PARKING DEMAND AS A FUNCTION OF LAND USE
IN THE CENTRAL BUSINESS DISTRICT, BEIRUT

By

ATA M. KHAN

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Advisor: Prof. N.C. JOUZY

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The purpose of this investigation was to determine the parking demand as related to land use in the central business district of Beirut, and to develop a mathematical model of parking demand. It was also hoped to develop a simplified form of parking standards to be used as general averages in planning parking spaces according to the land use of future developments, and to serve as a guide line for an ordinance of parking requirements for the central business district, Beirut, or of any city of similar characteristics.

S C O P E

The study was limited to the core of the central business district, Beirut. In the absence of any land use maps, field observations of existing land uses in the study area were carried out. A rough land use map was prepared and used for the purpose of zoning the study area.

The land use was classified in major categories, and only one type of basic unit (floor area) was used in expressing parking requirements. For land use manufacturing, for instance, employees could as well be used as the basic unit.

Only the land uses existing in the sampled blocks were studied. Economic limitations prevented from investigating the parking demand of places such as movie theatre, assembly hall, post, telegraph and telephone building.

Because of the difficulty in interviewing shoppers and business visitors, only the employees were requested to give information about their parking demand and characteristics. Therefore, the parking demand found as the result of investigation is for the long time parkers.

The present parking usage for different land uses was calculated from the results of employee questionnaires.

No information about the gross floor area of a building or its usage by different land use activities was available. The floor areas were estimated and checked by the covered areas of the buildings on the available maps.

A multiple linear regression model was used in finding the trend equations of Total Parking Demand. All the factors (variables) affecting the demand of a certain land use were studied but only the following could be included in the regression function:

X_1 = Employees per car

X_2 = Floor area per employee - square meter

X_3 = Building Index

The explanatory variables X_4 (Public Transit Service), X_5 (Income), X_6 (Walking Distance and Cost of Parking) could not be included in the regression model because of insufficient sample data and the difficulty in assigning numerical values.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

An investigation of parking demand as related to land use was carried out at the central business district of Beirut. The results show that a very high parking demand exists in the core of the central business district. The streets are congested and there are not enough off-street spaces to satisfy even the present demand (present usage) which is 61 percent of the total demand.

The parking demand for major land use categories were found out and trend equations were developed using the multiple linear regression model. The tests on the coefficients of the regression equation show a significantly high regression. These regression equations could be used in determining parking demand for a future development in the study area and serve as guide line for developing parking ordinances for the central business district of Beirut or of any other city having the same characteristics.

A simplified form of parking standards is proposed for the central business district of Beirut. These could be helpful for easy usage in general planning. Also these could be used by the authorities to require new and substantially reconstructed old buildings to provide off-street parking spaces adequate to meet the needs of vehicles that would be attracted to these buildings.

INTRODUCTION

Many communities are faced with the continued growth in traffic, competition for street space between moving and parked vehicles, and inadequate parking spaces. Yet for personal and family use, for use in business, and for the movement of people in mass, the motor vehicle is indespensable (22).* The economic health of the city may slip and its progress may halt unless parking and loading spaces are provided, especially in the central business districts, where space is limited and traffic at its most dense.

The central business districts (CBD) in many towns such as Los Angeles have turned into depressingly ugly places, but some cities such as New York (Manhattan), San Francisco and Chicago have had downtown areas of such intrinsic power and character that they have maintained their magnetism (22). The decay in the downtown areas is the result of sprawl, the accumulation of new wealth around the existing centers (4).

Inspite of the decay, downtown areas are not being abandoned, for they still perform important functions. Many people still consider the CBD as the best location for shopping, commerce and business activities inspite of the fact that many of these activities have moved out in other areas of the city. The future economic health of the CBD can be saved if transit, traffic and parking conditions are improved.

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* Numbers in parenthesis refer to listings in the bibliography.

Demand for parking arises from activity in an area. It is strongly influenced by land use and by the competing forms of transportation. Different land uses have different parking demands. Also as the bulk of a given activity increases, parking demand increases. It is likely that parking problems develop in areas devoted to multistoried residences, industrial buildings and especially in central business districts(11).

Common carriers and pedestrians do not create parking problems. As the population of the community increases there is, in general, a decrease in the percentage of people who use the private motor vehicle as the mode of travel. In smaller cities in the United States, as many as 80 percent of the persons entering the central business districts do so by private auto. In the cities of 100,000 to 500,000 population, this percentage decreases to an average value of 70 percent and is as low as 40 percent in cities of 500,000 and larger (20).

In general, there is a decrease in the number of vehicles parked in the CBD per 1000 population as the size of city increases. However, absolute numbers of private vehicles demanding parking space generally increases with the city size, and it is these that generate the parking problem (20).

To solve the parking problems in central business districts, a proper balance, transportationwise, between, (a) building bulk which generates moving and stationary vehicles, (b) street capacity for moving vehicles and (c) off-street terminal facilities for standing vehicles, is to be achieved (6). A minimum level of parking capacity, appropriate to the character and needs of parking demands to be served is absolutely essential (5).

Three different techniques were employed to investigate parking demands and characteristics in the CBD of Beirut, Lebanon. One of these is developed into a model, to relate parking demand to floor areas for different land use activities. The other two techniques namely the vehicle accumulation method and the vehicle-hour method are explained in detail in the text.

The City of Beirut

Beirut lies on the east of the Mediterranean. Beirut appears first in the history in a list of Thotmes III - early fifteenth century B.C. - and until about 1835 A.D. it was a completely fortified town enclosing areas known at present as Martyrs Square, Assour and Bab-Edriss. During the nineteenth century a road was built connecting it to Damascus, then followed by a railway. This increased its importance. It was taken as the capital successively in 1888, 1920, and finally as the capital for the Republic of Lebanon in 1941.

The population of Beirut is increasing rapidly being 120,000 in 1912, 410,000 in 1963 and is estimated to be between 510,000 and 600,000 in 1980 excluding its densly populated suburbs (Figures 1,2).

The number of registered vehicles in Lebanon is increasing at a high rate and still a higher rate of usage of these vehicles is resulting in traffic problems in the cities, especially in Beirut (Figure 3).

The city of Beirut is an important center of banking and commerce for Lebanon, and in many ways of the whole Middle East region (10). Its importance is primarily due to economic as well as political stability. Its international airport is gaining increased importance ever since it was constructed. This is in addition to its old port which has a free zone, 2 docks and a third under construction. It is also the center of all political and governmental activity and is an important educational center for the area.

The Central Business District

The central business district (CBD) (in any city) is the focal point of all the commercial activities of the entire urbanized area or of a whole region. It is essentially an area of retail trade, office, light manufacturing, and commercialized recreational activities, and has few or no dwellings. The central business district is generally irregular in size, but more often rectangular than circular (15). The streets are often congested and mass transportation provides better coverage.

The central business district of Beirut has approximately an area of 0.85 square kilometer (0.38 square mile) and includes an area bound generally in the north by the sea, and in the south by the Commercial Ring. The western boundary of the area is a line joining Normandy Hotel, Starco, Old Palace of Justice, Basta street up to the Commercial Ring. The eastern boundary is a line joining the free zone entrance, Cat Company and the intersection of Damascus road with the Commercial Ring (Figure 4).

The core of the central business district of Beirut (the central section of the CBD) occupies about one-third of the CBD area and has high density of commercial activity. It is bounded on the east by the Bourj square, on the west by the Grand Serail, on the south by the Commercial Ring and on the north by the Wegan street (Figure 5).

The core of any central business district is densely occupied by commercial, governmental or other uses which generate large volumes of traffic and the demand for space exceeds the supply. Around the core there is generally a ring of lower-density commercial use and a certain amount of available parking. The space in this area usually must serve both the ring and the core demands (2).

The CBD of an average American city of 250,000 - 500,000 population occupies an area of 0.46 square mile, and the core constitutes slightly more than one-quarter of the area of CBD. The core has only 20 percent of the parking spaces, but is the destination of the three-fourths of the shoppers (11).

The Study Area

The core of the CBD of Beirut is the area of interest for the present investigation of parking demand as a function of land use, and will be referred to as the study area.

The study area is subdivided into four zones; the blocks comprising a zone have predominantly the same land use activity or group of activities (Figure 5).

Zone A has a combination of light manufacturing and retail as its predominant land use. A considerable portion of it is occupied by old residences, and schemes to redevelop this area are underway. Zone B accommodates banks, airline offices and specialty stores. Zone C is the area of commercial activity and has office as the major land use. Zone D has retail stores besides an area of single story fish, meat and cloth market with very narrow streets for pedestrians.

PREVIOUS PARKING STUDIES IN THE CENTRAL BUSINESS DISTRICT, BEIRUT

In the central business district of Beirut, three basic types of field studies are required to determine the relative importance of different travel modes serving it, and to evaluate amount and character or parking as well as the facilities available (11). These three studies are:

1. The Cordon Count
2. Space Inventory
3. Parking Demand and Characteristics.

A Cordon Count of all vehicles and persons entering and leaving the central business district of Beirut was carried out during the week days on February 6, 7 and 10, 1964. The study was carried out by the students of the School of Engineering, American University of Beirut, and was directed by Dr. N. Jouzy of the School of Engineering and Mr. M.A. Itani of the Ministry of Public Works (10). The important results of the study are given.

1. The relative importance of each route as a traffic carrier leading to or leaving the CBD area is given by the inbound and outbound traffic volumes on these streets between 7 A.M. and 7 P.M. as well as per 24 hours in a typical week day (Figure 6).

2. A peak accumulation of 48,000 people occurred between 4.30 P.M. and 5 P.M., and out of these 40,000 remained in the CBD area after 7 P.M. (Figure 7).
3. Three peaks of traffic movement occurred during an average week day. The morning peak of total traffic movement occurred between 8 A.M. and 8.30 A.M. and found to be 9224 vehicles, of which 5062 vehicles entered and 4264 vehicles left the CBD boundary. The noon peak traffic movement occurred between 1 P.M. and 1.30 P.M. and was found to be 9676 vehicles, of which 4449 vehicles entered and 5227 vehicles left the CBD area. The evening peak occurred between 4.30 P.M. and 5 P.M. and was 9885 vehicles, of which 4886 vehicles entered and 4999 vehicles left the CBD area (Figure 8).
4. In the case of private vehicular traffic, the same three peaks occurred. The morning peak occurred between 8 A.M. and 8.30 A.M. and was found to be 5034 vehicles of which 2851 vehicles entered and 2183 vehicles left the CBD area. The noon peak occurred between 1 P.M. and 1.30 P.M. and was found to be 5296 private vehicles out of which 2298 vehicles entered and 2998 vehicles left the CBD boundary. The evening peak traffic movement of private vehicles occurred between 4.30 P.M. and 5 P.M. and was found to be 5524 private vehicles out of which 2632 vehicles entered and 2892 vehicles left the CBD area (Figure 9).

5. The proportion of vehicles of various types entering the CBD from 7 A.M. to 7 P.M. and during the three peak half-hours is illustrated in Figure 10. It is interesting to note that the proportion of vehicles during the peak hours is very nearly the same as that of 7 A.M. to 7 P.M.
6. The proportion of passengers by travel mode entering the CBD from 7 A.M. to 7 P.M. and during the three peak half-hours is shown in Figure 11. Also in this case, the proportion during the peak half-hours is nearly the same as that of 7 A.M. to 7 P.M.
7. Peak total vehicle accumulation in the CBD occurred between 12 and 12.30 P.M. when 5700 vehicles were either parked or moving in the streets within the CBD area (Figure 8). Peak private vehicle accumulation occurred between 10.30 A.M. and 11 A.M. when 4100 private vehicles were either parked or in motion (Figure 9).
8. The total area under the accumulation curve of private vehicles is 20,000 vehicle-hours which were accommodated during the 12 hour study period (Figure 9).

