss in utility is experienced in 80 of the 315 trips. The loss in almost all cases is very small.

TABLE 22

DAILY GAIN TO CONSUMERS CAUSED BY DECREASING WAITING TIME FOR A BUS BY 10% AND INCREASING FARE BY 20%

	INCOME GROUP					
	I	II	III	IV	V	TOTAL
Sample gain (Rs)	-.035	.478	1.34	1.54	1.76	5.08
Trips in sample	54	70	73	65	53	315
Gain/trip (Rs)	-.0006	.0068	.0184	.0237	.0332	.0161
Tot trips(000/day)	604	1618	293	253	132	2900
Total gain(Rs/day)	-400	6287	3070	3414	2506	14877

Summary and Conclusions

If you asked a group of people in Karachi how one could best improve the transport for the masses of Karachi, most would answer 'Improve the bus system'. As such, the major policy recommendation of expanding bus service is hardly surprising. However, whereas the group is likely to be thinking about increasing X-efficiency by reducing the turn-around time for buses in the workshop, this analysis is concerned with allocative efficiency. While X-efficiency is no less important, it is beyond the scope of this paper. This study considers how to improve the welfare of residents by reallocating resources, given the state of X-efficiency. What this study provides is an analysis, based on the individual's revealed value of time, which demonstrates that the addition of buses would be cost effective. Further the model simulates the impact of the increased bus service on the demand for other modes -- a useful result for planners.

The household survey conducted for this study shows that a smaller percentage of the poorest income group has a bus available to it, as compared to the middle income groups. This suggests that there may be a frustrated demand for buses. Simulations of the model support the result by showing that about 18% more trips by bus would have been undertaken had the bus been available to everyone in the sample.

The model predicts that if bus fares were raised by 20% while simultaneously lowering waiting time by 10%, there would be a gain to all income groups except the poorest. However the loss to this group is insignificant as compared to the gain by the other groups. Therefore, if there is a problem in obtaining the necessary funds to purchase additional buses in the public sector, raising fares as an alternative to obtaining the additional buses from the private sector is desirable. The simulated elasticities reveal that raising bus fares does not affect the demand for any mode significantly, but the decrease in waiting time has a noticeable impact on the demand for all modes -- especially for buses.

In summary, this study finds that probabilistic models, which are based on utility maximization, may successfully be applied to the modal choice problem in a developing country. The joint choice model reveals that the decision as to whether to buy a car or motorcycle is made simultaneously with the decision of which mode to take to work. However, had the simultaneity been ignored in this model, the loss in terms of biased coefficients would have been small.

REFERENCES

Adler, H. (1971), Economic Appraisal of Transport Projects, Indiana University Press, Bloomington, Indiana.

Adler, T.J. and Ben-Akiva, M. (1976), 'Joint-Choice Model for Frequency, Destination, and Travel Mode for Shopping Trips', Transportation Research Record 569.

Becker, G. (1965), 'A Theory of the Allocation of Time', The Economic Journal, vol 75.

Beesley, M.E. (1965), 'The Value of Time Spent Travelling: Some new evidence', Economica, Vol 32.

Blackburn, A.J. (1970), 'An Alternative to Aggregation and Estimation in the Non-Linear Model', in Quandt, R.E. (ed.), The Demand for Travel: Theory and Measurement, Heath, Lexington, Mass.

Bruzelius, N. (1979), The Value of Travel Time, Croom Helm, London.

De Donnea, F.X. (1972), 'Consumer Behaviour, Transport Mode Choice and Value of Time: Some Microeconomic Models,' Regional and Urban Economics, vol 1.

DeSerpa, A.J. (1971), 'A Theory of the Economics of Time,' The Economic Journal, vol 81.

DeSerpa, A.J. (1973), 'Microeconomic Theory and the Valuation of Travel Time: Some Clarification,' Regional and Urban Economics, vol 2.

Domencich, T. and Kraft, G. (1970), Free Transit, Heath, Lexengton, Mass.

Domencich, T. and McFadden, D. (1975), Urban Travel Demand: A Behavioural Analysis, North Holland, Amsterdam.

Esesjay Consult Limited (1975), 'Analysis of Existing Profile of Sind Road Transport Corporation and a short term augmentation of facilities and fleet project', Karachi.

Fertal, M., E. Weiner, A.Balek and A. Sevin (1966), Modal Split (U.S. Department of Commerce, Bureau of Public Roads, Washington, D.C.).

Gronau, R. (1976), 'Economic Approach to Value of Time and Transportation Choice', Transportation Research Record 587.

Hensher, D. A. (1976), 'Review of Studies Leading to Exesting Values of Travel Time', Transportation Research

Record 587.

Lancaster, K. J. (1966), 'A New Approach to Consumer Theory', Journal of Political Economy, vol 61.

Lansing, J.B. and Hendricks, G. (1967), 'Automobile Ownership and Residential Density', Survey Research Center, University of Michigan, Ann Arbor, Michigan.

Kraft, J. and Kraft, A. (1974), 'Empirical Estimation of the Value of Travel Time Using Multi-Mode Choice Models', Journal of Econometrics, vol 2.

