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ROAD FREIGHT TRANSPORT UTILIZATION

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PAKISTAN FREIGHT TRANSPORT : THE PRODUCTIVITY AND TIME USE OF COMMERCIAL VEHICLES

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ABSTRACT

As part of a wider study of freight transport undertaken in Pakistan during 1985-87 a survey of vehicle utilisation was carried out. Different vehicle activities were timed and recorded on a continuous basis for periods lasting from five days to four weeks. Using these data, it was possible to investigate three aspects of time related costs:-

i) A series of elasticities were calculated relating trips to travel time and these showed that, in Pakistan's conditions, time savings following road investment, would be fully used.

ii) An analysis of vehicle time budgets found that freight vehicles were in active use (travelling, loading, and unloading) for more than 12 hours per day.

iii) It was found that both time and distance could each independently provide a good explanation of tariffs. Although it was difficult to identify their separate influences the best estimate suggests that time and distance account for 45 per cent and 55 per cent of tariffs respectively.

1. INTRODUCTION

The relentless growth in traffic volumes experienced by many developing countries has, in recent years, led to an increased interest in providing high capacity roads that are primarily designed to reduce congestion and provide journey time savings. Although time savings have been a major component of the benefits of most road investments in developing countries the area has attracted comparatively little research. The two main elements of time related costs are passenger time, and vehicle and crew time. To improve our understanding of the latter for commercial vehicles this Paper presents and analyses data collected from a survey carried out in Pakistan during 1985-86.

The Paper examines three aspects of time related costs. These are:-

a) The use of time savings following road investment.

Common-sense suggests that if road investment brings about journey time savings then, on average, commercial vehicles should be able to make use of the time saved by making extra trips. However there is disagreement (among various authors) about the extent to which this can be achieved.

b) The amount of time a vehicle spends in different activities (travelling, loading, unloading, or at rest).

So far, in the study of vehicle operating costs, little data has been collected on estimating the proportion of time vehicles actually spend working or at rest. This data is needed to help estimate the benefits from changes in travel time for those cost components that are time dependent.

c) The relative importance of time and distance in the explanation of costs and tariffs.

Most components of vehicle operating costs can be separated into those that are clearly time dependent (e.g. driver's wages) and those that are clearly dependent on distance travelled (e.g. tyre wear). However for some components, (such as depreciation or maintenance), it is known that there is a dependency on both time and distance although there is some uncertainty as to the relative importance of each. An analysis of the extent to which tariffs can be explained by time worked and distance travelled would be useful in order to check the validity of our current models of vehicle operating costs used in road investment appraisal.

To collect information on the time utilisation of freight vehicles a "Vehicle Activity Survey" was undertaken. Data was recorded by both truck drivers and survey staff who travelled with each vehicle for periods lasting between five days and four weeks throughout Pakistan. The purpose of the survey was to record number of trips made and the time spent by the vehicle in different activities (namely travelling, loading, unloading, resting, and under repair) during each period. The data was recorded on a continuous 24 hours-per-day basis. In addition data was also collected on the distance travelled and on the revenues and expenses incurred.

This Paper presents part of a study of the freight transport industry of Pakistan that was carried out during a programme of cooperative research between the Overseas Unit of the Transport And Road Research Laboratory and the National Transport Research Centre (Islamabad). Other Working Papers provide a general description of the industry and cover topics such as the role of freight consignors and agents, freight tariffs, and operating costs.

2. THE VALUATION OF COMMERCIAL VEHICLE TIME SAVINGS

In order to value the benefits of journey time savings for commercial vehicles arising from road investment it is necessary to make assumptions or predictions about the extent to which the potential time savings may be translated into productive use. Some authors, such as Dawson and Vass (1974), assume in their formulation of vehicle operating costs constant working hours per year; this implies that all time savings following a road investment will be fully used.

In vehicle operating cost formulations which do not assume constant working hours annual time-related costs are divided by distance travelled per year. The latter figure may either be estimated by a formula derived from vehicle speed or guessed at by the user. Neither procedure is very satisfactory. For example both Winfrey (1969) and De Weille (1966) have proposed a formula from which it can be calculated that a one per cent decline in travel time would bring about a one per cent increase in distance travelled. It is assumed that the time spent travelling per day will remain constant. This implies that the time spent working per day (including loading and unloading) must rise as journey times fall. This is because if travel time is kept constant then time devoted to loading and unloading per day must rise as more trips are made. The assumption of constant travelling time is clearly unrealistic for commercial vehicles where loading and unloading time is an important component of the working day. The approach will nearly always tend to overestimate time savings benefits.

Other vehicle operating cost model formulations (such as TRRL's "Road Transport Investment Model" or the World Bank's "Highway Design Model") provide the user with the option to predict utilisation following road investment or to choose one of a variety of models to achieve the same result. Again no empirical evidence is presented to show how utilisation is likely to change following road investment.

The assumption that travel time savings can be readily translated into extra trips has been questioned by Fleischer (1962) and Thomas (1983). Their empirical investigations suggest that there is an inflexibility in vehicle operations relating to the constraints of drivers' hours and the scheduling of work which will prevent travel time savings from being fully used, particularly in the short-term.

It may be felt that the more inflexibility there is in vehicle operations (resulting from the constraints of drivers' hours regulations and acceptable loading and unloading times) then the greater the probability that time savings will not be fully used following road investment. To test this the author built a computer based simulation model in which the operations of a freight vehicle were constrained by a set of drivers' hours regulations and permitted loading and unloading times. The vehicle was assigned to undertake a random sequence of trips of different lengths. The constraints were shown to impinge on vehicle operations where it was predicted that certain activities (ie loading, unloading and short trips) could not be completed within the working day. When this happened the vehicle was assumed to remain idle for the rest of the day and the activity was postponed to the next day.

Using different input assumptions the results of the model suggested that while additional constraints on vehicle operations could be expected to reduce efficiency there are no "a priori" grounds to suggest that they will reduce the probability of using time savings. The model provided as many cases where total idle time fell (ie time savings were more than fully used) as cases where total idle time rose (ie time savings were not fully used) following a reduction in trip times. The exact outcome was shown to be dependent upon the particular trip length distribution and the set of constraints assumed in the model.

There are several ways of trying to estimate how time savings may be used following road investment. One approach is to ask operators to guess what their response would be given the predicted reduction in journey times. Even if it is assumed that each operator can correctly forecast his response the results are very difficult to interpret because unless a lot of detail is known there is no simple way of comparing those who say they can make productivity gains with those who say they cannot. It is possible, for example, that time savings will, on average, be fully used if only one operator in twenty can benefit.

Another approach is to look at changes in utilisation before and after an investment has been made. This was done by both Fleischer and by Thomas. Fleischer looked at one company operating on the route between Grants Pass, Portland and Seattle on the West Coast of the USA. There was a series of road improvements which gradually reduced journey times over many years. Fleischer found that an extra trip between Portland and Seattle could only be made once journey times had been reduced to a given amount. On the route between Grants Pass and Portland he found that it was only when the firm could relocate its depot could the reductions in journey times be translated into an increase in the distance travelled which occurred many years after the first road improvements. Unfortunately it is not known how representative or complete the case was. Without a total survey of all operators using the route it is not known whether other operators were able make use of the time savings. Likewise it is possible to imagine other situations with only one major route where impressive productivity gains could occur with only very small time savings.

Thomas carried out an historical "before and after" analysis as well as cross-sectional analysis to determine how vehicle productivity might change following road investment. For the historical analysis, data was collected on vehicle productivity before and after the new Kuala Lumpur - Karak highway was opened in West Malaysia which reduced vehicle trip times by an average of 45 minutes. By collecting data on the operations of various types of commercial vehicles Thomas could not find any dramatic improvements in vehicle productivity following the opening of the new road section. In fact for certain vehicle types the level of trip making per day fell in the Kuala Lumpur area. Unfortunately during the period which was covered by the data collection large changes were recorded in both the Malaysian commercial vehicle fleet numbers and in the levels of economic activity. Both of these factors could easily have swamped any beneficial effect of the road on vehicle productivity.