Limited parking and pedestrian studies in the core of the CBD of Beirut were carried out by a group of engineering students of the graduating class during the months of March and April 1964 (8). Also an inventory of all parking spaces, loading zones, taxi stands, and bus stops in all the CBD area was carried out during the month of March 1964, by the office of M. Echochard, a consultant in town planning (8). The important results of these studies are given below and are used in estimating parking demand:

1. There was very little (if any at all) parking program at the time of the studies. Curbs were haphazardly open to parking with no limitations to space and time. The subdivision of curbs for parking and no parking, was not systematic, parking being allowed on streets which were over capacitized and prohibited on streets which had practically no traffic.
2. Off-street parking facilities were mostly lots on land cleared as a result of demolishing old buildings to make way for the new ones, the construction of which had not yet started. The city did not own any parking garage or any land used for the purpose of off-street parking.
3. The off-street facilities had a capacity of 1725 parking spaces in all the CBD area, and have only 200 parking spaces in the study area (core of CBD) out of which 175 spaces were estimated for the use of private vehicles.
4. The existing curb parking in the CBD area totaled up to 2833 parking spaces, out of which 1731 spaces were legal, 223 spaces were reserved and 879 spaces were illegal. In the study area, the total existing parking on curb was 765 spaces, out of which 305 spaces were legal, 147 spaces were reserved and 313 spaces

were illegal. The percent of illegal parkers in the study area was found to be 41 percent.

An equivalent figure for an average American city (population between 250,000 and 500,000) is only 18 percent (2).

5. The result of the investigation of curb utilization showed that at 9 A.M. the curb utilization was 92.2 percent, at 1 P.M. 68.68 percent and at 3 P.M. 61.31 percent (Figure 12). The curb utilization is defined as the ratio of occupied to total available spaces where parking is allowed for private vehicles.

6. Of all the parkers in the core of CBD, 46.6 percent parked for 4 hours, 31.40 percent parked for 6 hours and 22.0 percent parked for an average of 1.8 hours. Therefore 78 percent of all the parkers are long time parkers (those who park in one place for 3 hours or more) and only 22 percent are short time parkers.

The parking demand in the study area (core of CBD) is investigated using the results listed above.

Parking Demand

Three methods were considered to investigate the demand for parking in the study area. These methods are:

1. Vehicle Accumulation method
2. Vehicle-hour method
3. Land use method

The first two of these methods are given here and the last method is developed in the next sections of this report.

The number of private vehicles accumulated in the CBD area reached a maximum accumulation between 10.30 A.M. and 11 A.M. which was 4100 vehicles. Usually 15 to 30 percent of the accumulated vehicles are in motion, and the rest are parked (11). Assuming 20 percent of the vehicles to be in motion, the 80 percent or 3280 vehicles demand parking.

To find the demand in the study area, it is assumed that the destination of 50 percent of long time parkers is in the study area. This assumption is based on the criteria that the core of CBD (which is the study area), occupies about one-third the CBD area and has higher density of commercial activities than the rest of the CBD area, therefore, 50 percent of the long time parkers are attracted to it, if not more. Also the core is the destination of 75 percent of short time parkers (11). Therefore, the number of private vehicles demanding parking in the study area is:

$$3280\ (\tfrac{1}{2} \times 0.78 + \tfrac{3}{4} \times 0.22) \text{ or } 1820 \text{ vehicles.}$$

A check on this figure can be made by using the existing supply in the study area to determine the demand (11). In an average American city (population 250,000-500,000), the demand to supply ratio in the core of CBD is 2.2 (2). In the absence of statistics, using this ratio for the core of CBD of Beirut the demand in the study area is:

$$627 \times 2.2 \text{ or } 1380 \text{ spaces.}$$

As we have 41 percent illegal parkers, the true demand would be:

$$1380 \times 1.41 \text{ or } 1940 \text{ spaces.}$$

The two methods yield nearly the same result. The average value of demand is 1880 spaces; the deficiency of parking spaces being the difference of demand and available spaces (627 spaces) is 1253 spaces.

The vehicle-hour method is used to find out the average duration of parking, and the parking demand. The total area under the vehicle accumulation curve is a measure of the vehicle-hours accommodated during the period of study (11).

The total area under the accumulation curve of private vehicles for the CBD of Beirut gives 20,000 vehicle-hours (Figure 9). As the total supply of Parking spaces for the private vehicles in all the CBD area is 4558 spaces, the average duration of parking is found by dividing the total vehicle-hours by the total number of spaces, which is 4.4 hours.

The average parking duration can also be found from the observed parking duration of the short and long time parkers. It was observed that out of all the parkers, 46.6 percent parked for 4 hours, 31.4 percent parked for 6 hours and 22 percent parked for an average duration of 1.8 hours (8). The sum of products of the parkers percentage and the corresponding number of hours gives percent-hours, which when divided by 100 results in an average parking duration of 4.2 hours for all the private vehicles, which is quite close to the average value of 4.4 hours found earlier.

Because of the lack of vehicle accumulation data in the study area, no attempt is made to find out vehicle-hours served in the study area.

The methods used to investigate the character of parking and the relationship between demand and capacity are approximate and leave much to guess work (5). Therefore, to get more accurate information about parking demand and its location, a comprehensive parking survey should be carried out or some less expensive but equally accurate technique should be developed as is done for this report.

PARKING DEMAND AS A FUNCTION OF LAND USE

Demand for parking arises from activity in an area and land use is the name given to the activity (6). Each area is characterized by the kind of activity or land use and the intensity of land use.

Different land uses attract different kinds of trips and therefore have different parking demands. A shopping center will attract shopping and work trips and an office will generate mainly the work trips. Also the intensity of land use is highly related to the number of trips. A shopping center located in a central business district will attract more trips than one located in an area where the intensity of land use is comparatively low (11).

To obtain a reliable insight into the parking demand as related to land use, it would be appropriate to go to the source of the parking demand, which is the floor area used for a certain land use activity. In expressing the demand, it is better to use basic units, related to the parking demand of the land use. Parking demand in a business establishment has probably a more direct relationship to the floor area than to the other factors, and is therefore expressed in terms of floor area. Similarly for other land uses the demand may be expressed in terms of the proper basic units such as seats in a place of public assembly and employees in an Industrial Institution (6).

Two types of parking demands exist in any central business district. One being the revealed or present demand or parking usage at the time of a study, and the other, the total demand (potential demand or future demand). The total demand is the sum of revealed demand and the suppressed demand. The suppressed demand is the parking space required by car owners who at present do not bring their cars to the CBD due to poor parking conditions and traffic congestion (17).

It is easy to determine the present parking usage in an area as was shown earlier, but to determine total parking demand, some reliable economic techniques must be developed which are applicable to that particular area.

In the central business district of Beirut, as shown earlier, there is a very high ratio of present demand to existing supply of parking space. In the core area of the CBD, 41 percent of total parkers were illegal parkers, which shows clearly that off-street provision for parking is not enough.

It was therefore, necessary to develop standards predicted on extensive fact-findings as to spaces required by various land use activities in the CBD of Beirut. These standards could help the authorities in preparing a comprehensive parking ordinance for the CBD of Beirut.

Need for a Mathematical Model of Parking Demand

Because of limited time and funds, a quick, inexpensive although comprehensive method of predicting parking demand for different land uses in the CBD of Beirut has to be developed.

The method selected was in effect, an application of a mathematical model. A mathematical model is a precise (quantified) description of the idealized situation. Thus, assuming that the model fits the situation, it provides us with a set of mathematical techniques for its analysis.

If the factors were known about a land use activity in a zone which affect the parking demand, such as floor area per employee, number of employees per car, intensity of space utilization in the building, it would be possible to predict or estimate the parking demand for that land use.

Before attempting to define the factors affecting the parking demand for a certain land use, it would be necessary to define the type of parking demand that is at present being dealt with.

The type of parking facility needed for long time parkers is different from that of short time parkers. The long time parkers, usually, are the employees working in the CBD area and the short time parkers are shoppers or people visiting offices for business. As observed earlier, in the core of CBD of Beirut (the study area) 78 percent of all the parkers were long time parkers, and they need off-street parking space. The short time parkers being only 22 percent of total parkers would be taken care of by the curb spaces available in the study area. No attempt was made to investigate the requirements of short time parkers, which would involve interviewing shoppers and people visiting offices for business. This was anticipated to be difficult for the reasons listed below:

1. The stores and offices in the study area were usually small in size and therefore numerous. It was difficult and expensive to interview enough shoppers and business visitors to get a satisfactory sample.

2. As compared to employees, the shoppers and business visitors were not as cooperative.

The investigation of parking demand related to land use was, therefore, restricted to the parking demand of off-street space for the long time parkers. From parking demand was meant the total parking demand as defined earlier. If found out that a considerable proportion of employees do not bring their cars to the CBD for reasons other than bad parking conditions and traffic congestion, the total parking demand would be adjusted accordingly.

Factors Affecting the Parking Demand

All the factors affecting the parking demand for a certain land use, expressed in terms of floor area, were studied carefully and are listed below:

1. The number of employees per car has an indirect relation to parking demand. As the number of employees per car increases, the demand decreases.
2. The number of employees working in a certain floor area is directly proportional to the demand. A better and easier way of representing this factor is the floor area per employee. As the floor area per employee increases, the parking demand decreases.
3. The intensity of space utilization in a building has a direct relationship with parking demand, and is expressed as building index. To illustrate, an office in an old building would not have utilized its psace as much as another office (of similar activity) located in a new compact building. Therefore the greater the space utilization (building index), the greater would be the demand.

   The building index was calculated by dividing the weighted average floor area per employee in the building with an arbitrarily chosen figure, 14.28 square meters per employee, and multiplying the result by 2.

4. The level of service offered by mass transportation has a primary influence on car usage and parking demand. The amount of parking demand could be modified depending on the use of transit in the area.
5. The income of an employee has a direct relationship with car ownership and its usage. The average income of the employees working in an office or store influences the parking demand. Although its effect is captured by the factor employees per car, yet it would be better if average income is considered in the investigation.
6. Walking distance and cost of parking have a complex relationship (11). Because of parking costs in an area of high land values, many people walk a considerable distance from the parked car to the destination to save some expense. As far as the demand for parking space is concerned, the walking distance and cost of parking might have a slight effect.

Choice of the Model

In developing the model, the parking demand expressed in terms of floor area was to be related to the factors affecting it. These factors are also called the variables explaining the parking demand and therefore termed as explanatory variables. The specific relationship for certain land use (including the numerical values for the parameters) which was ultimately to be selected was named the parking demand model. If the values for the explanatory variables were known, the model would yield a predicted value for the parking demand.

The following criteria were set forth for the choice of an adequate model (21).

1. The model should give predicted values of parking demand which correspond very closely to the actual values. This is sometimes called the maximum correlation criterion, namely, the model which has the highest correlation will usually generate the most accurate predictions.

2. The model should be simple in functional form. Also the explanatory variables included in the model should be simple in form and not too many in number. This is particularly desirable for economy reasons.

   Although simplicity is itself a desirable feature, yet the model should be a plausible one. Plausibility alone suggests that parking demand per —— floor area should be affected by many variables in complex and non-linear ways. To try to incorporate all the conceivable explanatory variables into the model would prove difficult if not impossible.

   Finally, simplification such as the assumption of linear relationships may lead to only modest errors in the relevant range of variations.

3. The model should be sharp. A model is sharp if it enables us to distinguish between alternate hypotheses, which could be

(a) the effect of alternative explanatory variables or

(b) presumed numerical value for some parameter.

The sharpness of the model stands for the efficiency in the case of point estimation, and for the power of test in hypothesis testing.

4. The model should be valid. This criteria pertains to the set of admissible hypotheses considered in the model. Does this set contain the true causal relationship? A model may be both accurate and simple with reference to the sample data, yet invalid.

The four criteria are not all mutually compatible. Therefore, in the choice of the model, elements of subjective judgment must enter.

Because of not being well enough acquainted with the data, it was difficult to choose a model. There were two alternates; either to proceed by trial and error or use the multiple linear regression model. It was decided to do the latter since it is simple in form and easy to use. The standard statistical methods can be used to test various hypotheses in it and interpret the results.

PREVIOUS INVESTIGATION

The technique of determining the parking demand in terms of spaces per ____ floor area for different land use activities is quite a recent one. Little or no reliable information was available on the parking requirements and parking-generating characteristics of various types of land uses till 1956 (6). Although as of August 1954, almost 311 municipalities in the United States had adopted ordinances requiring parking facilities in connecting with new or substantially altered buildings for various land uses (15). But these were drawn up in the absence of standards for determining the extent of parking requirements (6).

Recently (1956-), many investigations were carried out to observe parking demand generated by buildings used for different land use activities (5).