Lerman, Steven R. (1977), 'Location, Housing, Automobile Ownership, and Mode to Work: A joint choice analysis', Transportation Research Record 610.

Lisco, T. E. (1967), The Value of Commuters' Travel Time: A Study in Urban Transportation, unpublished Ph.D. thesis, Department of Economics, University of Chicago, Chicago.

Master Plan for Karachi Metropolitan Region (1972), Socio-economic homogeneous areas', MP-RR/50.

Master Plan for Karachi Metropolitan Region (1974), 'Final Report on Transportation', MP-RR/94.

Master Plan for Karachi Metropolitan Region (1979), 'Transportation -- its challenges to Karachi Metropolis', Newsletter Monthly, November 1979.

McFadden, D. (1973), 'Conditional Logit Analysis of Qualitative Choice Behaviour', in P. Zarembka (ed.) Frontiers in Econometrics, Academic Press, NY.

McFadden, D. (1977), 'Modelling the Choice of Residential Location', Cowles Discussion Paper No. 477, Yale University.

McGillivray, R.G. (1970), 'Demand and Choice Models of Modal Split', Journal of Transportation Economics and Policy, vol 4.

McGillivray, R.G. (1972), 'Mode Split and the Value of Time', Transportation Research, vol 6.

Meyer, J.R., J.F. Kain and M.Wohl (1966), The Urban Transportation Problem, Harvard University Press, Cambridge.

Moses, L.N. and Williamson, H.F. (1963), 'Value of Time, Choice of Mode and the Subsidy Issue in Urban Transport', Journal of Political Economy, vol 71.

Quandt, P. and Baumol, W., 'The Demand for Abstract Travel Modes: Theory and Measurement', Journal of Regional

Science, Volume 6.

Quarmby, D.A. (1967), 'Choice of Travel Mode for the Journey to Work: Some Findings', Journal of Transport Economics and Policy, vol 1.

Stopher, P. (1977), 'Value of Travel Time', National Academy of Sciences, Transportation Research Board, Transportation Research Record, No. 587.

Train, K. (1980), 'A Structured Logit Model of Auto Ownership and Mode Choice', Review of Economic Studies, Vol XLVII.

APPENDIX I

QUESTIONNAIRE

Serial No. ______

Transport Study
Applied Economics Research Centre
University of Karachi

HOUSEHOLD EXPENDITURE SURVEY ON TRANSPORT

1. Interviewer's Name ________________________
   Date: ________ Time: ____________

2. Name: ________________________________
   Full Address: ____
   ____

3. How many persons are there in the household? ____________
   How many are over the age of five years? ____________

4. For each person over the age of five years, please fill in the information requested below:

Name	Relationship to head of house	Age	Sex	Marital Status: S, M, or W	Education Years of Schooling	Occupation	Main mode of transport to work or school

5. For each earning member of the household, please fill in the information below:

Name	Hours/week	Income/mth (Rs)	Any Company Transport? Yes	No	If so, what?

6. Does the household have any other sources of income?

   Yes No

   If so, please specify the sources and average amount per month:

	Property	Remittances	Pension	Shares and Bonds	Other
Amount (Rs)					

from abroad

other

7. Is the house: owned rented other

What is the approximate current value of the house? Rs.

If rented, what is the rent per month? Rs.

8 (a) What is your monthly expenditure on the following items:

	Food	Schooling	Medical	Utilities	Servants	Recreation
Amount (Rs)						

(b) During the last six months, what were your expenditures on each of the following items:

	Home Improvement	Travel	Clothing
Amount (Rs)			

(c) During the last six monts, list your other major expenses (purchases, loans given, gifts, etc).

Item	Cost (Rs)

9. List below the weekly expenditure on public modes of transport for each member of the household that uses public transport:

Name	Bus (Rs)	Minibus (Rs)	Train (Rs)	Rickshaw (Rs)	Taxi (Rs)

10. Which of the following assets does the household own?

Refrigerator Radio Cassette Player Colour TV

B/W TV Air conditioner Shares and Bonds Telephone

11. Which of the following transport options are readily available in your area?

Bus Contract Bus Minibus Rickshaw Taxi Train Other ______

12. (a) Does the household own any means of transport?

Yes No

If so, list each mode and answer the questions below:

Mode No.	Transport Mode	Name of Owner	Make	Year	Year Bought	Value at time of purchase	Present Value	mpg	Weekly Expenditure on petrol

(b) Do you hire a driver? Yes No

If so, for how many hours a week and at what salary?