In the Malaysian cross sectional analysis Thomas derived a number of elasticities for different categories of commercial vehicles between trips made per day and average travel time per trip. Most of the Malaysian data was collected from a roadside interview survey in which drivers were asked what trips had been made in the previous 24 hours. The elasticities found ranged from -0.2 to -0.6. So that if travel time is reduced by one per cent then trip making can be expected to rise by between 0.2 and 0.6 per cent. The analysis suggests that the models which predict a one per cent increase in distance travelled for one per cent decline in travel time will clearly overestimate the effects of journey time savings. However to estimate the extent to which vehicle working time savings are used it is necessary to include loading and unloading time within trip times in the calculation of the elasticities. Loading and unloading times were not collected in the Malaysian study and as a result the derived elasticities underestimate the extend to which time savings may be used following journey time savings.

It is against this background that it was decided to repeat and extend the cross-sectional analysis used by Thomas in Malaysia using vehicle activity data from Pakistan.

3. THE ROAD FREIGHT TRANSPORT INDUSTRY IN PAKISTAN

Currently in Pakistan there are in the order of 45,000 trucks in operation, of which about 95 per cent are privately owned. The National Logistics Cell (part of the armed forces) has about 2000 trucks that are primarily used to supplement the railways in the long distance bulk movement of grains and fuel.

General information on private commercial road freight transport in Pakistan was collected from the Roadside Interview Survey of truck drivers. (This is described in Working Paper No. 253). Three quarters of the trucks surveyed were two axle Bedford trucks, 14 per cent were two axle Japanese trucks and the remainder were divided between three axle rigid vehicles and tractor trailer combinations.

Less than one per cent of the trucks surveyed were owned by a company for its own account operations. The industry is entirely organised on a "hire and reward" basis. Most trucks operate on the basis of picking up business where they can and going from job to job as demand requires. It is very common for drivers to work away from base for up to three weeks. The Roadside Interview Survey found that on average drivers of Bedford trucks returned to base after 7 days and returned to their family after 17 days.

The driver is responsible for finding the load, for collecting revenue, and for repairing the truck. When he returns to base he has to account for the revenue earned and the expenditures incurred. About 80 per cent of drivers are employees and approximately 17 per cent own their own vehicle. The remaining three per cent own a part share of the vehicle that they drive.

There is an extensive network of freight agents who assist the driver to find a load. Over 60 per cent of loads were found using agents. In practice vehicles can usually be found for a consignor within one hour. Virtually all agents are connected by telephone which plays an important part in their business.

There is very little specialisation in body types. About 85 per cent of the Bedfords and 60 per cent of other trucks are high sided, while 8 per cent of Bedfords and 20 per cent of other trucks are tankers.

Virtually all freight vehicles in Pakistan have sufficient space within the cab to seat four people. In addition there is usually a purpose built space on top of the cab where a driver or his assistant can rest or sleep whilst the vehicle is in motion. Just over half the trucks have two drivers and one assistant, the remainder have just one driver and one assistant.

4. SURVEY PROCEDURE

In Pakistan a high proportion of journeys last more than one day; for this reason it was felt to be inappropriate to use a roadside interview survey to collect data on the time and duration of vehicle activities. A "Vehicle Activity Survey" was undertaken whereby different activities were recorded and timed as they occurred. Data was collected from a sample of trucks on a continuous basis for periods lasting from five days to over four weeks. The data was collected by both survey staff and by cooperative drivers. The survey staff travelled with their allotted trucks continuously throughout the period, if necessary sleeping on board the truck as it travelled. Where cooperative drivers were used they were paid an additional sum to record their activities. In total over 600 days of useful data were collected, about one fifth of this being recorded by drivers, the rest by survey staff. This comprised 24 periods of data related to conventional two axle Bedford trucks, seven periods to Bedford tanker trucks and 14 periods to conventional two and three axle Mercedes trucks. The latter trucks were owned and driven by Afghan Refugees. Key data relating to the trucks that were used in the Vehicle Activity Survey are shown in Appendix 1.

In view of the difficulty encountered in placing the survey staff with vehicles many staff made use of their contacts to find vehicles with which they could work. Where possible an activity chart recorder was fixed to the vehicle chassis to record when the truck was in motion or at rest. The recorder provided a check on the manual records.

Detailed records of the timing of all movements, rest periods, loadings, unloadings, waiting periods, emergencies and repairs were collected on a continuous basis. Vehicle stops of less than 15 minutes were ignored. Cooperation was sought from the other drivers and assistants travelling with the vehicle to help record those details which the survey assistant or driver missed whilst he was asleep.

Additional data on the distance travelled, costs incurred and revenue earned were also recorded. English translations of the two survey forms used to record the data are shown in Appendix 2.

5. THE PATTERN OF VEHICLE USE

The Vehicle Activity Survey collected data on trucks engaged on a variety of patterns of operation and covered a wide spectrum of trip lengths. The 45 survey periods covered 405 loaded trips and 327 empty trips. Distances were recorded for 92 per cent of the trips and for these trips the mean loaded and mean empty trip distances were 347 kms and 150 kms respectively. Fifteen per cent of loaded trips and 42 per cent of empty trips were under 50 kms while eight per cent of the loaded trips and two per cent of the empty trips were over 1000 kms.

To analyse the pattern of vehicle productivity and time use it was necessary, as far as possible, to allocate time spent in different activities into empty and loaded trip periods. For each trip the time spent moving, loading, unloading, resting, or under repair was totalled. Because of the long journey distances one trip was usually broken up into a series of movements and rest periods. On average each loaded trip and each empty trip was composed of approximately 5 and 3 separate movements respectively.

Because the vehicle is at least partially loaded during loading and unloading these activities were defined to be part of a loaded trip. No difference was distinguished between resting and waiting in the subsequent analysis. Waiting to unload was counted as part of a loaded trip while waiting to load after completing an empty movement was counted as part of that empty trip. For a loaded trip to finish the truck would have to be completely unloaded; so a sequence of multiple partial loadings or unloadings would all be counted as part of one loaded trip. A loading is necessary to finish an empty trip. So a series of empty movements (made in any direction) were counted as part of one empty trip. Besides the loaded and empty trips there were also periods between two loaded trips when the vehicle did not move empty. In total 63 periods of this type were recorded. Detailed activity data is shown in Table A2 of Appendix 1. The mean periods spent in each activity for the whole survey are shown in Table 1.

Table 1

Mean Times Spent on Each Activity for Loaded and Unloaded Trip Periods

	Moving Hrs	Loading Hrs	Unloading Hrs	Resting Hrs	Repair Hrs	Total Hrs
Loaded Trips	10.8	2.2	1.9	6.5	0.3	21.8
Empty Trips	4.4	-	-	11.3	0.9	16.5
Empty Periods Between Loaded Trips	-	-	-	7.1	0.6	7.7

Source: Vehicle Activity Survey

On average loaded trip periods were found to last 21.8 hrs while empty trip periods were found to last 16.5 hrs. In total trucks were found to be loaded 56 per cent of the time. Rest and waiting time accounted for 30 per cent of loaded trip time, but overall 63 per cent of rest and waiting occurred while the truck was empty.

The average duration between the end of loading and arrival at the destination was found to be 14.9 hrs which gives an average loaded journey speed (including intermediate rest periods) of 23 kph. This is the same overall journey speed found for loaded Bedford trucks in the Roadside Interview Survey. Using data from the Vehicle Activity Survey an estimate of 109,000 kms was calculated for annual vehicle travel. This is very close to the mean estimate of 112,000 kms found from the Roadside Interview Survey.

The distribution of total loaded and empty trip times found by the survey is shown in Figure 1. Although 70 per cent of loaded trips took less than 24 hrs, 13 per cent lasted longer than 48 hrs.

A breakdown of time by activity is shown in Figure 2. This demonstrates the high degree of time utilisation of the surveyed vehicles. Most vehicles worked round the clock with activity interrupted only by short rest and waiting periods. Vehicles were found to be moving 40 per cent of the time and loading or unloading a further 11 per cent of the time. Rest periods accounted for 46 per cent of the time. In total trucks were in active use 51 per cent of the time (ie. over 12 hours per day).