The method of least-squares or linear regression analysis has been an extremely popular statistical tool, and was widely adopted by many disciplines. Traffic engineers have used it extensively in the urban travel studies (13). But from the literature read, it was found out that the regression technique has not been used in finding the parking demand. In fact, no work has been done in developing a parking demand model or in finding out the reliability of observed parking demand values.

MULTIPLE LINEAR REGRESSION MODEL

The salient features of the multiple linear regression model are given:

1. The behavioral unit is floor area (100 square meters). Differences in the size of the buildings from which the floor area is taken will be ignored. Therefore the size of building does not effect the behavioral unit.
2. The dependent variable or the variable to be explained is taken as parking demand per 100 square meters of floor area for a certain land use.
3. From the data of a certain land use activity, regression equations will be developed for each zone and finally a combined equation for all the zones. As an example, for land use, retail, four equations will be developed, one for each zone and finally the data of all the four zones will be combined to develop one equation for all zones (the study area).
4. The method of least-squares or linear regression technique will be used in developing the relationships. Basically, some dependent variable, Y_v the variable to be explained is assumed to be a linear function of certain explanatory or independent variables, x_{1v}, x_{2v}, ..., x_{mv}, where the subscript v denotes a single observation (The detailed theory is given in Appendix III).

The estimate of the regression equation is written

$Y = a + b_1 (x_1-\bar{x}_1) + b_2 (x_2-\bar{x}_2) + \dots + b_m (x_m-\bar{x}_m)$

where a is intercept on Y axis, $b_1, b_2, \dots, b_m$ are regression coefficients and are constant for a particular equation.

The parameters a, $b_1, b_2, \dots, b_m$, when assigned numerical values, define a unique linear function, summarizing the relationship between Y and $x_1, \dots, x_m$. The sample data consists of observations on both the dependent and independent variables (see Tables 1-9). Given the sample data, the parameters, a, $b_1, b_2, \dots, b_m$, are selected so as to minimize the sum of squared deviations between the actual and predicted values of the dependent variable. In other words, this operation means that the sum of the squared error terms, U_v^2, is minimized. The term U_v is called a random error term, being the vertical distance between the observed points and the regression plane.

The estimated values of the parameters, called least-squares estimates may be interpreted as follows:

The regression coefficient for the i-th explanatory variable, b_i, gives us the expected change in the value assumed by the dependent variable, Y, due to a unit increase in x_i.

The assumptions underlying the use of the regression model are listed and explained in Appendix III. The statistics of interest are, standard error of estimate S_a, multiple correlation coefficient R and coefficient of determination R^2. These statistics are also defined in Appendix III.

5. The regression equations will be tested using statistical tests of significance. The correlation of all the variables included in the equation will be tested by means of F statistic:

$$F = \frac{R^2 / (k-1)}{(1-R^2)/(n-k)}$$

where k is the number of parameters in the regression function, n is the size of the sample and $N_1 = k-1$, $N_2 = n-k$ are respective degrees of freedom (7).

The effect of each explanatory variable on the dependent variable will be tested by means of t statistic:

$$t = \frac{b_i - \beta_i}{Sb_2} \quad \text{for } \beta = 0 \text{ with n-m-1 degrees of freedom,}$$

m being number of explanatory variables (9).

6. The independent or explanatory variables to be used in the regression analysis will be in the form given below. If it becomes clear (as a result of investigation of functional relationships as will be explained later in the report) that assumptions of the linear regression model are violated, then the variables will be transformed.

x_1 = Employees per car.

x_2 = Floor area per employee - square meter.

x_3 = Building Index.

x_4 = Public transit service index.

x_5 = Income (average income of employees)

x_6 = Walking distance and cost of parking index.

7. Because of the lack of sufficient data or difficulty in assigning numerical values, some among the above listed independent variables may not be included in the regression model.

The major merits of the regression model are its simplicity and the ease in interpreting the results. If the assumption of the model are truly met then the regression model can comfortably handle several explanatory variables simultaneously, identifying the partial effect of each explanatory variable on the dependent variable (9). Finally, regression equations do yield sharp forecasts. Given the values of the independent variables, one can obtain a point estimate for the value taken by the dependent variable. If the relationship estimated by the regression equation truly applies, then the probable forecast error will be a minimum (3).

The limitations of the regression model are listed below (13).

1. Statistical bias might be introduced because of aggregation of behavioral unit.
2. The survey will provide cross-sectional description or parking demand at specific point in time, and the parking demand formula, estimated from these cross-sectional data are assumed to apply as time passes by. Cross-sectional estimate tend to overstate the effects of explanatory variables when compared with time series estimates. No time series data are presently available to allow for independent estimates of comparable

parking demand functions. The definition of time series is given in Appendix III.

3. In the empirical studies, it is rarely possible to specify all the pertinent variables. Some factors defy explicit quantification while data for others are often unavailable. To the extent that the excluded variables are correlated with the included explanatory variables, a bias will be introduced in the estimated regression coefficients. Often data for excluded variables are unavailable, accounting for their exclusion. Yet, it is sometimes possible to guess from auxiliary information the anticipated partial effects of the excluded variables on both the included variables and the dependent variable.

4. In connection with systems of equations, and also in other cases, the problem of identifiability of parameters comes up. Even if the distribution function of the observable variables is known completely, it may be impossible to determine (identify) all the parameters(9).

STUDY PROCEDURE

Having decided on the form of the model, and the variables that could be included, the study was planned so as to gather the sample data needed to develop the model.

To be acquainted well with the study area (defined in the introductory section of this report) it was desirable to gather all the available information from different sources. Maps of 1 to 2000 were acquired from the Conseil Executif des Grands Projets de la Ville de Beyrouth and were used in all the phases of the study after bringing them up to date by field checks. No other useful pertinent information could be obtained specially on the land use.

In the absence of any information about the land use activities carried out in the study area, field observations were carried out during the month of February 1965 to study the existing land use and to bring the maps up to date. A rough land use map was prepared and with its help, the study area was divided into four zones (Figure 5). The blocks comprising a zone had similar land use activities. A brief description of each zone is given in the introductory section of this report.

The next step was the selection of a simple random sample of blocks within each zone. The size of the sample was planned to be about 10 percent. Each block or a combination of blocks in a zone was numbered. The blocks, in some cases, were grouped to account for the irregularity in the size of the blocks (Figure 5).

In the selection of sample blocks, a simple random sampling method was used (1). The random number used and their ranks are listed in Table 10 for record. As a result, blocks A1, A2, B10, B9, C3, D5 and D10 were selected.

A field check was made to investigate the adequacy of the sample, and to estimate the number of man-hours that would be required in data collection from these blocks. The field checks showed that the blocks in the sample accommodated nearly all type of land use activities carried out in the CBD of Beirut. Therefore the sampled blocks were adequate for the study.

To collect data which would enable us to develop the regression model, and yield the answers to such questions as the present parking usage,mass transit usage and the like, it was decided to use a combination of direct interview of the manager of an office or a store (or some other responsible person) and employee questionnaires.

An instruction sheet was prepared for the use of the interviewers and was also intended to be used as the information sheet of each office or store.

The following information was to be collected about the office or the store:

1. Location, meaning the name of building, the street and the zone.

2. Type of building such as old or new.

3. Gross floor area occupied by the office or store.

4. Total number of employees.

5. Number of employees owning a car.

The employee questionnaire was written in Arabic and English and could be answered by the car owners as well as the ones not owning a car. It contained 8 questions, from which it was intended to find out (1) whether employees filling the questionnaire owned a car or not, (2) mode of travel to and from work (this helped in determining the percent of car owners using other modes of travel), (3) the reason for using other mode of travel if the employee owned a car (this helped in estimation of total or future parking demand), (4) the type of facility used by the parker, such as curb, off-street lot and garage, (5) walking distance from the parked car to the destination, (6) the direction of entry to the CBD area, (7) the total income of the employee per month and (8) up to how much money would a parker be willing to pay for a convenient parking garage.

Sample of instruction sheet and employee questionnaire are given in Tables 11, 12 and 13.

An introductory letter was written in Arabic and English signed by the Acting Dean of the School of Engineering, American University of Beirut, which explained the purpose of the investigation very briefly and asked for the cooperation in the study.

Field Work

The data was collected from the sampled blocks with the help of the students of the School of Engineering during the last week of March and the third week of April 1965. The study was carried out during the week days.

All the offices, stores or places of other land use activities located in the sampled blocks were studied. The purpose of the study was explained to the manager and if he agreed, the required information about the place was obtained. The floor areas were in most cases estimated (and later on checked by the covered areas of buildings from the maps). The questionnaires were given for all the employees, and the filled in questionnaires were collected at the end of the day or at some later date.

In general, people were cooperative and the study procedure was successful, even though many lack of knowledge of conveying information through questionnaires. Practically no one gave the information about the income, suggesting that some other way should be found for getting average income figures. It was found difficult to get any response from banks and other busy offices. A government office manager thought that it was against the regulations to ask the employees to give the needed information.

Office Work

The usable questionnaires collected from an office or store were attached to their respective information sheets. Reference numbers were assigned to the office or store and the information for each block was kept separate.

The land use was classified into the major categories given below:

A. Office (business, professional, administration).

B. Retail (sale and service of all small goods, like drugs, foods, clothes, and the like including restaurants).

C. Whole sale (storage, sale, service of all big goods like machines, vehicles, furniture, or big quantities).

D. Manufacturing (industrial production, assembling, testing, processing and the like).

E. Institutional (hospital, assembly hall, church, mosque, theatre).

F. Residential (houses, hotel).

Further, each land use was subdivided on the basis of the exact nature of activity and code numbers were used in summarizing the data (Tables 28,29). To illustrate, a travel agent's office was coded as A6 and a jeweller's shop as B6. The manufacturing and whole sale were coded as C and D respectively.

From the data collected, it was found out that variables x_4 to x_6 could not be included because of insufficient data and the difficulty of assigning them numerical values. Therefore data collected was used as the dependent variable, Y and the explanatory variables x_1, x_2 and x_3.

Some simple computations were required to bring the sample data into the simple reduced form needed in the model. For each observation, the variables were calculated as given:

1. Employees per car, x_1, was determined by dividing the total number of employees with the number of employees owning a car.
2. Floor area per employee - square meters, x_2, was found by dividing the gross floor area with the total number of employees.
3. Building Index, x_3, was determined by dividing the weighted average floor area per employee in the building with an arbitrarily chosen figure, 14.28 square meters per employee, and multiplying the result by 2.

   As an example, zone D had, in a remodled building, a bank with an average floor area of 10 square meters per employee, 3 general offices having an average floor area per employee of 16.82 square meters. Therefore, weighted average area per employee was determined to be $\frac{1}{4}(1 \times 10.00 + 3 \times 16.82) = \frac{1}{4}(60.46) = 15.11$ square meters, and the Building Index was found to be

$$\frac{14.28}{15.11} \times 2.00 = 1.88$$

Similarly, the Building Indicies for the rest of the blocks were determined.

4. The dependent variable, parking demand, spaces per 100 square meters of floor area, Y, was calculated by multiplying the ratio of number of employees owning a car to gross floor area - square meters by 100. To illustrate, an office in block C3 had gross floor area of 500 square meters, a total number of employees of 33 out of which 10 employees owned cars. Therefore, the total parking demand was calculated as $\frac{10}{500}$ x 100 or 2 spaces per 100 square meters of floor area.

Many small offices, stores and other land use activities had no cars demanding parking space, which meant zero demand. In order to avoid error by neglecting them, these were combined with other offices or stores having the same activity and located in the same block. That is why a combination of 2 or 3 offices or stores are referred to (in the Input Matrix) as one observation.

The information from the questionnaires was coded and summarized by zones. Then the summary results of the four zones were combined for the whole study area (Table 14).

The present parking usage (revealed demand) and the total parking demand for a certain land use was calculated as given below.

The number of car owners driving their cars to work is the present usage or revealed demand.

The suppressed demand was found from the number of car owners using means of travel other than their cars to work because of traffic congestion and bad parking conditions. The total parking demand was calculated as the sum of revealed and suppressed parking demands.

The data for each land use is given in reduced forms as Input Matrix in Tables 1-9.

Sources of Errors

The description of Parking demand (as revealed by the survey results) is subject to at least six sources of error (13).