______ hours/week at Rs_____ per month.

(c) Do you have a car-washer? Yes No

If so, how much do you pay him every month? Rs______

13 (a) During the last three months, how much have you spent on each of the following items:

Mode Name	Servicing and Oil change	Tune-up	Spare Parts	Other repairs and labour charges

(b) During the last one year, how much have you spent on the following items:

Mode Name	Painting/ Denting	Imported Tyres	Retreaded/ Local Tyres	Battery		Insurance	Overhaul
				Imported	Local		

14 (a) Yesterday, how many trips, if any, did each resident listed in the household profile make for the following purposes:

Name	Interviewed Yes	No	Work	School	Social/ Recreat- ional	Shopping	Personal or em- ployer's	Serve Passen- ger

(b) Split each of the trips on the next page into components depending on whether you break the trip or not. For example, a trip to your office and back in your car would count as two trips — one from home to work and the other from work to home. If you make a trip to the office by bus and it involves walking one mile to the bus stop, taking one bus for a certain distance and then changing to another bus, it would count as three trips — one trip by walking for the purpose of changing the travel mode, one by bus for the same purpose, and a third by bus to go to work.

This space for any special comments:

Name	Trip No.	Origin (Area)	Destination (Area)	Purpose	Mode Used	Time		Wait Time	Distance covered (miles)	No. of persons	Cost	No. of such trips per week
						Start	Finish					

APPENDIX II

COMPARISON OF THE UTILITY ARISING FROM TWO SITUATIONS

From Chapter 2,

$$U = Max(U_1,\ldots,U_N) = Max(V_1+\gamma_1,\ldots,V_N+\gamma_N)$$

Evaluated at the initial vector X^o, the utility is

$$Max(X_1^o\beta+\gamma_1,\ldots,X_N^o\beta+\gamma_N)$$

A new vector X is preferred to X^o if

$$E(U) \geq E(U^o)$$

ie.

$$E[Max(X_1\beta+\gamma_1,\ldots,X_N\beta+\gamma_N)] \geq E[Max(X_1^o\beta+\gamma_1,\ldots,X_N^o\beta+\gamma_N)]$$

In order to evaluate the left hand side, the problem is broken up into N different cases:

<u>Case 1</u>: The first alternative is chosen.

For this to occur, the following must be true:

$$X_1\beta + \gamma_1 \geq X_2\beta + \gamma_2$$

$$X_1\beta + \gamma_1 \geq X_3\beta + \gamma_3$$

$$X_1\beta + \gamma_1 \geq X_N\beta + \gamma_N$$

Since $\gamma_1,\ldots,\gamma_N$ are independent, the probability density function of the above event is:

$$f(\gamma_1)\left[\int_{-\infty}^{X_1\beta-X_2\beta+\gamma_1} f(\gamma_2)d\gamma_2 \ldots \int_{-\infty}^{X_1\beta-X_N\beta+\gamma_1} f(\gamma_N)d\gamma_N\right]d\gamma_1$$

This is because γ_1 is allowed to take on any value but $\gamma_i \leq X_1\beta - X_i\beta + \gamma_1$, $i = 2, \ldots N$. $f(\gamma_i)$ is the density function of γ_i.

The above expression may be written as

$$f(\gamma_1)F(X_1\beta - X_2\beta + \gamma_1) \ldots F(X_1\beta - X_N\beta + \gamma_1)d\gamma_1$$

where $F(\cdot)$ is the cumulative distribution of $f(\cdot)$.

The contribution to the utility from the first alternative is:

$$\int_{-\infty}^{\infty}(X_1\beta + \gamma_1)f(\gamma_1)F(X_1\beta - X_2\beta + \gamma_1) \ldots F(X_1\beta - X_N\beta + \gamma_1)d\gamma_1$$

Similarly, N such cases could be constructed and the expected utility is:

$$\int_{-\infty}^{\infty}(X_1\beta + \gamma_1)f(\gamma_1)F(X_1\beta - X_2\beta + \gamma_1) \ldots F(X_1\beta - X_N\beta + \gamma_1)d\gamma_1 +$$

$$\ldots + \int_{-\infty}^{\infty}(X_N\beta + \gamma_N)f(\gamma_N)F(X_N\beta - X_1\beta + \gamma_N) \ldots F(X_N\beta - X_{N-1}\beta + \gamma_N)d\gamma_N$$

In order to compare X and X^o, one has to evaluate the above expression at X and X^o and see which is bigger. Unfortunately, the expression is analtyically intractable and, due to many terms of the form $\exp(-e^{-k})$, difficult to evaluate numerically.

WORLD EMPLOYMENT PROGRAMME

Working Papers

THE INCOME DISTRIBUTION AND EMPLOYMENT PROGRAMME

WEP Research Working Papers are preliminary documents circulated informally in a limited number of copies solely to stimulate discussion and critical comment. They are restricted and should not be cited without permission. A set of selected WEP Research Working Papers, completed by annual supplements is available in microfiche form for sale to the public; orders should be sent to the ILO Publications, International Labour Office, CH-1211 GENEVA-22 Switzerland. This list includes many, but not all, papers which exist or may be issued im microfiche form.