Some variation was found in the daily pattern of activities although the differences were not particularly marked. Wednesday was found to be the most active day with movement accounting for 44 per cent and resting 40 per cent of the day. Total activity was not substantially reduced on Friday compared with other days apart from loading and unloading which accounted for 9 per cent of the day compared to the average of 11 per cent.

Figure 1

Trip Time Distribution

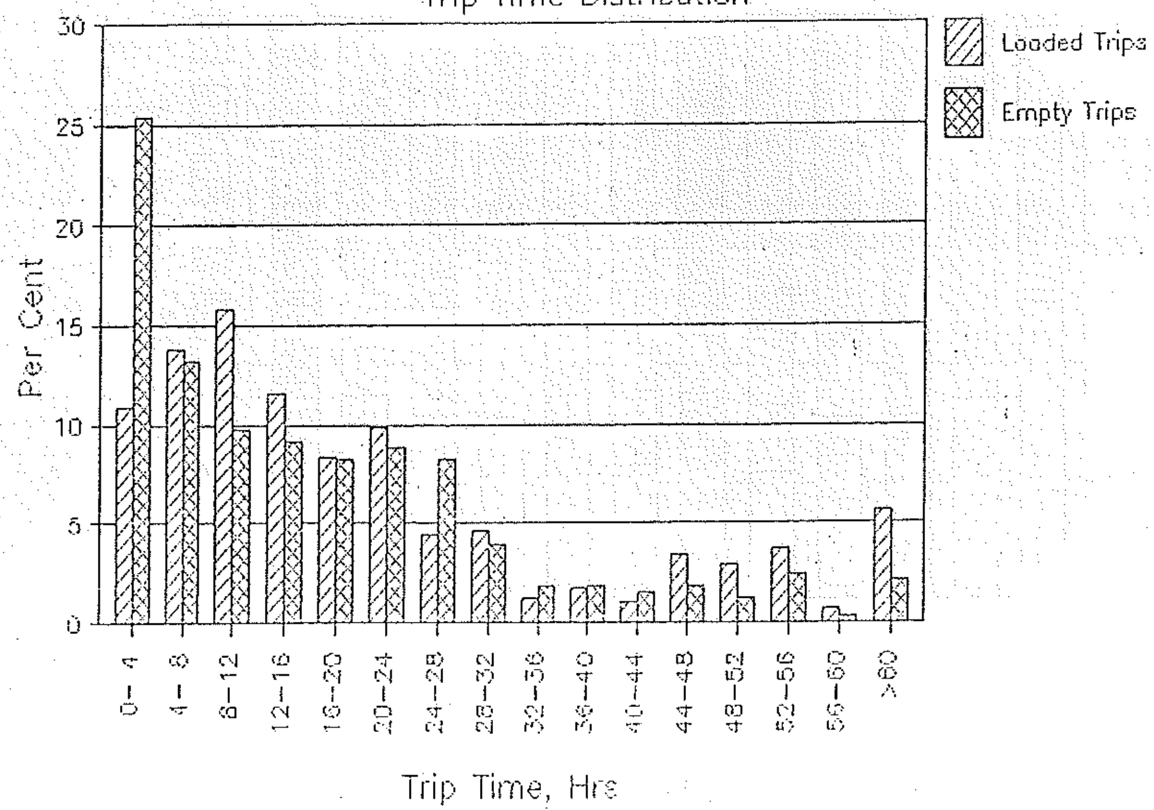


Figure 2

Breakdown of Vehicle Time by Activity

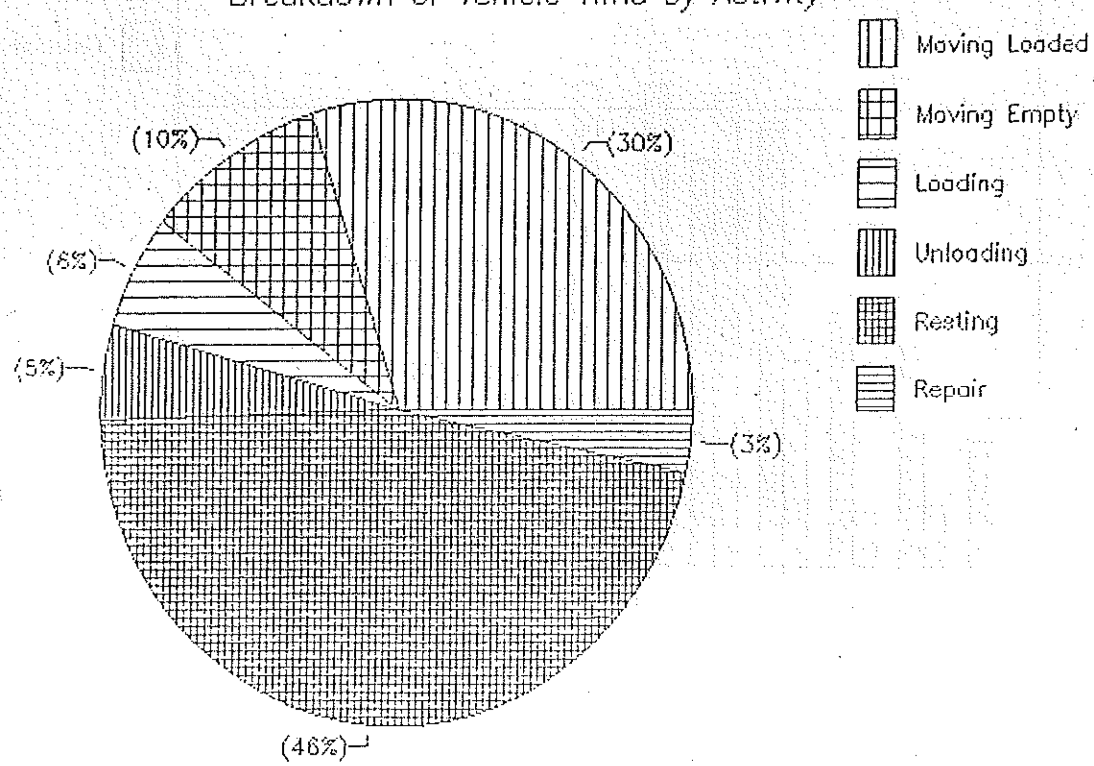


Figure 3

Distribution of Activities by Time of Day

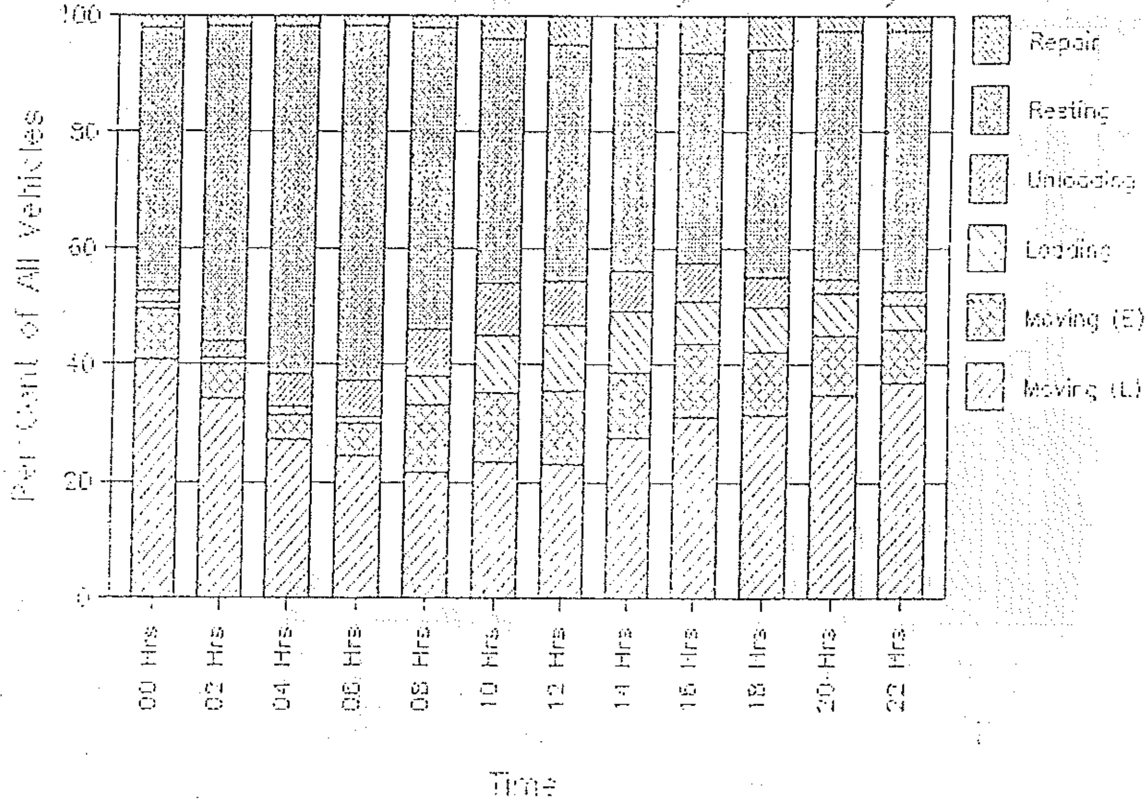


Figure 4

Loading & Unloading Start Times

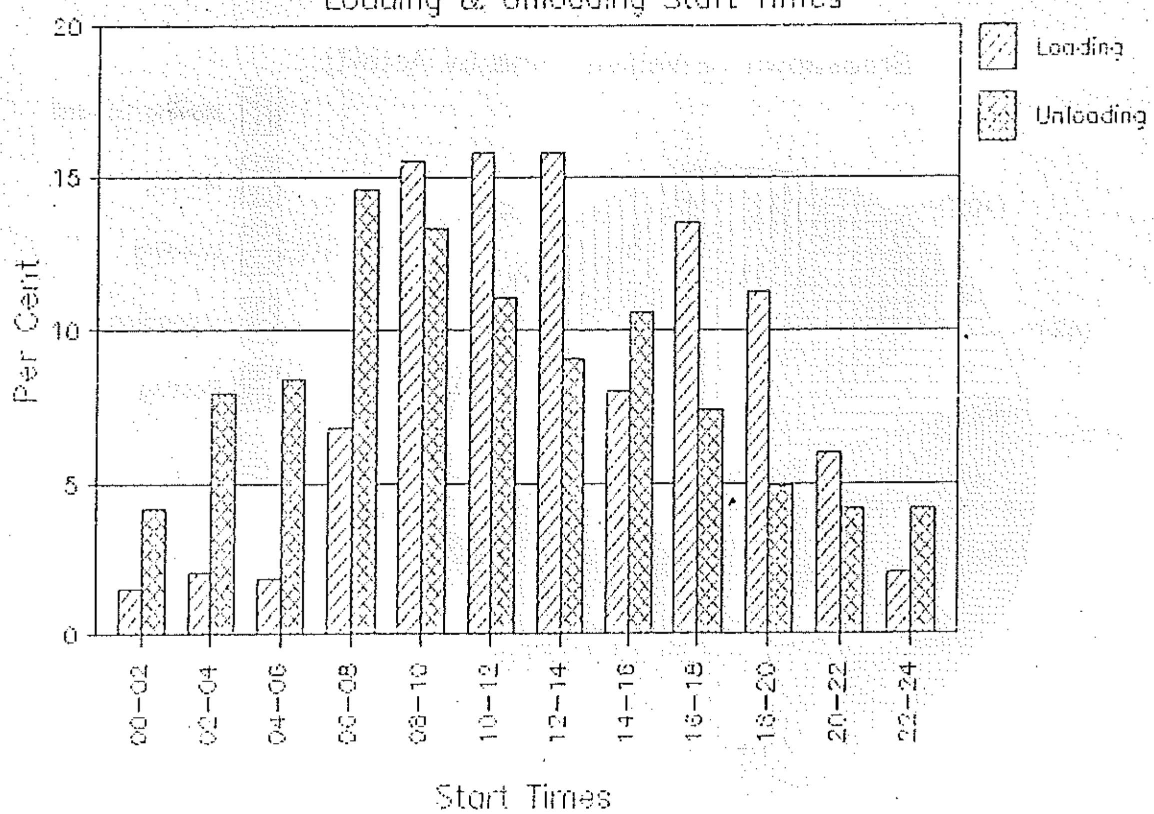


Figure 3 shows how vehicle use changes throughout the day. The most active movement times are between 16.00 hrs and 02.00 hrs. Trucks are most likely to be at rest between 02.00 hrs and 08.00 hrs. Even at the quietest time of day, 06.00 hrs, 37 per cent of vehicles are working. The most active loading and unloading times are in the middle of the working day between 08.00 hrs and 18.00 hrs.

Figure 4 gives the distribution of the start times of loading and unloading. Although most loading and unloading takes place during the "normal working day" 13 per cent of loading and 29 per cent of unloading was started between 20.00 hrs and 6.00 hrs. Unloading (which lasts less time) is more evenly distributed throughout the day than loading. In Pakistan it is usually necessary to hire labour for loading and unloading and so the industry appears to be quite flexible in allowing for it to take place throughout the night.

An analysis of the data showed that a rest or waiting period occurred in 57 per cent of the time periods immediately prior to a loading. On average this period lasted 8.9 hrs. In other words, as expected, drivers tended to take a break after completing a delivery and before collecting their next load. But many also took the opportunity for a break before unloading. In 40 per cent of the periods immediately prior to an unloading a rest or waiting period occurred which lasted on average 6.1 hrs.

6. THE RELATIONSHIP BETWEEN TRIPS AND VEHICLE WORKING TIME

In Section 2, it was reported that in order to estimate the extent to which journey time savings could be translated into extra trip making, Thomas collected cross sectional data from a survey in Malaysia to derive a series of elasticities between trip making and average trip movement times. This analysis was repeated and extended using data from the Vehicle Activity Survey in Pakistan.