1. Day to day variability (the interview dates, though on week days, were only samples from a population of all possible week days).
2. Sample variability among buildings.
3. The population of non-respondents might differ from the population for which no data could be collected.
4. Seasonal, cyclical, and random forces peculiar to the study period could introduce systematic biases.
5. The conscious or unconscious falsifications of reported information are unavoidable human failings. There is no a-priori reason to expect these errors to be compensating.

6. Recording errors might occur either by interviewers in recording or in coding and punching the data into cards.

For the first two kinds of errors, reliance is placed on the law of large numbers which states that with sufficiently large sample size, the sample statistics will converge to the population parameters.

Suppose that these are the only two sources of errors and that samples are truly randomly selected. Under these conditions, the laws of mathematical probability could be applied to the sample data, thereby allowing us to draw generalizations which pertain to the entire universe (parking demand of gross floor area of all the buildings in the study area on all the possible week days).

ANALYSIS OF DATA

In an attempt to justify the independent variables and their forms, which were to be used in developing a multiple regression equation, it was thought beneficial to regress the dependent variable (Y) with each independent variable (x_1, x_2 and x_3) singly. Also it was desired to find the scatter diagrams and to find the functional relationships that existed.

An IBM 1620 data processing system program was used (18). For each set of data, the following were determined:

1. A scatter plot of the data.
2. A plot of the average values.
3. A simple correlation analysis.
4. A possibility of six different least square fits; namely: $Y = A + Bx$, $Y = x/(B + Ax)$, $Y = Axe^{Bx}$, $Y = Ax\,e^{Bx^2}$, $Y = A\,e^{Bx}$ and $Y = Ax^B$.
5. A test of the goodness of the chosen fits.
6. A plot of the chosen fit or any group of fits on the original data.

The data was coded and punched in the cards. The analysis was carried out for all the sets of data, results were studied and the best least square fits were determined. The simple correlation coefficients and their confidence levels are listed in Table 15.

Also the best least square fits are listed in the same table.

The significance of a simple correlation coefficient r, was tested by using t statistic found as $t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$ with n-2 degrees of freedom, n being the number of observations (7). To illustrate: for land use, office, in Zone B, the simple correlation coefficient r between x_2 and Y was -0.3627, n being 17, the t value was

$$t = \frac{0.3627\sqrt{17-2}}{\sqrt{1-0.132}} = 1.51$$

From the t-table with 15 degrees of freedom, at 10 percent level of significance t was 1.753 and at 20 percent level, t was 1.341. Therefore the correlation was significant at 80 percent level of confidence.

From the best least square fits of the various functional relationships studied, and correlation between the dependent variable and each independent variable, it became clear that the assumptions regarding the input data to the model were very nearly satisfied and the regression equations could be developed only with modest errors.

The regression equations were developed with the help of IBM 1620 data processing system. A program entitled "Multiple Linear Regression Analysis" was used, which was developed at the computer center, University of California, Davis, California (16).

The following items were computed:

1. Raw sums of squares and products.

2. Residual sums of squares and gross products.

3. Average of the variables.

4. Standard error of the dependent variable.

5. Multiple correlation coefficient.

6. Constant coefficient and its standard error.

7. Regression coefficients and their standard errors.

The input matrices were coded and punched into the cards. While developing the equations for all zones (the study area), the data was partitioned.

The summary results are given in Tables 16-27, and equations for different land uses are listed under results.

The correlation of all the variables included in an equation was tested by the F statistics:

$$F = \frac{R^2/(k-1)}{(1-R^2)/n-k}$$

where k is the number of parameters in the regression function, n is the size of the sample and $N_1 = k-1$, $N_2 = n-k$ are respective degrees of freedom (7).

To illustrate: for land use office in zone C. $R^2 = 0.994$, $n = 35$, $k = 4$, $N_1 = 3$, $N_2 = 31$, therefore

$$F = \frac{0.994/3}{0.006/31} = \frac{0.3313}{0.00019} = 1740.0$$

From F-table with $N_1 = 3$, $N_2 = 31$, the value of F at 1 percent level of significance was 4.51. Therefore the correlation was significant at 99 percent confidence level.

The effect of each explanatory variable on the dependent variable was tested by means of t statistic:

$$t = \frac{b_i - \beta_i}{S_{bi}} \text{ for } \beta_i = 0 \text{ with n-m-1 degrees of freedom,}$$

m being the number of explanatory variables (9).

To illustrate: for land use office in zone C, t statistic for b_1, b_2 and b_3 were calculated

$$t_1 = \frac{b_1 - 0}{S_{b1}} = \frac{-0.317}{0.072} = -4.4,$$

$$t_2 = \frac{b_2 - 0}{S_{b2}} = \frac{-0.098}{0.028} = -3.50,$$

and $$t_3 = \frac{b_3 - 0}{S_{b3}} = \frac{4.949}{0.626} = 7.90$$

From t-table at 1 percent significance level for 35-3-1 = 31 degrees of freedom, the values of t = 2.75. Hence we can say at the 99 percent confidence level, that all the explanatory variables affect the dependent variable.

Results

A total number of 1365 employee questionnaires were distributed out of which 592 were filled in properly and were used in summarizing the results (Table 14). Out of the 592 employees, who filled the questionnaires, 398 were car owners.

Out of all the car owners working in the study area who do not drive their cars to work, only 3 percent find the mass transit to be cheaper. The rest 97 percent do not bring their cars to the CBD area because of bad parking conditions and traffic congestion. Therefore, neglecting 3 percent, the total parking demand is based on the assumption that if proper parking facility is provided, and traffic conditions are improved, all the car owners would drive their cars to work.

The present parking usage was calculated for the major land use categories. It was found out that for land use office, present parking usage is 60.7 percent of total demand, for land use, retail, the present usage is 58.4 percent of total demand, for land use, whole sale, the present usage is 46.7 percent of total demand and for land use, manufacturing, the present usage is 77.8 percent of total demand.

The present parking usage and total demand are listed in Table 28 for major land use categories. The total demand for different types of offices and stores are listed in Table 29.

It was found difficult to get any reliable information about income of employees. Also many employees did not check the questions about the walking distances and the cost of parking that they would be willing to pay.

Therefore, the reported information about the income, walking distances, and cost of parking was not included in the regression analysis.

In Zone A, a group of residential buildings in sample were studied and it was found that in block A1, the parking demand was 1 space per 2.15 families, and in block A2, 1 space per 6 families. Also in Zone A, there was only one office in the sample, which was neglected.

The simple correlation coefficients and the best least square fits for different land uses in all the zones are listed in Table 15. The least square fits in most cases show linear or very closely linear relationships.

It is observed that the correlation of variables x_1 and x_2 with the dependent variable Y is highly significant. The variable x_3 (Building Index) is significant at 99.9 percent confidence level in case of offices, and is not so much significant in other cases. The reason is that in case of retail, whole sale and manufacturing, the space is utilized to the maximum irrespective of the building type.

A significantly high simple correlation does not necessarily indicate a causal relationship. The correlation coefficient may possibly indicate a stochastic interdependence between, say, x_1 and Y but whether x_1 has caused it or x_1Y, or their relationship is due to the fact that they are both related to other factors, cannot be determined by means of the correlation coefficient (9). Therefore, a significantly high correlation is confirmed by further analysis which takes into account all the factors. This is done by the multiple regression analysis, the results of which are given below.

The linear regression equations for the land use, office, are:

1. Zone B

$$Y = 2.701 - 1.003\,(x_1 - 2.726) - 0.167\,(x_2 - 16.999) - 0.863\,(x_3 - 1.635) \quad \ldots\ldots \quad (1)$$

$R^2 = 0.990$, $F = 428.0$, $t_1 = -9.20$, $t_2 = -7.59$, $t_3 = -2.29$

The multiple correlation is significant at 99 percent confidence level.

The effect of variables x_1, x_2 on Y is significant at 99 percent confidence level and that of x_3 on Y is significant at 95 percent level.

2. Zone C

$$Y = 2.765 - 0.317\,(x_1 - 2.973) - 0.098\,(x_2 - 16.733) + 4.949\,(x_3 - 1.628) \quad \ldots\ldots \quad (2)$$

$R^2 = 0.994$, $F = 1715.0$, $t_1 = -4.40$, $t_2 = -3.50$, $t_3 = 7.90$

The multiple correlation is significant at 99 percent confidence level, and the effect of all the explanatory variables on the dependent variable is significant at 99 percent confidence level.

3. Zone D

$$Y = 2.22 - 0.175\,(x_1 - 3.599) - 0.015\,(x_2 - 17.223) + 4.804\,(x_3 - 1.662) \quad \ldots\ldots \quad (3)$$

$R^2 = 0.956$, $F = 35.0$, $t_1 = -0.81$, $t_2 = -0.17$, $t_3 = 1.49$

The multiple correlation is significant at 99 percent confidence level and the effect of all the explanatory variables on the dependent variable is not significant even at 95 percent confidence level.

4. All Zones

$$Y = 2.667 - 0.471\,(x_1 - 2.997) - 0.131\,(x_2 - 16.879) + 1.675\,(x_3 - 1.635) \quad \ldots\ldots\ldots\ldots \quad (4)$$

$R^2 = 0.992$, $F = 2360.0$, $t_1 = -6.19$, $t_2 = -4.67$, $t_3 = 2.96$

The multiple correlation and the effect of all the explanatory variables on the dependent variable are significant at 99 percent confidence level.

The linear regression equations for land use, <u>retail</u>, are given:

1. Zone A

$$Y = 2.585 - 0.340\,(x_1 - 6.999) - 0.222\,(x_2 - 10.145) - 7.132\,(x_3 - 2.388) \quad \ldots\ldots\ldots\ldots \quad (5)$$

$R^2 = 0.958$, $F = 22.8$, $t_1 = -4.09$, $t_2 = -2.32$, $t_3 = -1.27$

The multiple correlation is significant at 95 percent confidence level.

The effect of variable x_1 on Y is significant at 95 percent confidence level, and those of x_2 and x_3 is not.

2. Zone B

$$Y = 5.414 - 0.975\,(x_1 - 3.371) - 0.457\,(x_2 - 15.759)$$
$$- 0.317\,(x_3 - 2.058) \quad \text{.........................} \quad (6)$$

$R^2 = 0.986$, $F = 713.0$, $t_1 = -3.93$, $t_2 = -5.86$, $t_3 = -0.52$

The multiple correlation is significant at 99 percent confidence level.

The effect of variables x_1, x_2 on Y is significant at 99 percent confidence level and that of x_3 is not significant even at 95 percent level.

3. Zone C

$$Y = 2.052 - 0.451\,(x_1 - 4.812) - 0.074\,(x_2 - 22.087)$$
$$- 0.028\,(x_3 - 1.615) \quad \text{.........................} \quad (7)$$

$R^2 = 0.918$, $F = 15.0$, $t_1 = -2.29$, $t_2 = -1.89$, $t_3 = -0.02$

The multiple correlation is significant at 95 percent confidence level. The effect of all the explanatory variables on the dependent variable is not significant even at 95 percent confidence level.

4. Zone D

$$Y = 2.169 - 0.170\,(x_1 - 5.065) - 0.088\,(x_2 - 16.600)$$
$$- 0.880\,(x_3 - 1.694) \quad \text{.........................} \quad (8)$$

$R^2 = 0.968$, $F = 192.0$, $t_1 = -3.54$, $t_2 = -2.15$, $t_3 = -0.39$

The multiple correlation is significant at 99 percent confidence level.

The effect of variable x_1 on Y is significant at 99 percent confidence level, and that x_2 is significant at 95 percent confidence level. The variable x_3 has no effect on Y even at 95 percent confidence level.

5. All Zones

$$Y = 3.729 - 0.513\,(x_1 - 4.425) - 0.259\,(x_2 - 16.185) - 0.438\,(x_3 - 1.925) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

$R^2 = 0.990$, $F = 22,500$, $t_1 = -4.71$, $t_2 = -5.63$, $t_3 = -0.85$

The multiple correlation is significant at 99 percent confidence level.

The effect of variables x_1, x_2 on Y is significant at 99 percent confidence level. The variable x_3 has no effect on Y even at 95 percent confidence level.

The variable x_3 did not show any significant effect on the dependent variable Y, so it was excluded from the input matrix of land use retail, and regression equation was developed for all zones. As can be seen below, the exclusion of x_3 from the regression function has reduced the overall regression. Therefore, it is clear that although x_3 may not have a significantly high effect on the dependent variable Y, yet its inclusion in the function improves the multiple correlation.