WP 1 "Part des Salaires dans le Revenu National et Développement Economique" (March 1974)
.... Jacques Lecaillon and Dimitrios Germidis

WP 2 "Les Disparités de Revenus entre Salariés et Travailleurs Indépendants dans les Secteurs Non-Agricoles au Sénégal, Cameroun, Madagascar et Côte-d'Ivoire (March 1974)
.................Jacques Lacaillon and Dimitrios Germidis

WP 3 "Redistribution of Income, Patterns of Consumption and Employment - A Case Study for the Philippines" (May 1974)
.... Felix Paukert, Jiri Skolka and Jef Maton

WP 4 "Les Disparités de Revenus entre Travailleurs Ruraux et Salariés Urbains dans le Dynamique de Développement" (July 1974) .... Jacques Lecaillon and Dimitrios Germidis

WP 5 "Mexican Income Distribution within and between Rural and Urban Areas" (July 1974)
.... Wouter van Ginneken

WP 6 "The Pattern of Income Distribution in West Malaysia 1957-1970" (July 1974)
.... Lim Lin Lean

WP 7 "A Methodology for Estimating Statewise Size Distributions of Income in Rural India" (September 1974)
.... Michael Farbman

WP 8 "Income Distribution in the Philippines : the Employed and the Self-Employed (October 1974)
.... José Encarnación, Jr

WP 9 "Changes in the Size Distribution of Income in Postwar Japan (October 1974)
.... Richard Wada

WP 10 "Les Disparités de Salaires au Sénégal, Cameroun, Madagascar et Côte d'Ivoire (Octobre 1974)
.... Jacques Lecaillon and Dimitrios Germidis

WP 11 "Développement Economique et Politique des Revenus" (November 1974)
.... Jacques Lecaillon and Dimitrios Germidis

WP 12 "The Rich, the Poor and the Taxes they pay in India : A Study of Central Government Taxes and their Impact on Income Distribution" (December 1974)
.... Anand P. Gupta

WP 13 "Sectoral Employment and Income Distribution in Rural India" (February 1975)
.... Michael Farbman

WP 14 "The Regional amd Rural-Urban Income Distribution in the Sudan". (March 1975)
.... Wouter van Ginneken

WP 15 "Income Distribution and Employment Characteristics : Hong-Kong 1971" (March 1975)
.... Ronald Hsoa and L.C. Chau

WP 16 "Characteristics of the Head of Household and Income Inequality in Mexico" (July 1975)
.... Wouter van Ginneken

WP 17 "Bibliography on Income Distribution (Volume I), (August 1975)
.... Thomas S. Windmuller and Farhad Mehran

WP 18 "Bibliography on Income Distribution (Volume II) (August 1975) ...... Thomas S. Windmuller and Farhad Mahran

WP 19 "Incidence of Central Government Expenditures in India" (August 1975) ...... Anand P. Gupta

WP 20 "Dealing with Grouped Income Distribution Data" (August 1975) ...... Farhad Mehran

WP 21 "Health, Employment and Income Distribution" (August 1975) ...... Carl M. Stevens

WP 22 "Can Educational Policy Equalize Income Distribution in Latin America?" (August 1975)
.... Martin Carnoy

WP 23 "The Changing Structural Distribution of Income and Employment in Turkey and Kuznet's Hypothesis" (September 1975)
.... Layla Ecevit and Erdogan Czötün

WP 24 "Employment and Income Distribution in West Malaysia" (September 1975)
.... Lim Lin Lean

WP 25 "Urban Development, Income Distribution and Employment in Lagos" (September 1975)
.... O.J. Fapohunda, M.P. van Dijk and Jaap Reijmerink

WP 26 "Taxation, Government Spending and Income Distribution in the Philippines" (October 1975)
.... Edita A. Tan

WP 27 "Industrialisation and Income Distribution in Hong-Kong 1961-1971" (October 1975)
.... Ronald Hsia and L.C. Chau

WP 28 "Solving India's Employment Problem : Role of Fiscal Policy" (October 1975)
.... Anand P. Gupta

WP 29 "A Note on Income Distribution and Poverty in Trinidad and Tobago" (October 1975)
.... Rapph M. Henry

WP 30 "Income Distribution in Iran : The Statistics of Inequality" (October 1975)
.... Fahrad Mehran

WP 31 "Income in Kind and Redistribution of Income in Hong Kong" (November 1975)
.... Ronald Hsia and L.C. Chau

WP 32 "Income Distribution and Employment in Turkey : Policies, Practices and Prospects" (November 1975)
.... Duncan R. Miller

WP 33 "Taxes and Incomes : Distribution of Tax Burdens in Iran" (December 1975)
.... Farhad Mehran

WP 34 "Aspects of Income Distribution in Turkey" (December 1975)
.... Duncan R. Miller

WP 35 "The Dynamics of Human Resources Development in Turkey and Their Implications for Employment and Income Distribution" (December 1975)
.... Duncan R. Miller

WP 36 "The Regional Distribution of Government Expenditures in Botswana" (December 1975)
.... Richard J. Szal

WP 37 "Impact of Economic Growth on the Size Distribution of Income : The Postwar Experience of Japan" (December 1975)
.... Richard O. Wada

WP 38 "The Development of Manufacturing Industries in Ghana and the Government's Role in It" (January 1976)
.... Kodwo Ewusi

WP 39 "Intersectoral Terms of Trade and Transfer of Resources from Agriculture : The Case of Egypt" (January 1976)
.... Abdel-Fadil

WP 40 "The Role of Asset Redistribution in Poverty-Focused Development Strategies" (January 1976)
.... Alejandro Foxley, Eduardo Aninat, José P. Arellano