The Pakistan survey data was collected over periods lasting up to four weeks. During the survey some of the truck drivers took their normal "day off" recreational rest while other drivers did not. In order to estimate the extent to which this lack of uniformity may have biased the result an additional analysis was undertaken using data adjusted for long rest periods. A relationship had been found between rest days per month and loaded journey time from data collected from the Roadside Interview Survey and this was used to smooth the total amount of time devoted to long rest periods in the "adjusted data set" referred to below. A further analysis was carried out which excluded data from the tanker trucks which have their own unique pattern of operation. The following three data sets were prepared:

i) The basic data set (45 cases)

ii) The adjusted data set (45 cases)

iii) The adjusted data set excluding tankers (38 cases)

Each data set was derived from the 45 survey periods of the Vehicle Activity Survey. For each case the number of the trips made per day, the moving and working time per trip and the mean working time per day was calculated.

One approach to the problem of estimating the utilisation of time savings is to determine the relationship between total working time per day and average movement time per trip. If it is believed that time savings cannot be fully used then it could be expected that working time per day (ie all moving time and loading and unloading time) would rise with mean travel time. This analysis is presented in Table 2.

Table 2

Regressions Relating Total Working Time Per Day To Movement Time Per Trip

Basic data set. N = 45

i) Total working time per day = 11.0 + 0.11 * (Mean movement time per trip) (se = 0.04)

R squared value = 0.13, T value = 2.56, Chance Probability = 0.014

Adjusted data set. N = 45

ii) Total working time per day = 10.8 + 0.074 * (mean movement time per trip) (se = 0.035)

R squared value = 0.09, T value = 2.09, Chance Probability = 0.042

Adjusted data set excluding tankers. N = 38

iii) Total working time per day = 11.5 - 5.7 * 10^-5 * (mean movement time per trip) (se = 0.07)

R squared value = 0.00, T value -7.9 * 10 ^-4, Chance Probability = 0.999

(Note: Chance probability = probability that there is no relationship.)