The equation for land use retail (all zones) with variables x_1 and x_2 is:

$$Y = 3.722 - 0.425\,(x_1 - 4.425) - 0.140\,(x_2 - 16.185) \ldots\ldots \quad (10)$$

$R^2 = 0.988$, $F = 28,000$, $t_1 = -3.150$, $t_2 = -2.460$

The multiple correlation is significant at 99 percent confidence level.

The effect of explanatory variables on the dependent variable is significant at 95 percent confidence level.

The linear regression equation for land use, whole sale, for all the zones is:

$$Y = 1.838 - 0.404\ (x_1 - 3.352) - 0.040\ (x_2 - 3.086)$$
$$+ 0.915\ (x_3 - 1.077) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

$R^2 = 0.954$, $F = 28.9$, $t_1 = -3.74$, $t_2 = -3.64$, $t_3 = 0.99$

The multiple correlation is significant at 99 percent confidence level.

The effect of explanatory variables x_1, x_2 on Y is significant at 95 percent level of confidence and that of x_3 is not.

The linear regression equation for land use, manufacturing for all the zones is:

$$Y = 1.505 - 0.220\ (x_1 - 6.450) - 0.020\ (x_2 - 16.047)$$
$$- 0.941\ (x_3 - 1.900) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

$R^2 = 0.982$, $F = 73.0$, $t_1 = -4.15$, $t_2 = -0.95$, $t_3 = -1.07$

The multiple correlation is significant at 99 percent confidence level.

At 95 percent level of confidence, only x_1 has an effect on Y.

In general, the tests show a significantly high regression and the effect of any excluded variables is very small.

CONCLUSIONS AND RECOMMENDATION

General

The investigation of parking demand as related to land use, in the central business district of Beirut shows that:

1. The techniques developed to determine total and existing demand has proved to be very useful. The application of regression model is successful.
2. Simplified form of parking standards are developed for different land use activities.
3. The regression model could be used for determining future demand for parking if the numerical values of the variables are known.

From the previous parking studies and the present investigations it was found out that:

1. In the core of the central business district Beirut, a very high demand for parking space exists. The illegal parkers constitute 41 percent of all the parkers and the present usage is 61 percent of the total demand.

2. An estimated number of 1880 parking spaces were required in the study area in 1964. Since the long time parkers constituted 78 percent of all the parkers, most of these required spaces should be provided in off-street facilities.

3. To relieve the CBD of Beirut from traffic congestion and to reduce the illegal parking, zoning powers must be used by the authorities to require new and substantially reconstructed old buildings to provide off-street parking spaces adequate to meet the needs of vehicles that would be attracted to these buildings.

Parking Standards

A simplified form of parking standards for the CBD of Beirut is proposed as listed below. These standards were determined from the study and their reliability is verified.

Land Use	Parking spaces per 100 sq.m. of floor area
Office	2.66
Retail	3.73
Whole Sale	1.84
Manufacturing	1.50

The proposed parking standards should be used:

1. As general averages in planning spaces according to the land use of the future developments.
2. To serve as a guide line in the development of the ordinance of parking requirements for the CBD of Beirut, or of any other city of similar characteristics.

To compare, the demand for parking space in the CBD of Beirut is higher than that of an average U.S. city (5). Whereas the demand in the CBD, Birmingham, England is still higher than of Beirut (17).

Parking Demand Model

The results of the investigation show that:

1. The regressions for different land uses are significant at very high confidence level.
2. The application of the regression technique is an efficient way of estimating the requirements. For a future development, if the variables are assigned numerical values, which could be known as the part of the plan, the point estimates of the demand could be found. This could be of great help in the planning operations.
3. The parking demand trend equations for different land uses could be used for the CBD areas of the other cities having the same characteristics as Beirut.

Future Research

The parking demands for the land uses such as movie theatre, assembly hall, and the like, which were not investigated, could be determined using the methods of this study. Also other units of measuring the demand, such as employees, could be tried.

Some methods other than the ones used could be developed to get the information about the income of the employees. The inclusion of this variable in the regression function might improve the multiple correlation and result in a better trend equation.

The shoppers and business visitors could be interviewed, and the demand for parking could be investigated. Also it would be interesting to see the effect of this information on the demand as determined from the employees only.

The regression technique could be applied in developing trend equations of parking demand for the suburban areas of the cities.

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APPENDIX I

TABLES

TABLE 1

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

Land Use: Office | Zone : B

Y = Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor Area
X_1 = Employees per Car.
X_2 = Floor Area per employee - sq.m.
X_3 = Building Index.

Reference No.	Observation No.	X_1	X_2	X_3	Y
B100001	1	1.50	21.66	2.00	3.07
B100002	2	2.32	14.48	2.00	2.97
B100003	3	4.23	15.27	2.00	1.54
B100004	4	2.64	12.72	2.00	2.97
B100005	5	2.50	15.00	2.00	2.66
B100006	6	3.00	11.11	2.00	3.00
B100007	7	4.00	9.75	2.00	2.56
B100008	8	4.00	11.25	1.38	2.22
B100009	9	4.00	21.25	1.38	1.17
B100010	10	1.50	20.00	1.38	3.33
B100011	11	2.66	7.50	1.38	5.00
B100012	12	1.00	19.00	1.38	5.26
B90001) B90002)	13	3.50	25.75	1.38	1.09
B90003	14	2.00	25.00	1.38	2.00
B90004	15	1.50	20.00	1.38	3.33
B90005) B90006)	16	4.00	14.25	1.38	1.75
B900011	17	2.00	25.00	1.38	2.00
Max. Value		4.230	25.750	2.000	5.260
Min. Value		1.000	7.500	1.380	1.090
Range		3.230	18.250	0.620	4.170
Average		2.726	16.999	1.635	2.701
Std. Dev.		1.034	5.510	0.305	1.122

TABLE 2

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

Land Use : Office | Zone : C

Y = Dependent Variable, Parking Demand, Spaces per 100 sq.m of floor Area.
X_1 = Employees per Car.
X_2 = Floor Area per employee - sq.m.
X_3 = Building Index.

Reference No.	Observation No.	X_1	X_2	X_3	Y
C30001	1	3.50	14.28	1.60	2.00
C30002	2	4.09	8.97	1.60	2.72
C30003	3	2.00	25.00	1.14	2.00
C30004) C30005)	4	6.00	8.33	1.60	2.00
C30006) C30007)	5	2.00	15.00	1.60	3.33
C30008	6	2.00	20.00	1.60	2.50
C30009	7	3.00	13.33	1.60	2.50
C30010	8	3.00	13.33	1.60	2.50
C30011	9	13.00	4.62	1.60	1.66
C30012	10	2.00	15.00	1.60	3.33
C30013	11	2.00	30.00	1.60	1.66
C30014) C30015)	12	2.50	22.00	1.60	1.81
C30016	13	3.00	16.66	1.60	2.00
C30017	14	2.00	20.00	1.60	2.50
C30018	15	4.00	17.50	1.60	1.42
C30019	16	2.00	20.00	1.60	2.50
C30020	17	2.00	17.50	1.60	2.85
C30021	18	2.00	15.00	1.60	3.33

TABLE 2 (Continued)

Reference No.	Observation No.	X_1	X_2	X_3	Y
C30022) C30023)	19	3.50	20.00	1.60	1.42
C30024) C30025)	20	5.00	15.00	1.60	1.33
C30026	21	2.00	20.00	1.60	2.50
C30027	22	5.00	8.00	1.60	2.50
C30028) C30029)	23	3.00	21.66	1.60	1.53
C30030	24	2.00	20.00	1.60	2.50
C30031	25	2.00	12.50	1.60	4.00
C30032	26	2.00	15.00	1.60	3.33
C30033) C30034)	27	1.66	20.00	1.60	3.00
C30035	28	2.00	25.00	1.60	2.00
C30036	29	2.00	15.00	1.60	3.33
C30037	30	1.50	13.33	1.60	5.00
C30038	31	2.00	20.00	1.60	2.50
C30039	32	3.00	16.66	1.60	2.00
C30040) C30041)	33	5.00	12.00	1.60	1.66
C30064	34	5.00	12.00	1.60	1.66
C30042	35	1.00	10.00	2.85	10.00
Max. Value		13.000	30.000	2.850	10.000
Min.		1.000	4.620	1.140	1.330
Range		12.000	25.380	1.710	8.670
Average		2.973	16.733	1.622	2.691
Std. Dev.		2.075	5.392	0.224	1.476

TABLE 3

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

Land Use; Office Zone : D

Y = Dependent Variable , Parking Demand Spaces per 100 sq.m of floor Area.
X_1 = Employees per Car.
X_2 = Floor Area per employee - sq.m
X_3 = Building Index.

Reference No.	Observation No.	X_1	X_2	X_3	Y
D50001	1	3.00	20.00	1.60	1.66
D50002	2	3.00	16.66	1.60	2.00
D50003	3	9.00	6.66	1.60	1.66
D50004	4	1.33	25.00	1.60	3.00
D50005	5	2.00	25.00	1.60	2.00
D50006	6	3.50	18.20	1.60	1.56
D100001	7	3.00	10.00	1.88	3.33
D100002) D100003) D100007)	8	1.57	16.82	1.88	3.78
D100004) D100005) D100006)	9	6.00	16.67	1.60	1.00
Max. Value		9.000	25.000	1.880	3.780
Min. Value		1.330	6.660	1.600	1.000
Range		7.670	18.340	0.280	2.780
Average		3.600	17.223	1.662	2.221
Std. Dev.		2.305	5.717	0.116	0.876

TABLE 4

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

Land Use: Retail — Zone: A

Y = Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor area.
X_1 = Employees per car
X_2 = Floor area per employee - sq.m.
X_3 = Building Index

Reference No.	Observation No.	X_1	X_2	X_3	Y
A10002) A10003) A10004)	1	7.00	18.57	2.36	0.77
A2001	2	4.50	11.11	2.56	2.00
A10005) A10006) A10007)	3	2.50	10.40	2.36	3.85
A10008	4	2.00	8.00	2.36	6.25
A10009) A10010)	5	5.00	6.00	2.36	3.33
A10011) A10013) A10014)	6	14.00	9.86	2.36	0.72
A10015) A10016) A10012)	7	12.00	7.08	2.36	1.18
Max. Value		14.000	18.570	2.560	6.250
Min. Value		2.000	6.000	2.360	0.720
Range		12.000	12.570	0.200	5.530
Average		6.714	10.145	2.388	2.585
Std. Dev.		4.291	3.840	0.069	1.877

TABLE 5

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

Land Use: Retail   Zone : B

Y = Dependent variable, Parking Demand, spaces per 100 sq.m. of floor Area.
X_1= Employees per car
X_2= Floor Area per employee - sq.m.
X_3= Building Index

Reference No.	Observation No.	X_1	X_2	X_3	Y
B100013	1	1.20	25.00	1.90	3.33
B100014	2	1.00	4.00	1.80	25.00
B100015	3	3.00	20.00	1.90	1.66
B100016	4	2.00	16.60	1.90	3.00
B100017	5	3.00	7.00	1.90	4.76
B100018	6	5.00	6.00	1.80	3.33
B100019	7	6.00	12.50	1.80	1.33
B100020	8	10.00	1.81	1.90	5.55
B100021	9	3.00	3.61	1.90	9.23
B100022) B100023)	10	4.00	13.50	1.80	1.85
B100024	11	5.00	15.71	1.90	1.27
B100025) B100026)	12	2.00	15.00	1.80	3.33
B100027) B100028) B 90012)	13	3.00	22.66	1.80	1.47
B100029) B 90013)	14	3.00	20.66	1.80	3.22
B100030	15	2.00	37.50	1.90	1.33
B100031	16	2.00	7.00	1.90	7.14

TABLE 5 (Continued)

Reference No.	Observation No.	X_1	X_2	X_3	Y
B100032	17	2.00	10.00	1.90	5.00
B100033	18	1.00	16.00	1.90	6.25
B100034	19	1.00	6.00	1.90	16.60
B100035) B100036)	20	2.50	2.00	1.90	20.00
B100037	21	3.00	20.00	1.80	1.66
B100038	22	1.00	5.00	1.80	20.00
B100039	23	3.00	16.66	1.90	2.00
B100040	24	2.00	12.00	1.80	4.16
B100041) B100043)	25	5.50	16.81	1.80	1.08
B100044	26	5.00	30.00	1.90	0.67
B100045	27	4.50	31.10	1.90	0.71
B100046	28	1.33	30.00	1.90	2.50
B90007) B90008)	29	1.66	16.40	1.80	3.65
B90009) B90010)	30	17.00	5.06	1.80	1.16
B90014	31	1.33	27.50	1.80	2.73
B90015	32	1.00	6.00	1.80	16.60
B90016	33	2.00	27.50	1.80	1.81
B90017	34	4.66	29.28	1.80	0.73
Max. Value		17.000	37.500	1.900	25.000
Min. Value		1.000	1.810	1.800	0.670
Range		16.000	35.690	0.100	24.330
Average		3.372	15.742	1.850	5.415
Std. Dev.		3.026	9.656	0.050	6.318

TABLE 6

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

Land Use: Retail　　　　　　　　　　　　　　　Zone: C

Y = Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor Area.
X_1 = Employees per Car.
X_2 = Floor Area per employee - sq.m
X_3 = Building Index.