WP 41 "International Migration of Turkish Workers : A Special Case in the Public Policy of Income Distribution and Employment" (February 1976)
.... Duncan R. Miller

WP 42 "What does Social Security do to Incomes?" (July 1976)
.... Alejandro Foxley, Eduardo Aninat, José P, Arellano

WP 43 "Changes in Employment and the Distribution of Income during the Brazilian 'Miracle'" (July 1976)
.... Samuel A. Morley

WP 44 "Who Benefits from Government Expenditures?" (July 1976)
..............Alejandro Foxley, Eduardo Aninat, José P.Arellano

WP 45 "Changes in Income Distribution, Employment and Structure of the Economy : A Case Study of Iran" (September 1976)
.... Jiri Skolka and Michel Garzuel

WP 46 "Inequality and Basic Needs in Swaziland" (October 1976)
.... Richard J. Szal and Ralph van der Hoeven

WP 47 "Policy Planning for Employment and Income Distribution in Rural India" (December 1976)
.... Michael Farbman

WP 48 "Underemployment and Basic Needs Satisfaction" (January 1977) ....Peter Richards

WP 49 "Employment Performance of Ghanian Manufacturing Industries" (January 1977) .... Kodwo Ewusi

WP 50 "Unemployment in Developing Countries" (February 1977)
.... Harold Lydall

WP 51 "The Incidence of Taxation" (February 1977)
.... Alejandro Foxley, Eduardo Aninat, José P. Arellano

WP 52 "Income Distribution during the process of Development" (February 1977) .... Harold Lydall

WP 53 "Net Incidence of Government Expenditures Taxation and Social Security" (February 1977)
.... Alejandro Foxley, Eduardo Aninat, José P. Arellano

WP 54 "Zambia's Income Distribution during the Early Seventies" (March 1977)
.... Rolph van der Hoeven

WP 55 "A Monetary Will-O'-The Wisp : Pursuit of Equity Through Deficit Spending (Part I)" (March 1977)
.... Leopoldo Solís

WP 56 "A Monetary Will-O'-The Wisp : Pursuit of Equity Through Deficit Spending (Part II)" (March 1977)
.... Leopoldo Solís

WP 57 "DIstribution of Benefits from Public Consumption Expenditures Among Households in Iran" (July 1977)
.... Farhad Mehran

WP 58 "Rubber Technology and Exports in West Malaysia" (August 1977) .... Jacques Gaude and Michel Garzuel

WP 59 "Education and Income Distribution in Asia : A Preliminary Analysis" (September 1977) ...... Peter Richards

WP 60 "Poverty : Measurement and Analysis" (October 1977)
.... Richard Szal

WP 61 Technology, Products and Income Distribution : A Conceptualisation and Application to Sugar Processing in India" (November 1977).................. Jeffrey James

WP 62 "The Impact of Income Maintenance Programmes on Poverty in Britain" (December 1977) .... Wilfred Beckerman

WP 63 "The Time-Distance Approach to the Analysis of Dynamic Aspects of Inequalities" (December 1977) .... Pavle Sicherl

WP 64 "Patterns of Inequality in Education in Asia (Part I)" (December 1977) .... Mauricio Leonor

WP 65 "Three Notes on the Concept of Poverty" (January 1978) .... Amartya Sen

WP 66 "The Cha-Am-Road - Employment and Income Distribution Effects of Rural Road Construction" (April 1978) .... Christer Holtsberg

WP 67 "Income Distribution by Size, Employment and the Structure of the Economy : A Case Study for the Republic of Kora" (May 1978) .... Jiri Skolka and Michel Garzuel

WP 68 "General Equilibrium Analysis of the Colombian Income Distribution : Applications to Rural Development, Wage and Income Policies" (June 1978) .... François Bourguignon

WP 69 "Fiscal Incidence in Sri Lanka" (August 1978) .... Patricia J. Alailima

WP 70 "Estimates of Poverty in Italy in 1975" (September 1978) .... Wilfred Beckerman

WP 71 "Redistribution of Income, Patterns of Consumption and Employment : The Case Study for Malaysia" (October 1978) .... Jef Maton and Michel Garzuel

WP 72 "Income Distribution by Size, Structure of the Economy and Employment : A Comparative Study for Four Asian Countries", (March 1979) .... Felix Paukert, Jiri Skolka and Jef Maton

WP 73 "Income Inequality and Fiscal Policies in Botswana" (April 1979) .... Richard J. Szal

WP 74 "Static and Dynamic Indices of Income Inequality (May 1979) .... Irma Adelman and Peter Whittle

WP 75 "Some Distributional Issues in Planning for Basic Needs Health Care" (June 1979) .... Peter Richards

WP 76 "Basic Needs in Mexico : Analysis and Policies (July 1979) .... Wouter van Ginneken

WP 77 "Land Tenure, Government Policies and Income Distribution in Sri Lanka (September 1979) .... W. Gooneratne

WP 78 "Dimensions and Targets in Basic Education (An illustrative exercise in assessing the fulfilment of education as a basic need)" (October 1979) .... M.D. Leonor, Jr.