Although both of the first two regressions shown in Table 2 have positive slope coefficients and are significant at the 5 per cent level of probability they have very low explanatory power. The last regression has no significance at all. The analysis shown in Table 2 shows no consistent relationship between total working time per day and movement time per trip hence there is little evidence to suggest that journey time savings will not be fully used.

To carry out his analysis Thomas calculated elasticities between trips made per day and movement time per trip. Without the incorporation of loading and unloading time these elasticities cannot be used directly to estimate the extent to which time savings can be used following journey time savings. However the analysis is useful for indicating how the total distance travelled by each vehicle might change with a change in travel time. For example if trip distances remained constant an elasticity of -0.8 would suggest that a one per cent decline in travel time will bring about an increase of 0.8 per cent in the number of trips made, and hence in the total distance travelled, per vehicle.

An elasticity of -1 between trips made and movement time is unlikely where loading and unloading times are significant. An elasticity of this magnitude would imply that that total working time (including moving, loading, and unloading time) will increase with travel time savings.

The most convenient way of estimating an elasticity is by using a log - log regression analysis. The elasticity is the coefficient "b" in the following regression:-

$$\text{Log (trips)} = a + b*\text{Log (journey time)}$$

Using the three Pakistan data sets mentioned above Table 3 gives the results of regressions relating trips per day to mean trip movement times. Separate regression results are given for "loaded trips" and for "all trips". "All trips per day" refers to the mean number of loaded and empty trips made per day. Precise definitions of loaded and empty trips are given in Section 5. above.

Table 3

Regressions Relating Trips Per Day to Moving Time Per Trip

Basic data set. N = 45

iv) Log (all trips per day) = 0.682 - 0.698 Log (movement time per trip)
(se = 0.036)

R squared value = 0.90, T value = -19.6, Chance Probability = 0

v) Log (loaded trips per day) = 0.518 - 0.709 Log (loaded movement time per trip)
(se = 0.046)

R squared value = 0.85, T value = -18.1, Chance Probability = 0

Adjusted data set. N = 45

vi) Log (all trips per day) = 0.715 - 0.755 Log (movement time per trip)
(se = 0.032)

R squared value = 0.93, T value = -23.7, Chance Probability = 0

vii) Log (loaded trips per day) = 0.56 - 0.768 Log (loaded movement time per trip)
(se = 0.042)

R squared value = 0.88, T value = -18.0, Chance Probability = 0

Adjusted data set excluding tankers. N = 38

viii) Log (all trips per day) = 0.724 - 0.765 Log (movement time per trip)
(se = 0.043)

R squared value = 0.90, T value = -17.9 Chance Probability = 0

ix) Log (loaded trips per day) = 0.506 - 0.702 Log (loaded movement time per trip)
(se = 0.048)

R squared value = 0.86, T value = -14.6 Chance Probability = 0

The regressions shown in Table 3 have high R squared values and are very significant. The derived elasticities relating trips per day to mean movement time per trip lie within the range -0.70 to -0.77. So that if mean movement times are cut by one per cent then trip making will rise by just over 0.7 of one per cent. These elasticities are much higher than those found by Thomas.

To estimate the extent to which time savings can be fully used following road investment it is necessary to calculate the elasticities using total working time including loading and unloading time. Regressions showing these elasticities are given in Table 4. For each data set three elasticities are presented these relate the following variables:-

i) "all trips per day" to "mean total working time per trip"

ii) "loaded trips per day" to "mean loaded working time per loaded trip"

iii) "loaded trips per day" to "mean total working time per loaded trip"

The last type of elasticity provides an estimate (as far as is practical in Pakistan conditions) of the response of "round trip" making to total working time per "round trip". In the analysis total working time refers to all empty and loaded moving time and loading and unloading time. Loaded working time refers to loaded moving time and loading and unloading time. No rest, waiting, or repair time is included in the calculation of working time.

Table 4

Regressions Relating Trips Per Day To Working Time Per Trip

Basic Data Set. N= 45

x) Log (all trips per day) = 0.909 - 0.838 Log (mean total working time per trip)
(se = 0.047)

R squared value = 0.88, T value = -17.7, Chance Probability = 0

xi) Log (loaded trips per day) = 0.873 - 0.913 Log (mean loaded working time per loaded trip)
(se = 0.061)

R squared value = 0.84, T value = -14.9, Chance Probability = 0

xii) Log (loaded trips per day) = 0.90 - 0.864 Log (mean total working time per loaded trip)
(se = 0.045)

R squared value = 0.90, T value = -19.3, Chance Probability = 0

Table 4 continued.

Adjusted Data Set. N = 45

xiii) Log (all trips per day) = 0.968 - 0.913 Log (mean total working time per trip)
(se = 0.041)

R squared value = 0.92, T value = -22.4, Chance Probability = 0

xiv) Log (loaded trips per day) = 0.951 - 0.995 Log (mean loaded working time per loaded trip)
(se = 0.054)

R squared value = 0.89, T value = - 18.4, Chance Probability = 0

xv) Log (loaded trips per day) = 0.969 - 0.932 Log (mean total working time per loaded trip)
(se=0.038)

R squared value = 0.93, T value = -24.4, Chance Probability = 0

Adjusted data set excluding tankers. N = 38

xvi) Log (all trips per day) = 1.00 - 0.95 Log (mean total working time per trip)
(se = 0.054)

R squared value = 0.89, T value = -17.5, Chance Probability = 0

xvii) Log (loaded trips per day) = 0.88 - 0.925 Log (mean loaded working time per loaded trip)
(se = 0.066)

R squared value = 0.85, T value = -14.1, Chance Probability = 0

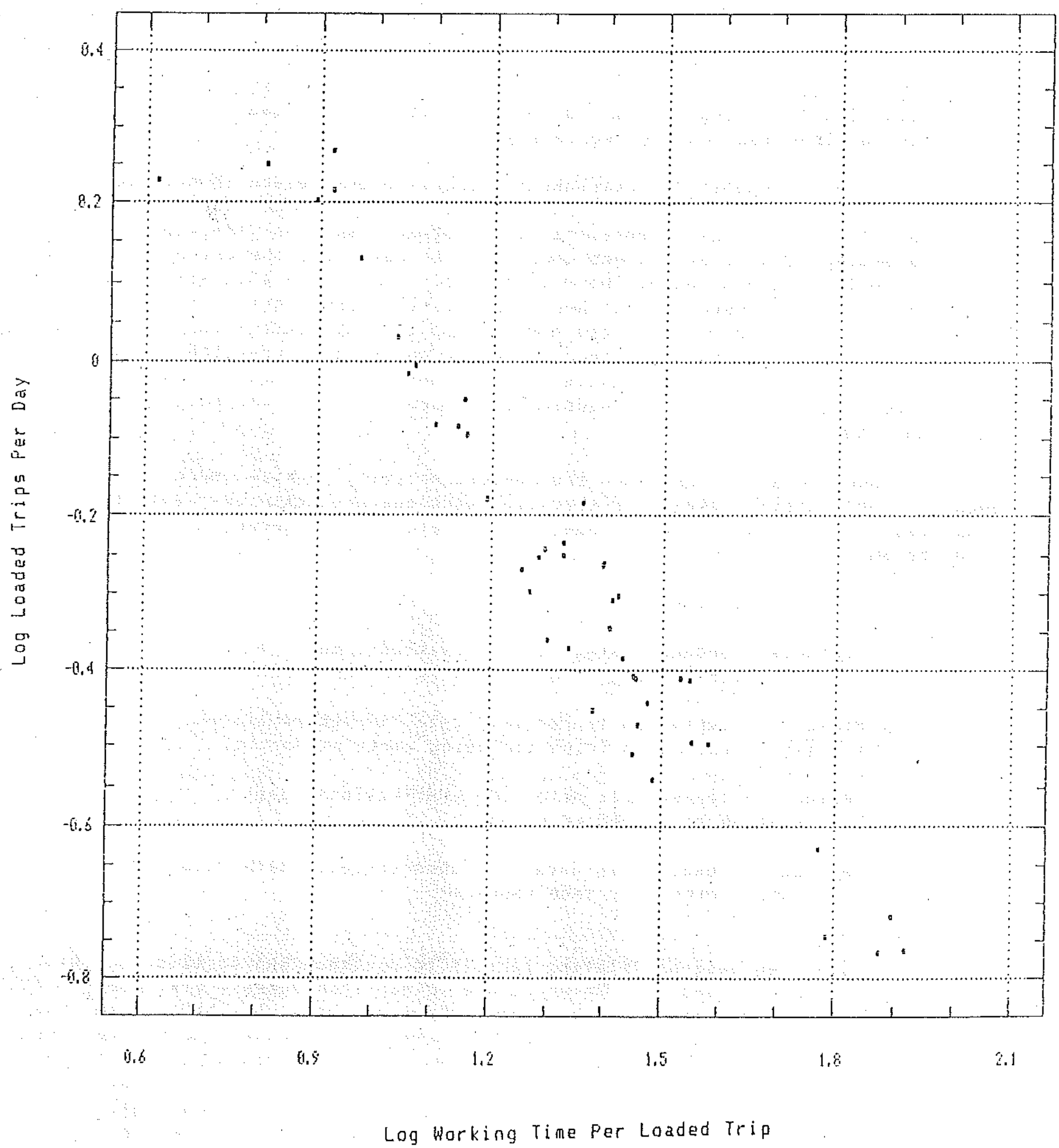
xviii) Log (loaded trips per day) = 1.03 - 0.98 Log (mean total working time per loaded trip)
(se = 0.052)