Reference No.	Observation No.	X_1	X_2	X_3	Y
C30043) C30044)	1	10.00	5.50	1.92	1.81
C30045	2	4.00	5.00	1.92	5.00
C30046) C30047)	3	4.00	25.00	1.92	1.00
C30048) C30049)	3	3.50	12.00	1.92	2.38
C30050	5	1.00	25.00	1.92	4.00
C30051	6	7.00	21.40	1.92	0.66
C30052) C30053)	7	7.00	17.80	0.70	0.80
C30054) C30055)	8	2.00	65.00	0.70	0.77

	X_1	X_2	X_3	Y
Max. Value	10.000	65.000	1.920	5.000
Min. Value	1.000	5.000	0.700	0.660
Range	9.000	60.000	1.220	2.062
Average	4.812	22.087	1.615	2.062
Std. Dev.	2.783	17.840	0.528	1.529

TABLE 7

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

Land Use: Retail Zone: D

Y = Dependent Variable, Parking Demand, Spaces per 100 sq.m of floor Area.
X_1 = Employees per Car.
X_2 = Floor Area per employee - sq.m
X_3 = Building index.

Reference No.	Observation No.	X_1	X_2	X_3	Y
D50007) D50008)	1	28.00	9.35	1.66	0.38
D50009) D50010) D50011)	2	3.00	11.00	1.66	3.03
D50012	3	3.00	16.66	2.06	2.00
D50013) D50014)	4	4.00	8.50	2.06	2.94
D50015	5	2.00	20.00	1.66	2.50
D50016	6	1.00	30.00	1.66	3.33
D100008) D100009)	7	2.00	13.50	1.66	3.70
D100010) D100012)	8	3.00	15.00	1.66	2.22
D100013) D100014) D100022)	9	5.50	11.82	1.66	1.53
D100015) D100016)	10	5.00	22.00	1.66	0.91
D100017	11	1.00	15.00	1.66	6.66
D100018) D100019)	12	3.00	31.66	1.66	1.05

TABLE 7 (Continued)

Reference No.	Observation No.	X_1	X_2	X_3	Y
D10020) D10021)	13	6.00	25.80	1.66	0.64
D10023) D10024)	14	6.00	14.17	1.66	1.17
D10025) D10026)	15	4.00	20.50	1.66	1.21
D10028	16	2.00	20.00	1.66	2.50
D10029	17	2.00	15.00	1.66	3.33
D10027) D10030)	18	7.00	20.00	1.66	0.71
D100031	19	4.00	6.87	1.66	3.63
D100032) D100033)	20	12.00	11.66	1.66	0.71
D100035) D100036)	22	6.00	13.33	1.66	1.25
D100037	23	2.00	20.00	1.66	2.50
Max. Value		28.000	31.660	2.060	6.660
Min. Value		1.000	6.870	1.660	0.380
Range		27.000	24.790	0.400	6.280
Average		5.065	16.600	1.694	2.171
Std. Dev.		5.441	6.428	0.112	1.397

TABLE 8

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

LAND USE: Wholesale ZONE: All zones

Y = Dependent variable, Parking Demand, Spaces per 100 sq.m. of floor area.

X_1 = Employees per car

X_2 = Floor area per employee - sq.m.

X_3 = Building Index

Reference No.	Observation No.	X_1	X_2	X_3	Y
C30057	1	1.00	72.00	1.10	1.38
C30058	2	3.33	10.00	1.10	3.00
C30059	3	3.00	10.00	1.10	3.33
C30060) C30061)	4	8.00	15.62	1.10	0.80
C30062	5	2.00	25.00	1.10	2.00
D50017	6	1.66	50.00	1.28	2.00
D50018	7	5.83	14.28	1.28	1.20
A10017	8	2.00	50.00	0.56	1.00
Max. Value		8.000	72.000	1.280	3.33
Min. Value		1.000	10.000	0.560	0.80
Range		7.000	62.000	0.720	2.530
Average		3.352	30.862	1.077	1.838
Std. Dev.		2.234	21.900	0.209	0.868

TABLE 9

MULTIPLE LINEAR REGRESSION ANALYSIS

INPUT MATRIX

LAND USE: Manufacturing ZONE: All zones

Y = Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor area.

X_1= Employees per car.

X_2= Floor area per employee - sq.m.

X_3= Building Index.

Reference No.	Observation No.	X_1	X_2	X_3	Y
A10018) A10019)	1	5.00	14.00	2.02	1.43
A10020	2	8.00	10.00	2.02	1.25
A10021	3	3.00	15.00	2.02	2.22
A10022	4	6.00	10.00	2.02	1.66
A10023) A10024)	5	11.00	19.09	2.02	0.48
A20002	6	2.66	12.50	1.70	3.00
A20003	7	5.00	11.43	1.70	1.75
A20004	8	11.00	36.36	1.70	0.25
Max. Value		11.00	36.36	2.22	3.00
Min. Value		2.66	10.00	1.70	0.25
Range		8.34	26.36	0.52	2.75
Average		6.457	16.047	1.925	1.505
Std. Dev.		3.051	8.171	0.185	0.831

TABLE 10

SIMPLE RANDOM SAMPLING

(Random Numbers and their ranks)

Zone A

Random Number	Rank
104	1
128	2
217	4
195	3
272	7
605	6
538	5

Zone B

Random Number	Rank
380	10
374	9
971	20
218	6
731	18
076	2
605	15
835	19
108	4
398	12
595	14
385	11
306	8
654	16
272	7
913	21
684	17
489	13
069	1
104	3
128	5

Zone C

Random Number	Rank
171	3
282	5
093	1
312	7
361	8
295	6
235	4
578	10
553	9
100	2

Zone D

Random Number	Rank
244	5
459	10
766	17
390	7
812	19
764	16
149	3
703	13
908	21
247	6
409	9
726	15
214	3
011	1
805	18
131	2
217	4
274	11
404	8
712	14
855	20
958	23
926	22
676	12

TABLE 11

SAMPLE INFORMATION AND INSTRUCTION SHEET
AMERICAN UNIVERSITY OF BEIRUT

CENTRAL BUSINESS DISTRICT, BEIRUT, PARKING STUDY.

INSTRUCTIONS

INTERVIEW FORM AND EMPLOYEE QUESTIONNAIRE.

1. Explain to the Manager that this is a part of the survey to improve Parking conditions in the Central Business District and that his cooperation will of great service to the city.

2. Get the following information about the Office, Store etc.
   a) Location i.e. Name of building & the street.

      ____

   b) Land Use. [|] ____________________

   c) Type of building Old ______ New ______

   d) Gross floor area occupied by the Office, Store etc. ________

   e) Total No. of employees. ________

   f) No. of employees owning a car. ________

INTERVIEW INSTRUCTIONS.

1. Use a separate form for each interview.

2. Interview both men and women. Do not interview any one under 16 years of age. Do not concentrate on any one group or class, otherwise sample taken may not be true one.

EMPLOYEE QUESTIONNAIRE INSTRUCTIONS

1. Give the manager of office or store etc. enough copies of employee questionnaire to be distributed. Should the management prefer that you distribute questionnaires to employees, please do so.

2. Explain to the manager or employee that you will collect the filled in questionnaires at the end of the day or the next day.

3. Pick up and return the employee questionnaires with interview forms to the School of Engineering.

20 March 1965

TABLE 12

SAMPLE EMPLOYEE QUESTIONNAIRE

AMERICAN UNIVERSITY OF BEIRUT.

CENTRAL BUSINESS DISTRICT, BEIRUT PARKING STUDY

EMPLOYEE QUESTIONNAIRE

Dear Sir,

This is a part of the survey to improve parking conditions in the Central Business District. Your cooperation will be of great service to the city.

1. Do you own a car? Yes _____ No _____
2. How do you generally travel to and from work? (check one.)

   a) By car _____ b) By bus _____

   c) By service _____ d) Walk _____
3. Why do you use other means of travel rather than drive your car?

   a) Traffic congestion _____ b) Parking conditions bad _____

   c) Public transport cheaper _____
4. Where do you generally park your car?

   a) At curb _____ b) In off street lot _____

   c) In garage _____
5. About how much do you walk from parked car to the destination?

   a) Less than 100m _____ b) 100m _____ c) 200m _____

   d) 300m _____ e) More than 300m _____
6. From which direction do you enter the Central Business District?

   a) Ras Beirut _____ b) Saifi _____ c) Nahr _____

   d) Rue de Damas _____ e) Basta _____
7. About how much is your total income per month?

   a) Less than L.L. 500 _____ b) L.L. 500 - 600 _____ c) L.L. 600 - 800 _____

   d) L.L. 800 - 1000 _____ e) More than L.L. 1000 _____
8. Up to how much would you be willing to pay for a convenient Parking garage per day?

   a) Less than L.L. 0.50 _____ b) L.L. 0.50 _____ c) L.L. 0.75 _____
   d) L.L. 1.00 _____ e) More than L.L. 1.00 _____

____

Name of office or shop

23 March 1965

TABLE 13

SAMPLE EMPLOYEE QUESTIONNAIRE

الجامعة الاميركية في بيـــــروت ــ كلية الهندسة

بيـــــروت لبـــنان

سيدى الفاضل

تحية واحتراما

هذه دراسة ترمي لتحسين مواقف السيارات الخاصة في منطقة بيروت التجارية • ان اجابتكم للملحق التالي تساعد هذا الغرض ــ شكرا

١) هل تملك سيارة؟ نعم ـــــ لا ـــــ

٢) ما هي طريقة انتقالك من البيت الى العمل وبالعكس ؟ (ضع اشارة على بند واحد فقط)

(ا) سيارة ـــــ (ب) باص ـــــ (جـ) سرفيس ـــــ (د) ماشيا ـــــ

٣) لماذا تفضل استعمال وسائل نقل اخرى على استعمال سيارتك؟

(ا) ازدحام السير ـــــ(ب) مواقف غير صالحة ـــ(جـ) رخص وسائل النقل العمومي ـــــ

٤) اين تقف بسيارتك عادة؟

(ا) عند المنعطف ـــــ(ب) في شارع جانبي ـــــ(جـ) في كاراج ـــــ

٥) ما المسافة التي توقف فيها سيارتك بعيدا عن غايتك ؟

(ا) اقل من ١٠٠ متر ـــــ(ب) ١٠٠ متر ـــــ(جـ) ٢٠٠ متر ـــــ (ة) ٣٠٠ متر ـــــ

(هـ) اكثر من ٣٠٠ متر ـــــ

٦) من اية جهة تدخل الى المنطقة التجارية عادة ؟

(ا) راس بيروت، الصنائع، الحمرا ـــــ

(ب) الصيفي، الرميله، مدخل بيروت الشرقي ـــــ

(جـ) النهر ـــــ

(د) الاوزاعي، طريق الشام ـــــ

(هـ) بسطة، مصيطبه ، طريق جديده ـــــ

٧) ما هو دخلك الشهرى؟

(ا) اقل من ٥٠٠ ليره لبنانيه ـــــ(ب) ٥٠٠ ــ ٦٠٠ ل.ل.ـــ(جـ) ٦٠٠ ــ ٨٠٠ ل.ل. ـــــ