WP 79 "The Poor, the Non-Poor and the Taxes they Pay in India : A State-Wise Study" (November 1979) .... Anand P. Gupta

WP 80 "Estimates of Poverty in Greece, 1974" (December 1979)
.... Wilfred Beckerman

WP 81 "Stabilization Policies and Stagflation : The Cases of Brazil and Chile" (December 1979)
.... Alejandro Foxley

WP 82 "Consumer Information from Public and Private Sources : Some Canadian Results" (December 1979)
.... R.R. Kerton and T. Chowdhury

WP 83 "Income Distribution Implications of the Thai Rice Price Policy" (January 1980) ...... Christer Holtsberg

WP 84 " A Dynamic Analysis of Regional Disparities in Yugoslavia" (January 1980) .... Pavle Sicherl

WP 85 "Basic Needs and the Provision of Government Services : An Area Study of Ranaghat Block in West Bengal" (February 1980)
.... T.M. Vinod Kumar and Jatin De

WP 86 "Consumer Income Distribution and Appropriate Technology : The Case of Bicycle Manufacturing in Malaysia" (March 1980)
.... Fong Chan Onn

WP 87 "Basic Needs in Panama : The Health Sector (April 1980)
.... Christoph Bunge

WP 88 "Product Choice and Poverty : A Study of the Inefficiency of Low-Income Consumption and the Distributional Impact of Product Changes (May 1980)
.... Jeffrey James

WP 89 "Technological Choice, Employment Generation, Income Distribution and Consumer Demand : The Case of Furniture Making in Kenya", (June 1980)
.... William J. House

WP 90 "Who Benefits from Government Expenditures in India?" (June 1980) .... Anand P. Gupta

WP 91 "The Impact of the Elimination of Food Subsidies on the Cost of Living Egypt's Urban Population" (September 1980)
.... Karima Korayem

WP 92 "Lusaka Housing Project : A Critical Overview of Low Cost Housing in Zambia" (September 1980)
.... Mary Turok and Bish Sanyal

WP 93 "The Distribution of and Access to Basic Health Services in Thailand" (September 1980)
.... Medhi Krongkaew

WP 94 "Appropriate Products, Employment and Income Distribution in Bangladesh : A Case Study of the soap industry", (October 1980)
.... A.K.A. Mubin and David J.C. Forsyth

WP 95 "Politique économique et revenus en Côte-d'Ivoire" (Novembre 1980) ..... Yolande Bresson

WP 96 "Income Distribution and Employment in the Footwear Industry", (February 1981) ..... George A. Aryee

WP 97 "The Distribution of Income in Thailand" (February 1981)
.... Carmel Ullman Chiswick

WP 98 "The impact of income maintenance programmes on poverty in Canada, 1975" (March 1981)
.... Wilfred Beckerman

WP 99 "La planification régionale au Sénégal" (May 1981)
.... Makhtar Diouf

WP 100 "Effects of alternative measurement techniques on the estimation of the inequality of income" (June 1981)
.... Harold Lydall

WP 101 "Provision and distribution of selected public goods and services in India" (June 1981)
.... Mafooz Ahmed, Ausaf Ahmad

WP 102 "Implications of a basic needs strategy for the edible oil industry" (July 1981)
.... Radha Sinha, S.P. Sinha, G.R. Mishra and Gautam Pingle

WP 103 "The impact of income maintenance payments on poverty in Ireland" (August 1981)
.... Wilfred Beckerman

WP 104 "Poverty and unemployment in India: Is there light at the end of the tunnel?" (September 1981)
.... Anand P. Gupta

WP 105 "Comparable income distribution data for Mexico (1968), United Kingdom (1979) and The Federal Republic of Germany (1974), (September 1981)
.... Wouter van Ginneken, Michel Garzuel

WP 106 "The impact of rural roads on poverty alleviation: A review of the literature" (November 1981)
.... John Howe

WP 107 "Decentralised planning in Papua New Guinea (November 1981) .... Diana Conyers

WP 108 "Criteria for rural road planning" (November 1981) .... John Howe

WP 109 "Passenger Transport in Karachi: A nested logit model" (December 1981) .... Mateen Thobani

WORLD EMPLOYMENT PROGRAMME

TECHNOLOGY AND EMPLOYMENT PROGRAMME

Working Papers

WP.1	Employment and coffee production techniques	L.D. Smith and C.F. Brown February 1974
WP.2	The choice of technique and employment in the textile industry	Howard Pack March 1974
WP.3	Thai workers in heavy road construction activities. An ergonomic pilot study	B. Eriksonn A. Yllö N. Lundgren April 1974
WP.4	Mass production of dwellings in Colombia: A case study	P. Strassmann April 1974
WP.5	Capital-labour substitution possibilities: A review of empirical research	J. Gaude May 1974
WP.6	Indirect employment effects of investment in industry	J. Krishnamurty
WP.7	Industrialised systems building for developing countries: A discouraging prognosis	P. Strassmann July 1974
WP.8	Concept and measurement of labour-intensity	A.S. Bhalla August 1974
WP.9	Conventional technology, construction wages and employment	P. Strassmann August 1974
WP.10	"Men and machines": A Philippines case study of labour-capital substitution in road construction	Deepak Lal September 1974
WP.11	Effect of farmers' education on agricultural productivity and employment: A case study of Punjab and Haryana States of India (1960-1972)	D.P. Chaudhri October 1974
WP.12	The green revolution, mechanisation and employment	Iftikhar Ahmed January 1975
WP.13	The role of design in the choice of road construction techniques	G.A. Edmonds February 1975