R squared value = 0.91, T value = - 18.7, Chance Probability = 0

Elasticities relating trips per day to working time are given by the regressions shown in Table 4. These range from -0.84 to -1. All of the regressions are highly significant and have high R squared values. Figure 5 gives a typical plot of the Log - Log relationship (in this case the data used in Regression (xv) is used). Overall, by introducing loading and unloading into the analysis, the elasticity values have risen by 25 per cent. The mean value of the elasticities is -0.92 so that we could expect commercial vehicles to make use of over 90 per cent of the time savings following road investment.

Figure 5

Loaded Trips Per Day Against Working Time Per Trip



7. THE RELATIONSHIP BETWEEN REVENUE AND JOURNEY TIME AND DISTANCE

Road freight transport in Pakistan is largely organised on a free market basis. Freight tariffs are competitively determined by supply and demand and there is little direct government intervention. The industry is dominated by a large number of individual entrepreneurs operating a "hire and reward" service. Entry into the industry is cheap and easy; there is a relatively lax licensing system and there is little enforcement of axle load limits or construction and use regulations.

In this competitive environment there is every reason to believe that revenues and tariffs reflect operating costs. To examine whether it was possible to identify the proportions of operating costs that are dependent on time and distance, an analysis was undertaken to determine the extent to which tariffs could be explained by these variables. A model of this sort could be useful in helping construct and check the relative importance of time related costs within the more complex cost models used in road investment appraisal. The analysis was carried out using simple and multiple regression techniques with data collected from the Vehicle Activity Survey. A similar investigation of tariffs using data from the Roadside Interview Survey is reported in Working Paper No. 255.

Four sets of data from the Vehicle Activity Survey were analysed. Because the tariff rates for carrying petroleum products are set by oil companies directly on a distance basis, data relating to tankers were excluded from the analysis.

The sets of data were as follows :-

i) Bedfords - grouped data, 26 observations, data relating to periods lasting from five days to four weeks.

ii) Bedfords - empty and loaded trip data, 176 observations, data relating to trips including empty movements.

iii) Bedfords - loaded trip data, 201 observations, data relating to loaded trips only.

iv) Mercedes - loaded trip data, 77 observations, data relating to loaded trips only (non tankers).

Simple regressions relating tariffs to distance and tariffs to time are shown in Tables 5 and 6. Revenues are in Pakistan Rupees, distances are in kilometres and time is in hours. The regressions show that both time and distance are good explanatory variables of tariffs. The relationships are very significant and the R squared values are high. Distance is a better explanatory variable for the grouped Bedford data set and for the Mercedes data set while time is a better explanatory variable for two Bedford trip data sets. Moving time appears to be a better explanatory variable than working time.

Table 5

Regressions Relating Tariffs to Distance

Bedfords - grouped data set N = 26

xix) Tariff Revenue (for period) = 1499 + 2.50 * (Empty & Loaded Distance)
(se = 0.17)

R squared value = 0.90, T value = 15.0, Chance Probability ≑ 0

Bedfords - empty and loaded trip data set N = 178

xx) Trip Tariff = 286 + 2.28 * (Empty & Loaded Trip Distance)
(se = 0.12)

R squared value = 0.67, T value = 18.8, Chance Probability = 0

Bedfords - loaded trip data set N = 201

xxi) Trip Tariff = 363 + 2.76 * (Loaded Trip Distance)
(se = 0.15)

R squared value = 0.62, T value = 18.0, Chance Probability = 0

Mercedes - loaded trip data set N = 77

xxii) Trip Tariff = 165 + 6.14 * (Loaded Trip Distance)
(se = 0.39)

R squared value = 0.76, T value = 15.8, Chance Probability = 0

Table 6

Regressions Relating Tariffs To Time

Bedfords - grouped data set   N = 26

xxiii) Tariff Revenue (for period) = -1634 + 86.2 * (Empty & Loaded Work Time)
(se = 7.13)

R squared value = 0.86, T value = 12.1, Chance Probability = 0

Bedfords - empty and loaded trip data set   N = 178

xxiv) Trip Tariff = 246 + 73.7 * (Empty & Loaded Moving Time)
(se = 3.77)

R squared value = 0.69, T value = 19.6, Chance Probability = 0

xxv) Trip Tariff = 93.6 + 66.9 * (Empty & Loaded Work Time)
(se = 3.47)

R squared value = 0.68, T value = 19.3, Chance Probability = 0

Bedfords - loaded trip data set   N = 201

xxvi) Trip Tariff = 250 + 97.7 * (Loaded Moving Time)
(se = 3.9)

R squared value = 0.76, T value = 24.9, Chance Probability = 0

xxvii) Trip Tariff = 34.6 + 87.6 * (Loaded Work Time)
(se = 3.6)

R squared value = 0.75, T value = 24.4, Chance Probability = 0

Mercedes - loaded trip data set   N = 77

xxviii) Trip Tariff = 452 + 147 * (Loaded Moving Time)
(se = 12.2)

R squared value = 0.66, T value = 12.1, Chance Probability = 0

xxix) Trip Tariff = 381 + 115 * (Loaded Work Time)
(se = 12.9)

R squared value = 0.52, T value = 8.9, Chance Probability = 0

Table 7

Regressions Relating Tariffs to Time And Distance

Bedfords - grouped data set   N = 26

xxx) Tariff Revenue (for period)

= -350 + 1.61 * (Empty & Loaded Distance)   T value = 4.96
(se = 0.324)   Chance Probability = 0.00005

+ 35.3 * (Empty & Loaded Work Time)   T value = 3.09
(se = 11.4)   Chance Probability = 0.0052

R squared value = 0.93

Bedfords - empty and loaded trip data set   N = 178

xxxi) Trip Tariff = 141 + 37.8 * (Empty & Loaded Work Time)   T value = 4.67
(se = 8.06)   Chance Probability = 0.00001

+ 1.1 * (Empty & Loaded Distance)   T value = 3.96
(se = 0.28)   Chance Probability = 0.00011

R squared value = 0.70

Bedfords - loaded trip data set   N = 201

xxxii) Trip Tariff = 47.5 + 80.1 * (Loaded Work Time)   T value = 10.2
(se = 7.87)   Chance Probability = 0

+ 0.292 * (Loaded Distance)   T value = 1.07
(se = 0.27)   Chance Probability = 0.286

R squared value = 0.75

Mercedes - loaded trip data set   N = 77

xxxiii) Trip Tariff = -3.08 + 5.43 * (Loaded Distance)   T value = 9.27
(se = 0.586)   Chance Probability = 0

+ 21.7 * (Loaded Work Time)   T value = 1.62
(se = 13.4)   Chance Probability = 0.1104

R squared value = 0.78

Multiple regressions relating tariffs to working time and distance are shown in Table 7. These multiple regressions provide a slightly better explanation than the simple regressions. The R squared value is raised in three of the four data sets by between two and three per cent compared with best alternative simple regression. However in the last two regressions the second term has very little significance. Comparing the results with the simple regression results it is quite clear that there is a high degree of correlation present between time and distance.