(ة) ٨٠٠ ــ ١٠٠٠ ل.ل.ـــ(هـ) اكثر من ١٠٠٠ ل.ل. ـــــ

٨) ما هو المبلغ الاقصى الذى ترغب في دفعه لتامين موقف لسيارتك في كاراج يوميا ؟

(ا) اقل من ٥٠ ق.ل.ـــ(ب) ٥٠ ق.ل.ـــ(جـ) ٧٥ ق.ل.ـــ(د) ١٠٠ ق.ل.ـــ(هـ) اكثر من ١٠٠ ق.ل.ـــ

اسم المؤسسة التي تعمل فيها ـــــ

٢٠ اذار سنة ١٩٦٥

TABLE 14

SUMMARY DATA OF EMPLOYEE QUESTIONNAIRES

Question		Zone A		Zone B		Zone C		Zone D		All Zones	
		No.	percent	No.	percent	No.	percent	No.	percent	No.	percent
1*	a †	37	19.80	94	53.50	55	67.00	57	38.80	243	41.00
	b	150	80.20	82	46.50	27	33.00	90	61.20	349	59.00
2	a	33	17.65	42	24.14	40	50.00	33	28.00	148	26.50
	b	98	52.40	16	9.19	4	5.00	10	8.36	128	22.90
	c	39	20.85	104	59.78	30	37.50	66	56.00	239	42.70
	d	17	9.10	12	6.89	6	7.50	9	7.64	44	7.90
3	a	2	50.00	7	13.46	0	0.00	0	0.00	9	9.50
	b	2	50.00	42	80.76	15	100.00	24	100.00	83	87.50
	c	0	0.00	3	5.78	0	0.00	0	0.00	3	3.00
4	a	4	12.07	7	15.20	2	5.00	5	19.20	18	12.40
	b	11	33.33	22	47.80	14	35.00	10	38.50	57	39.30
	c	18	54.60	17	37.00	24	60.00	11	42.30	70	48.30
5	a	14	41.10	8	20.00	21	55.25	6	17.16	49	33.40
	b	1	3.40	0	0.00	1	2.63	1	2.86	3	2.04
	c	7	20.50	4	10.00	3	7.92	2	5.72	16	10.80
	d	9	26.40	12	30.00	7	18.40	1	2.86	29	19.76
	e	3	8.60	16	40.00	6	15.80	25	71.50	50	34.00
6	a	28	15.20	47	31.50	17	23.30	11	15.30	103	21.50
	b	15	8.20	27	18.12	12	16.45	15	20.80	69	14.50
	c	44	23.90	23	15.45	8	10.99	12	16.65	87	18.20
	d	19	10.30	30	20.15	18	24.63	13	18.05	80	16.80
	e	78	42.40	22	14.78	18	24.63	21	29.20	139	29.00
7	a	-	-	85	61.60	8	38.10	24	44.50	117	55.00
	b	-	-	9	6.50	2	9.50	14	25.90	25	11.70
	c	-	-	15	10.90	3	14.30	5	9.25	23	10.80
	d	-	-	14	10.10	2	9.50	3	5.55	19	8.90
	e	-	-	15	10.90	6	28.60	8	14.80	29	13.60
8	a	28	87.50	43	51.20	21	47.70	5	15.65	97	50.50
	b	4	12.50	25	29.80	10	22.70	12	37.50	51	26.60
	c	-	-	7	8.34	6	13.65	6	18.75	19	9.90
	d	-	-	5	5.90	6	13.65	6	18.75	17	8.80
	e	-	-	4	4.76	1	2.30	3	9.35	8	4.20

* Number 1 corresponds to Question 1 in the employee questionnaire.

† Figure a corresponds to part a of question number 1 in the employee questionnaire.

TABLE 15

SIMPLE CORRELATION COEFFICIENTS*, BEST LEAST SQUARE FITS

Zone	Land Use	Variable	Simple Correlation Coefficient, r	Number of Observations, n	t Statistic	Confidence Level Percent	Best least square fit
All zones	Office	X_1	-0.410	61	-3.45	99.0	$X_1 = AY^B$, A = 5.322, B = -0.798
"	"	X_2	-0.267	61	-2.25	95.0	$X_2 = A+BY$, A = 19.793, B = -1.109
"	"	X_3	+0.519	61	5.46	99.9	$X_3 = A+BY$, A = 1.385, B = 0.093
"	Retail	X_1	-0.328	72	-3.08	99.0	$X_1 = AY^B$, A = 5.229, B = -0.556
"	"	X_2	-0.434	72	-4.47	99.9	$X_2 = A+BY$, A = 19.608, B = -0.919
"	"	X_3	+0.078	72	0.66	50.0	$X_3 = AY^B$, A = 1.735, B = 0.042
"	Whole Sale	X_1	-0.337	8	-0.93	60.0	$X_1 = A+BY$, A = 4.951, B = -0.869
"	"	X_2	-0.405	8	-1.19	70.0	$X_2 = A+BY$, A = 49.690, B = -10.239
"	"	X_3	+0.252	8	0.66	40.0	$X_3 = AYe^{BY}$, A = 1.487, B = -0.459
"	Manufacturing	X_1	-0.947	8	-24.20	99.9	$X_1 = Ae^{BY}$, A = 13.684, B = -0.578
"	"	X_2	-0.645	8	- 2.70	95.0	$X_2 = Y/(B+AY)$, A = 0.092, B = -0.016
"	"	X_3	-0.009	8	- 0.02	not significant	$X_3 = Y/(B+AY)$, A = 0.507, B = 0.014

* Simple correlation coefficients of dependent variable Y with the independent variables X_1, X_2 and X_3 where

X_1 = Employees per car,

X_2 = Floor area per employee, and

X_3 = Building Index

TABLE 16

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Office

Zone: B

Dependent Variable, Parking Demand, Spaces per 100 sq. m. of floor area; Y

	Employees Per Car X_1	Floor Area per employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 sq.m. of floor area Y
SUMS OF PRODUCTS				
	144.570	750.161	76.480	112.665
	750.161	5428.791	460.800	742.468
	76.480	460.800	47.044	75.007
	112.665	742.468	75.007	145.460
SUMS OF PRODUCTS OF DEVIATIONS				
	18.198	-37.761	0.684	-12.534
	-37.761	516.131	-11.783	-38.144
	0.684	-11.783	1.582	- 0.085
	-12.534	-38.144	- 0.085	-21.422
M E A N S				
	2.726	16.999	1.635	2.701

Standard Error of Dependent Variable = 0.431

Multiple Correlation Coefficient = 0.995

Coefficient of Determination = 0.990

COEFFICIENT AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	2.701	0.104	-
X_1	-1.003	0.109	-9.20
X_2	-0.167	0.022	-7.59
X_3	-0.863	0.376	-2.29

TABLE 17

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Office — Zone: C

Dependent Variable, Parking Demand, Spaces per 100 sq. m. of floor area; Y

Employees Per Car X_1	Floor Area per employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 sq. m. of floor area Y
SUMS OF PRODUCTS			
460.252	1518.072	167.328	251.229
1518.072	10818.196	944.072	1542.050
167.328	944.072	94.280	166.464
251.229	1542.050	166.464	344.952
SUMS OF PRODUCTS OF DEVIATIONS			
150.748	-223.542	- 2.173	-36.596
-223.542	1017.930	- 9.733	-77.578
- 2.173	- 9.733	1.451	8.834
- 36.596	- 77.578	8.834	77.286
MEANS			
2.973	16.733	1.628	2.765

Standard Error of Dependent Variable = 0.678

Multiple Correlation Coefficient = 0.997

Coefficient of Determination = 0.994

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	2.765	0.115	-
X_1	-0.317	0.072	- 4.40
X_2	-0.098	0.028	- 3.50
X_3	4.949	0.626	7.90

TABLE 18

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Office

Zone: D

Dependent Variable, Parking Demand, Spaces per 100 sq. m. of floor area; Y

	Employees Per Car X_1	Floor Area Per Employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 m^2 of floor area Y
SUMS OF PRODUCTS				
	164.483	473.297	53.119	61.294
	473.297	2963.952	255.525	344.517
	53.119	255.525	24.988	33.974
	61.294	344.517	33.974	51.322
SUMS OF PRODUCTS OF DEVIATIONS				
	47.843	-84.738	-0.736	-10.669
	-84.738	294.163	-2.135	0.222
	- 0.736	- 2.135	0.121	0.746
	-10.669	0.222	0.746	6.922
MEANS				
	3.599	17.223	1.662	2.221

Standard Error of Dependent Variable = 0.541

Multiple Correlation Coefficient = 0.978

Coefficient of Determination = 0.956

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	2.22	0.180	–
X_1	-0.175	0.216	-0.81
X_2	- .015	.088	-0.17
X_3	4.804	3.205	1.49

TABLE 19

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Office   Zone: All Zones

Dependent Variable, Parking Demand, Spaces per 100 sq. m. of floor area: Y

Employees Per Car X_1	Floor Area Per Employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 sq.m. of floor area Y
SUMS OF PRODUCTS			
769.306	2741.531	296.928	425.189
2741.531	19210.939	1660.397	2629.036
296.928	1660.397	166.312	275.445
425.189	2629.036	275.445	541.735
SUMS OF PRODUCTS OF DEVIATIONS			
221.326	-344.609	-2.073	-62.456
-344.609	1830.279	-23.534	-117.313
- 2.073	- 23.534	3.164	9.364
- 62.456	-117.313	9.364	107.779
MEANS			
2.997	16.879	1.635	2.667

Standard Error of Dependent Variable = 0.911

Multiple Correlation Coefficient = 0.996

Coefficient of Determination = 0.992

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	2.667	0.116	-
X_1	- 0.471	0.076	-6.19
X_2	- 0.131	0.028	-4.67
X_3	+ 1.675	0.566	2.96

TABLE 20

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Retail

Zone: A

Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor area; Y

Employees Per Car X_1	Floor Area Per Employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 m^2 of floor area Y
SUMS OF PRODUCTS			
496.500	489.145	116.540	79.767
489.145	823.783	169.829	162.004
116.540	169.829	39.971	43.118
79.767	162.004	43.118	71.486
SUMS OF PRODUCTS OF DEVIATIONS			
153.500	-7.995	-.500	-46.940
- 7.995	103.234	.192	-21.644
- .500	.192	.034	- .117
-46.940	-21.644	-.117	24.678
M E A N S			
6.999	10.145	2.388	2.585

Standard Error of Dependent Variable = 1.005

Multiple Correlation Coefficient = 0.979

Coefficient of Determination = 0.958

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	2.585	.380	-
X_1	-.340	.083	-4.090
X_2	-.222	.0995	-2.230
X_3	-7.132	5.587	-1.276

TABLE 21

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Retail

Zone: B

Dependent Variable, Parking Demand, Spaces per 100 sq. m. of floor area; Y

	Employees Per Car X_1	Floor Area Per Employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 sq.m. of floor area Y
SUMS OF PRODUCTS				
	697.643	1617.252	232.769	404.443
	1617.252	11616.034	1134.090	1626.877
	232.769	1134.090	193.840	352.284
	404.443	1626.877	352.284	2354.300
SUMS OF PRODUCTS OF DEVIATIONS				
	311.239	-189.125	- 3.213	-216.223
	-189.125	3171.512	30.910	-1274.642
	- 3.213	30.910	49.722	- 26.766
	-216.223	-1274.642	-26.766	1357.344
M E A N S				
	3.371	15.759	2.058	5.414

Standard Error of Dependent Variable = 4.302

Multiple Correlation Coefficient = 0.993

Coefficient of Determination = 0.986

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	5.414	0.738	-
X_1	-0.975	0.248	-3.93
X_2	-0.457	0.078	-5.86
X_3	-0.317	0.612	-0.52

TABLE 24

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Retail   Zone: C

Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor area; Y

Employees per car X_1	Floor Area per Employee-m^2 X_2	Building Index X_3	Parking Demand spaces per 100 sq.m. of floor area Y
SUMS OF PRODUCTS			
247.250	646.400	62.940	66.190
646.400	6449.050	238.248	266.929
62.940	238.248	23.098	29.611
66.190	266.929	29.611	52.609
SUMS OF PRODUCTS OF DEVIATIONS			
61.968	-203.968	0.762	-12.831
-203.968	2546.188	-47.122	-95.747
0.762	- 47.122	2.232	3.092
- 12.831	- 95.747	3.092	18.906
M E A N S			
4.812	22.087	1.615	2.052

Standard Error of Dependent Variable = 1.234

Multiple Correlation Coefficient = 0.958

Coefficient of Determination = 0.918

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	2.052	0.436	-
X_1	-0.451	0.197	-2.29
X_2	-0.074	0.039	-1.89
X_3	-0.028	1.145	-0.024

TABLE 23

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Retail

Zone: D

Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor area; Y

	Employees Per Car X_1	Floor Area per employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 sq.m. of floor area Y
SUMS OF PRODUCTS				
	1271.250	1674.970	196.190	160.525
	1674.970	7289.066	643.885	791.515
	196.190	643.885	66.354	84.810
	160.525	791.515	84.810	153.132
SUMS OF PRODUCTS OF DEVIATIONS				
	681.152	-259.031	- 1.252	-92.229
	-259.031	950.522	- 3.216	-36.867
	- 1.252	- 3.216	0.292	0.240
	- 92.229	- 36.867	0.240	44.871
MEANS				
	5.065	16.600	1.694	2.169

Standard Error of Dependent Variable = 1.172

Multiple Correlation Coefficient = 0.984

Coefficient of Determination = 0.968

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	2.169	0.244	-
X_1	-0.170	0.048	-3.54
X_2	-0.088	0.041	-2.15
X_3	-0.880	2.239	-0.39

TABLE 24

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Retail

Zone: All Zones.