WP.14	Selection of road projects and the identification of the appropriate road construction technology: General considerations	Moise Allal February 1975	66 67 68 69
WP.15	A framework for data collection on road construction	G.A. Edmonds March 1975	72 73
WP.16	The Green Revolution in Bangladesh: Adoption, diffusion and distributional question	Iftikhar Ahmed June 1975	75 76 77
WP.17	A planning model incorporating technological choices and non-homogeneous supplies of labour	J. Gaude June 1975	79 80 81
WP.18	Organisation, consumer time and technology in services	A.S. Bhalla and J. Gaude July 1975	83 84 85
WP.19	Low-cost technology, cost of labour management and industrialisation	A.S. Bhalla July 1975	87 88
WP.20	Can-making techniques in Kenya, Tanzania and Thailand	R.M. Bell, C.M. Cooper, R. Kaplinsky October 1975	91 92 93 94
WP.21	A case study of alternative techniques for open-top can manufacture in Thailand	R.M. Bell, C.M. Cooper, R. Kaplinsky	97 98 99
WP.22	The effect on employment of change in technology in tea and coffee plantations in India. Part A - Coffee	I.Z. Bhatty December 1975	101 102 103
WP.23	The effect on employment of change in technology in tea and coffee plantations in India. Part B - Tea	I.Z. Bhatty December 1975	105 106 107
WP.24	Technologie et emploi dans le secteur de la construction en Tunisie	R. Ferchiou and R. Lakhoua December 1975	109 110 111
WP.25	Technological development and role of R and D institutes in developing countries - The Korean case	Nam Kee Lee December 1975	113 114 115
WP.26	The role of services in increasing capacity utilisation: The case of Tanzanian manufacturing industry	S.M. Wangwe December 1975	117 118 119
WP.27	Local capability and preparedness for appropriate technology transfer to developing countries	M.M. Suri December 1975	121 122 123

3

WP.28	Agricultural mechanisation in Iran	V.F. Nowshirvani March 1976	125 126
WP.29	Labour-intensive construction of irrigation works	M.I. Hussain August 1976	128 129
WP.30	Structure of the agricultural machinery and implements in industry to Iran	V.F. Nowshirvani March 1977	131 132
WP.31	Employment and technology transfer and adaptation: The case of the agricultural machinery industry in Iran	V.F. Nowshirvani March 1977	134 135 136
WP.32	Technology, products and income distribution: A conceptualisation and application to sugar processing in India	J. James November 1977	138 139 140
WP.33	Study of small contractors in Kenya	J. Capt and G.A. Edmonds December 1977	142 143 144
WP.34	Technological linkages between formal and informal sectors of manufacturing industries	Susumu Watanabe March 1978	146 147 148
WP.35	Technology diffusion from the formal to the informal sector: The case of the auto-repair industry in Ghana	A.N. Hakam July 1978	150 151 152
WP.36	Technologies appropriate for a basic needs strategy	A.S. Bhalla August 1978	154 155
WP.37	National appropriate technology groups and institutions: a preliminary assessment	A.K.N. Reddy September 1978	157 158 159
WP.38	Cambio tecnologicao y empleo en la produccion agroindustrial de azucar en Tucuman	Manuel Mora Y Araiyo y Dora Orlansky October 1978	161 162 163 164
WP.39	Technological change and the condition of rural women: a preliminary assessment	Iftikhar Ahmed October 1978	166 167 168
WP.40	Equipment for labour-based road construction	J. Howe and I. Barwell November 1978	170 171 172
WP.41	Scope for application and upgrading of indigenous technology - the case of irrigation works	M.I. Hussain November 1978	174 175 176
WP.42	Choice of manufacturing technology in the leather shoe and brick industries in Malaysia	Chee Peng Lim December 1978	178 179 180