One way of testing the usefulness of the multiple regression model when multicollinearity is present between the independent variables is to compare the R squared value of the regression with the squared correlation coefficient between the independent variables. This is done in Table 8. In this table it can be seen that for the two Bedford trip data sets the multiple regression R squared value is lower than the squared correlation coefficient between the independent variables. This suggests that multiple regression results for these two data sets are not satisfactory. Taking this into account together with the significance tests it appears that the multiple regression for the grouped Bedford data set provides the best explanation.

Table 8 provides an estimate of the percentage of the mean tariff of each data set that is explained by time and distance in the different multiple regressions. The Bedford grouped data set and the Mercedes data set have a total percentage "explained" by time and distance that is greater than 100 per cent. This is because the constant term in the regression equation is negative.

Table 8

Proportion of Tariffs explained by Time and Distance

Data Set	Per Cent Of Tariffs Explained By:- Constant Term	Work Time	Distance	Multiple Regression R squared	Squared corr. coefficient between Time & Distance
Bedfords - grouped data	-2.8	46.3	56.5	0.93	0.86
Bedfords - empty & loaded trip data	13.4	51.5	35.1	0.70	0.83
Bedfords - loaded trip data	4.2	88.6	7.1*	0.75	0.79
Mercedes - loaded trip data	-0.1	16.5*	83.6	0.78	0.56

* Term not significant at 5 % probability.

Table 8 suggests that multiple regression analysis cannot easily be used to explain tariffs. There is considerable variation in the relative importance of time and distance for the different data sets. Assuming that the grouped Bedford data set provides the best explanation and adjusting for the constant term then working time and distance account for 45 and 55 per cent of tariffs respectively. The grouped data regression suggests that revenue will increase by Rs 1.6 for each extra kilometre travelled and increase by Rs 35.3 for each extra hour worked.

8. CONCLUSION

Vehicle time utilisation has been relatively neglected as an area of research and yet it plays an important part in the calculation of benefits arising from journey time savings. To estimate time savings benefits satisfactorily following a road investment it is necessary to make assumptions on the likely change in vehicle utilisation. Measured on a per kilometre basis the indivisible components of operating costs (labour, depreciation, interest, and overheads) will fall as utilisation rises. Previous research has suggested that freight vehicle time savings may not be fully used.

Freight vehicles are used very intensively in Pakistan. The survey found that vehicle running accounted for 40 per cent of the time and that with loading and unloading vehicles were in active use for over 12 hours per day. Vehicles are used intensively at night; the most active running period was between 4.00 pm. and 2.00 am. Even at the quietest time of day, 06.00 hrs, 37 per cent of vehicles were working. Although most loading and unloading does take place during the "normal working day" 13 per cent of loading and 29 per cent of unloading was started between 8.00 pm. and 6.00 am.

There was no consistent change in working time per day with changing journey times. In addition, elasticities relating trips made per day to mean trip working time ranged between -0.84 and -1. with a mean value of - 0.92. Both the analysis of working time per day and the elasticity analysis suggest that in Pakistan's conditions, journey time savings following road investment are likely to be fully translated into extra trips.

A statistical analysis of freight tariffs with trip times and distances found that either time or distance could provide a good explanation of tariffs. However the high degree of correlation between time and distance made it difficult to identify the separate explanatory power of either variable. The best analysis suggested that time and distance could account for 45 per cent and 55 per cent of tariffs respectively.

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APPENDIX 1.

Table A1

Vehicle Activity Survey Data

Code No.	Make	Axles	Type	Start Date	Survey Days	No. of trips: (loaded)	(empty)
1	Bedford	2	Simple truck	03/07/85	13	6	4
2	Bedford	2	Simple truck	03/07/85	7	4	3
3	Mercedes	3	Simple truck	07/10/85	16	6	6
4	Bedford	2	Simple truck	03/07/85	10	4	3
5	Bedford	2	Simple truck	01/11/85	16	27	3
6	Bedford	2	Simple truck	17/10/85	13	26	12
7	Mercedes	2	Simple truck	21/11/85	11	6	5
8	Bedford	2	Simple truck	08/05/86	7	6	6
9	Bedford	2	Simple truck	07/09/85	19	10	10
10	Mercedes	3	Simple truck	17/07/85	12	7	6
11	Mercedes	3	Simple truck	23/08/85	17	8	8
12	Mercedes	3	Simple truck	20/09/85	18	8	8
13	Mercedes	3	Simple truck	08/10/85	19	8	8
14	Bedford	2	Simple truck	08/02/86	6	4	5
15	Bedford	2	Tanker	19/02/86	20	9	6
17	Bedford	2	Simple truck	11/02/86	18	11	12
19	Bedford	3	Simple truck	15/03/86	16	13	13
20	Mercedes	3	Simple truck	11/02/86	16	6	6
21	Mercedes	3	Simple truck	14/03/86	17	6	6
22	Mercedes	3	Simple truck	30/03/86	17	5	5
23	Bedford	3	Simple truck	01/04/86	15	14	14
24	Bedford	2	Tanker	16/03/86	33	11	6
26	Bedford	2	Simple truck	03/04/86	29	16	17
28	Bedford	3	Simple truck	16/04/86	16	18	19
29	Mercedes	3	Simple truck	15/04/86	16	5	5
30	Bedford	2	Simple truck	08/03/86	10	5	4
31	Bedford	2	Simple truck	19/03/86	17	9	10
32	Bedford	2	Tanker	16/05/86	5	1	1
33	Bedford	2	Tanker	08/05/86	9	2	2
34	Bedford	2	Simple truck	09/07/86	19	16	15
35	Bedford	2	Simple truck	18/06/86	7	6	5
36	Bedford	2	Simple truck	06/05/86	12	8	9
38	Bedford	3	Simple truck	01/05/86	15	21	21
40	Bedford	2	Tanker	12/06/86	15	3	4
42	Bedford	2	Simple truck	02/10/85	10	13	8
43	Bedford	2	Simple truck	15/09/86	16	15	11
44	Bedford	2	Simple truck	02/03/86	14	12	3
45	Bedford	2	Tanker	26/05/86	11	2	3
46	Bedford	2	Simple truck	06/04/86	15	10	8
47	Bedford	2	Simple truck	22/03/86	14	20	11
48	Mercedes	3	Simple truck	08/09/85	8	3	2
49	Bedford	2	Tanker	01/09/85	16	3	4
50	Mercedes	3	Simple truck	25/09/85	8	2	1
51	Mercedes	3	Simple truck	02/09/85	6	2	2
52	Mercedes	3	Simple truck	12/02/86	16	8	7

Table A2

Time Utilistation Data: Vehicle Activity Survey

Code No.	Total time Hrs	Loaded moving time Hrs	Empty moving time Hrs	Loading time Hrs	Unloading time Hrs	Rest time Hrs	Repair time Hrs	Loaded trips /Day No.	Total trips /Day No.	Moving time /Loaded trips Hrs	Moving time /all trips Hrs	Working time /all trips Hrs	Loaded Working time/ Loaded trips Hrs	Working time/ Loaded trips Hrs
1	287.7	91.5	22.7	6.5	6.3	158.2	2.5	0.50	0.83	15.2	11.4	12.7	17.4	21.2
2	158.7	75.3	11.0	7.9	5.8	48.5	10.1	0.61	1.06	18.8	12.3	14.3	22.3	25.0 *
3	384.0	97.7	29.4	10.2	7.0	225.0	14.7	0.38	0.75	16.3	10.6	12.0	19.2	24.1
4	210.0	88.5	11.5	3.5	4.5	97.0	5.0	0.46	0.80	22.1	14.3	15.4	24.1	27.0
5	356.0	107.0	5.0	64.0	49.0	99.0	32.0	1.82	2.02	4.0	3.7	7.5	8.1	8.3
6	303.0	88.0	28.0	48.0	53.5	71.5	14.0	2.06	3.01	3.4	3.1	5.7	7.3	8.4
7	241.7	69.3	17.6	8.7	11.6	129.1	5.4	0.60	1.09	11.6	7.9	9.7	14.9	17.9
8	158.3	44.8	20.0	9.8	8.7	73.0	2.1	0.91	1.82	7.5	5.4	6.9	10.5	13.9
9	421.9	162.5	47.4	20.7	17.6	164.6	9.1	0.57	1.14	16.2	10.5	12.4	20.1	24.8
10	388.5	127.2	44.2	10.5	15.5	165.2	25.7	0.43	0.80	18.2	13.2	15.2	21.9	28.2
11	384.7	131.7	38.7	16.0	18.5	169.2	10.5	0.50	1.00	16.5	10.7	12.8	20.8	25.6
12	449.5	174.0	47.0	33.0	29.0	153.5	13.0	0.43	0.85	21.7	13.8	17.7	29.5	35.4
13	447.0	168.5	35.0	46.5	22.0	136.0	39.0	0.43	0.86	21.1	12.7	17.0	29.6	34.6
14	132.7	58.8	16.2	7.7	9.0	40.4	0.7	0.72	1.63	14.7	8.3	10.2	18.9	22.5
15	449.3	137.6	16.9	13.9	10.5	231.9	38.5	0.48	0.80	15.3	10.3	11.9	18.0	19.9
17	422.0	148.8	41.7	25.0	17.8	186.7	1.9	0.63	1.31	13.5	8.3	10.1	17.4	21.2
19	368.1	90.9	29.3	26.9	17.6	198.7	4.6	0.85	1.70	7.0	4.6	6.3	10.4	12.7
20	335.0	109.7	34.2	12.5	14.0	159.5	5.0	0.43	0.86	18.3	12.0	14.2	22.7	28.4
21	365.0	106.5	29.5	17.5	19.0	194.0	18.5	0.37	0.75	17.7	11.3	14.4	23.8	28.7
22	364.0	76.0	40.0	12.0	13.0	216.0	7.0	0.33	0.66	15.2	11.6	14.1	20.2	28.2
23	349.6	71.2	27.0	36.1	17.6	197.6	0.0	0.96	1.92	5.1	3.5	5.4	8.9	10.9
24	775.5	332.3	47.2	14.6	24.8	347.4	9.1	0.34	0.53	30.2	22.3	24.6	33.8	38.1
26	690.5	186.7	55.5	29.1	24.2	349.7	45.3	0.56	1.15	11.7	7.3	9.0	15.0	18.5
28	360.2	50.5	29.4	22.5	13.5	244.3	0.0	1.20	2.47	2.8	2.2	3.1	4.8	6.4
29	377.0	95.5	20.5	16.0	19.0	213.0	11.0	0.32	0.64	19.1	11.6	15.3	26.5	30.6
30	218.9	86.1	12.2	22.0	11.9	86.5	0.0	0.55	0.99	17.2	10.9	14.7	24.0	26.4
31	392.0	108.6	32.4	14.6	16.4	201.3	18.6	0.55	1.16	12.1	7.4	9.1	15.5	19.1
32	127.0	31.2	36.8	4.2	3.0	51.9	0.0	0.19	0.38	31.2	34.0	37.6	38.3	75.1
33	185.1	61.8	46.3	2.4	7.7	65.0	1.8	0.26	0.52	30.9	27.0	29.6	36.0	59.1
34	430.7	101.5	70.9	34.5	22.2	201.6	0.0	0.89	1.73	6.3	5.6	7.4	9.9	14.3
35	131.5	32.5	18.1	10.3	8.9	61.7	0.0	1.10	2.01	5.4	4.6	6.3	8.6	11.6
36	304.2	74.4	49.4	18.6	14.6	145.0	2.1	0.63	1.34	9.3	7.3	9.2	13.5	19.6
38	332.8	27.9	24.1	19.4	16.1	211.8	33.6	1.51	3.03	1.3	1.2	2.1	3.0	4.2
40	342.5	117.7	97.0	2.7	18.8	100.0	6.3	0.21	0.49	39.2	30.7	33.7	46.4	78.7 *
42	239.7	37.7	20.5	21.5	22.2	126.3	11.5	1.30	2.10	2.9	2.8	4.9	6.3	7.8
43	348.5	63.0	36.5	41.0	29.0	161.5	17.5	1.03	1.79	4.2	3.8	6.5	8.9	11.3
44	313.0	142.0	3.8	14.3	10.2	136.6	6.1	0.92	1.15	11.8	9.7	11.4	13.9	14.2
45	252.5	71.8	81.4	5.3	7.3	81.8	4.7	0.19	0.48	35.9	30.6	33.2	42.2	83.0*
46	327.2	82.0	9.8	28.0	35.7	169.2	2.5	0.73	1.32	8.2	5.1	8.6	14.6	15.6
47	322.2	80.9	8.8	48.8	47.7	120.6	15.5	1.49	2.31	4.0	2.9	6.0	8.9	9.3
48	173.5	46.8	11.7	3.5	3.0	108.4	0.0	0.41	0.69	15.6	11.7	13.0	17.8	21.7
49	363.0	109.5	59.0	5.5	9.5	170.0	9.5	0.20	0.46	36.5	24.1	26.2	41.5	61.2
50	173.0	48.2	10.0	8.2	5.0	101.8	4.8	0.27	0.40	24.1	19.4	23.8	30.7	35.7
51	120.0	28.7	16.7	7.0	7.3	52.3	8.0	0.40	0.80	14.3	11.3	14.9	21.5	29.8
52	354.5	133.5	32.0	23.0	18.0	137.0	11.0	0.54	1.02	16.7	11.0	13.8	21.8	25.8

APPENDIX 2

Vehicle Activity Survey Questionnaire 1.

HICLE UTILIZATION MAY, 1985
RRL NTRC PAKISTAN FREIGHT TRANSPORT PROJECT
LOCK 4-B, AL-MARKAZ F-7, ISLAMABAD

REF. NO. NAME OF DRIVER ADDRESS PHONE NO. CITY NO.
NO. OF DRIVERS REGISTRATION NO. NO. OF AXLES
LADEN WEIGHT TON MODEL MAKE
ORD. TRUCK TANKER FLAT BODY OTHER PLACE ______ DATE ______

START		ACTIVITIES	FINISH		WHEN THE VEHICLE MOVING								
ate	Time Morning Noon Evening Night	1. Moving 2. Waiting for Loading or Unloading 3. Loading 4. Un-Loading 5. Resting 6. Stop due to Emergency condition. 7. Repair	TIME Morning Noon Evening Night	DATE	Origin	Destination	Distance in Miles	HOW MUCH TRUCK LOADED					Detail of Cargo
								Empty	1/4	1/2	3/4	Full	

Vehicle Activity Survey Questionnaire 2.

DRIVER'S LOG BOOK SURVEY
(Pakistan Freight Transport Project)

TRANSPORT & ROAD RESEARCH LABORATORY (UK) AND NATIONAL TRANSPORT RESEARCH CENTRE, BLOCK 4-B, MARKAZ F-7, ISLAMABAD - PAKISTAN (TELE: 820366)

Truck Registeration No: ______ Make: ______ Agent: ______

Model: ______ No.of Driver: ______ No. of Axle: ______

Ord.Truck	Tanker	Flat Body	Other

	1	2	3	4	5	6	7	8	9	10
Origin & Date										
Distination & Date										
Distance										
Loaded or Empty										
Diesel										
Mobile Oil										
Grease etc.										
Agency Commission										
Labour Loading & Unloading										
Octori										
Police										
Tyre repairing										
Other repair										
Food, etc.										
Revenue										
Total Expenditure										
Profit or Loss										