WP.43	The effect of higher oil prices on technology and employment in Pakistan	M. Ahmed January 1979	182 183
WP.44	The technological and employment implications of higher oil prices: a case study of Sri Lanka	Marga Institute, Sri Lanka January 1979	185 186 187 188
WR.45	The changing patterns of intersectoral technological linkages in the rural machinery industry in China	Jon Sigurdson January 1979	190 191 192
WP.46	Technological change and rural women - a conceptual analysis	Amit Bhaduri January 1979	194 195
WP.47	Technical co-operation between large and small firms in the Filipino automobile industry	Susumu Watanabe March 1979	197 198 199
WP.48	(with Jobs and Skills Programme for Africa) Small contractors: untapped potential or economic impediment? Some observations on the construction industry in Cameroon, Niger and Sierra Leone	Bernd Balkenhol April 1979	201 202 203 204 205 206
WP.49	On the production of appropriate technology	Henry J. Bruton June 1979	208 209
WP.50	Impacts of higher oil prices on India	Ashok V. Desai September 1979	211 212
WP.51	The generation and dissemination of appropriate technologies in developing countries: a methodological approach	Amilcar O. Herrera October 1979	214 215 216
WP.52	Some economic implications of higher oil prices: the case of Bangladesh	Rizwanul Islam November 1979	218 219
WP.53	Organising for technology appropriation: an approach to appropriate technology implementation	Geoff Lamb December 1979	221 222 223
WP.54	Inter-sectoral linkages in the metal engineering industry in Kanpur, India	T.S. Papola R.S. Mathur December 1979	225 226 227
WP.55	Technological linkages in the Mexican garment industry	Alfonso Mercado January 1980	229 230
WP.56	Consumer, income distribution and appropriate technology: the case of bicycle manufacture in Malaysia	Fong Chan Onn March 1980	232 233 234
WP.57	Energy options for low-lift irrigation pumps in developing countries - the case of Bangladesh and Egypt	David Birch J.R. Rydzewski April 1980	236 237 238

WP.58	Technological linkages in the Egyptian cotton weaving industry	Hatem El Karanshawy Mohamed Sakr April 1980
WP.59	Product choice and poverty: a study of the inefficiency of low-income consumption and distributional impact of product changes	J. James May 1980
WP.60	Technological choice, employment generation, income distribution and consumer demand: the case of furniture making in Kenya	W.J. House May 1980
WP.61	Technology and rural women in Africa	Marilyn Carr July 1980
WP.62	Some technological issues of informal sector industries in Khartoum	Ali Ahmed Suliman July 1980
WP.63	Labour-based technology for large irrigation works: problems and prospects	Asit K. Biswas August 1980
WP.64	Farm equipment innovations, agricultural growth and employment in Zambia	B.H. Kinsey August 1980
WP.65	Technology, employment and basic needs in leather industries in developing countries	Arie Kuyvenhoven August 1980
WP.66	Institutional factors and government policies for appropriate technologies in South-East Asia	Shinichi Ichimura September 1980
WP.67	Institutional factors affecting the generation and diffusion of agricultural technology: Issues, concepts and analysis	Vernon W. Ruttan October 1980
WP.68	Technology for construction and maintenance of irrigation and drainage works in Egypt: a preliminary assessment	M.H. Amer October 1980
WP.69	Development and application of indigenous low-cost technology to minimise water losses due to seepage in irrigation canals: the case of Bangladesh	A. Khair S. Sc. Dutt M.A. Rahman October 1980
WP.70	Institutional aspects of the construction industry in developing countries	G.A. Edmonds October 1980
WP.71	Market structures, industrial organisation and technology	David J.C. Forsyth October 1980
WP.72	Energy policy and the social objectives of development	C. Baron October 1980

WP.73	Construction industry in Ghana	G. Ofori October 1980	296 297
WP.74	Appropriate products, employment and income distribution in Bangladesh: a case study of the soap industry	A.K.A. Mubin October 1980	299 300 301
WP.75	Technology policy and development financing: observations on some institutional constraints in Africa	B. Balkenhol October 1980	303 304 305
WP.76	Farm equipment innovation for small-holders in semi-arid Kenya: a conceptual and empirical analysis.	G. Muchiri October 1980	307 308 309
WP.77	Choice of appropriate technique in the African bread industry with special reference to Sierra Leone.	E. Chuta January 1981	311 312 313
WP.78	Income redistribution, technology and employment in the footwear industry, a case study in Kumasi, Ghana	G.A. Aryee January 1981	315 316 317
WP.79	A conceptual framework for the analysis of the effects of technological change on rural women	Ann Whitehead June 1981	319 320 321
WP.80	Farm equipment innovations and rural industrialisation in Eastern Africa: An overview	B.F. Johnston July 1981	323 324 325
WP.81	External development finance and choice of technology	A.G. Fluitman and J. White July 1981	327 328 329
WP.82	Capital goods and technological change: Some theoretical and practical issues from Africa	Thandika Mkandawire July 1981	331 332 333
WP.83	Transport technology for the rural areas of India	National Council of Applied Economic Research, India July 1981	335 336 337 338
WP.84	Implications of a Basic Needs Strategy for the Edible-Oil Industry	Radha Sinha, S.P. Sinha, G.P. Mishra and Gautam Pingle July 1981	340 341 342 343
WP.85	New technologies in newspaper production in developing countries and their labour and social implications	Rex Winsbury September 1981	345 346 347
WP.86	Technologies for rural women's activities - Problems and prospects in Sierra Leone	Y. Stevens October 1981	349 350

WP.87	Rural women, their activities and technology in Ghana: An overview	Eugenia Date-Bah October 1981
WP.88	Transport technology and employment in Rural Malaysia	John D. Smith December 1981
WP.89	Passenger Transport in Karachi : A nested logit model	Mateen Thobani December 1981