Dependent Variable, Parking Demand, Spaces per 100 sq. m. of floor area; Y

Employees Per Car X_1	Floor Area Per Employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 sq.m. of floor area Y
SUMS OF PRODUCTS			
2712.264	4427.76	608.439	710.925
4427.767	26177.933	2186.052	2847.325
608.439	2186.052	323.264	509.823
710.926	2847.325	509.823	2631.528
SUMS OF PRODUCTS OF DEVIATIONS			
1302.661	-729.318	- 4.993	-447.398
-729.318	7315.611	-57.608	-1499.036
- 4.993	- 57.608	56.382	- 7.173
-477.398	-1499.036	- 7.173	1630.014
M E A N S			
4.425	16.185	1.925	3.729

Standard Error of Dependent Variable = 3.820

Multiple Correlation Coefficient = 0.995

Coefficient of Determination = 0.990

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	3.729	0.450	-
X_1	-0.513	0.109	-4.71
X_2	-0 259	0.046	-5.63
X_3	-0.438	0.511	-0.85

TABLE 25

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use : Retail

Zone : All Zones

Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor area ; Y

	Employees per car X_1	Floor Area per employee.m^2 X_2	Parking Demand Spaces per 100sq.m. of floor Area. Y
SUMS OF PRODUCTS.			
	2712.643	4427.767	735.074
	4427.767	26177.933	3619.733
	735.074	3619.733	2840.619
SUMS OF PRODUCTS OF DEVIATIONS.			
	1302.661	-729.318	-451.014
	-729.318	7315.611	-718.453
	-451.014	-718.453	1842.870
M E A N S.	4.425	16.185	3.722

Standard Error of Dependent Variable = 4.739

Multiple Correlation Coefficient = 0.994

Coefficient of Determination = 0.988

COEFFICIENTS AND STANDARD ERRORS.

Variable.	Coefficient	Standard Error.	"t" Statistic
Const.	3.722	0.558	-
X_1	-0.425	0.135	-3.150
X_2	-0.140	0.057	-2.460

TABLE 26

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Whole Sale

Zone: All Zones

Dependent Variable, Parking Demand, Spaces per 100 sq.m. of floor area; Y

Employees Per Car X_1	Floor Area Per Employee-m^2 X_2	Building Index X_3	Parking Demand Spaces Per 100 sq.m. of floor area Y
SUMS OF PRODUCTS			
129.833	576.512	29.770	44.076
576.512	11456.902	256.160	392.292
29.770	256.160	9.640	16.217
44.076	392.292	16.217	33.073
SUMS OF PRODUCTS OF DEVIATIONS			
39.919	-251.219	0.871	-5.239
-251.219	3836.951	-9.874	-61.695
0.871	- 9.874	0.352	0.366
- 5.239	- 61.695	0.366	6.025
MEANS			
3.352	3.086	1.077	1.838

Standard Error of Dependent Variable = 0.523

Multiple Correlation Coefficient = 0.977

Coefficient of Determination = 0.954

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	1.838	0.185	-
X_1	-0.404	0.108	-3.74
X_2	-0.040	0.011	-3.64
X_3	0.915	0.917	0.99

TABLE 27

MULTIPLE LINEAR REGRESSION ANALYSIS

Land Use: Manufacturing Zone: All Zones

Dependent Variable, Parking Demand, Spaces per 100 sq. m. of floor area; Y

Employees Per Car X_1	Floor Area per Employee-m^2 X_2	Building Index X_3	Parking Demand Spaces per 100 sq.m. of floor area Y
SUMS OF PRODUCTS			
407.760	954.600	98.280	58.350
954.600	2594.372	240.034	158.175
98.280	240.034	29.072	22.720
58.350	158.175	22.720	23.646
SUMS OF PRODUCTS OF DEVIATIONS			
74.940	126.549	0.240	-19.308
126.549	534.194	-3.887	-35.036
0.2400	-3.887	0.192	- 0.155
-19.308	-35.036	-0.155	5.526
M E A N S			
6.450	16.047	1.900	1.505

Standard Error of Dependent Variable = 0.322

Multiple Correlation Coefficient = 0.991

Coefficient of Determination = 0.982

COEFFICIENTS AND STANDARD ERRORS

Variable	Coefficient	Standard Error	't' Statistic
Const.	1.505	0.114	-
X_1	-0.220	0.053	-4.15
X_2	-0.020	0.021	-0.95
X_3	-0.941	0.881	-1.07

TABLE 28

TOTAL PARKING DEMAND AND PRESENT PARKING USAGE
(CENTRAL BUSINESS DISTRICT, BEIRUT)

Land Use.	Present Parking Usage.	Total Parking Demand
	Spaces per 100 sq.m. of Floor Area	
A. OFFICE.		
Business, Professional, Administration.	1.619	2.667
B. RETAIL.		
Sale and Service of all small goods, like drugs, foods, clothes, etc. including Restaurants.	2.177	3.729
C. WHOLESALE.		
Storage, Sale, Service of all big goods, like Machines, vehicles, furniture or big quantities	1.189	1.838
D. MANUFACTURING.		
Industrial production, assembling, testing, processing etc.	1.171	1.505

TABLE 29

TOTAL PARKING DEMAND FOR DIFFERENT LAND USES
(CENTRAL BUSINESS DISTRICT, BEIRUT)

Land Use Code	Classification	Number in Sample	Total Parking Demand spaces per 100 sq.m.of floor area.
A.	OFFICE		
1.	Bank	6	2.65
2.	Govt. Office	1	2.72
3.	P.T.T.	-	-
4.	Medical Office	2	2.00
5.	Utility Co. Office	-	-
6.	Travel Agents, Air line Co. Offices.	3	2.74
7.	General Business Office	48	2.66
8.	Taxi -'Service' Agency	1	2.00
B.	RETAIL		
1.	Men's wear, tailor	15	4.25
2.	Ladies wear, dress maker, cosmetics.	4	4.53
3.	General Clothing	11	2.30
4.	Shoes and boots	6	2.61
5.	Furnishing, radio - TV	4	1.98
6.	Jewler, leather goods.	15	6.95
7.	Pharmacies (Drug Stores)	-	-
8.	Photographic	2	1.44
9.	Book Store	-	-
10.	Restaurants.	1	0.66

TABLE 29 (Continued)

Land Use Code	Classification	Number in Sample	Total Parking Demand Spaces per 100 sq.m. of floor area
11.	Sale of Type writers. electrical appliances.	2	0.79
12.	General Grocery	3	3.23
13.	Optics	-	-
14	Toys Shop	2	0.69
15.	Watches, Clocks.	1	2.50
16.	Arms Shop.	1	1.25
17.	Machine parts tools.	2	4.37
18.	Barber shop, ladies hair dresser	1	3.33
19.	Bakery	1	0.72
20.	Fruit shop, meat shop	1	1.18
C.	WHOLE SALE	8	1.84
D.	MANUFACTURING	8	1.50
E.	INSTITUTIONAL	-	-
F.	RESIDENTIAL	-	-

APPENDIX II

FIGURES

POPULATION GROWTH CURVES

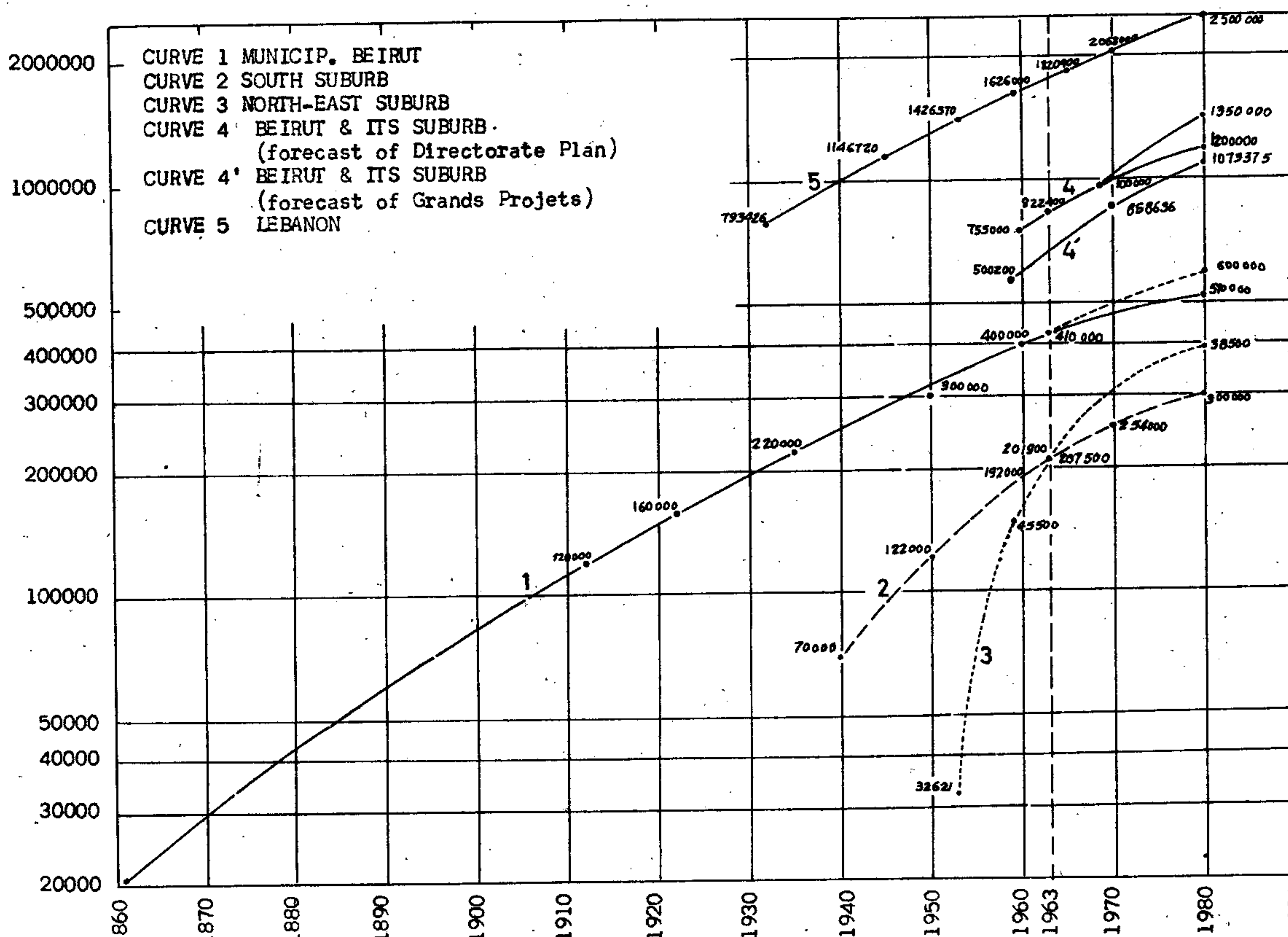


FIG.1

POPULATION AND AREA OF CITY OF BEIRUT

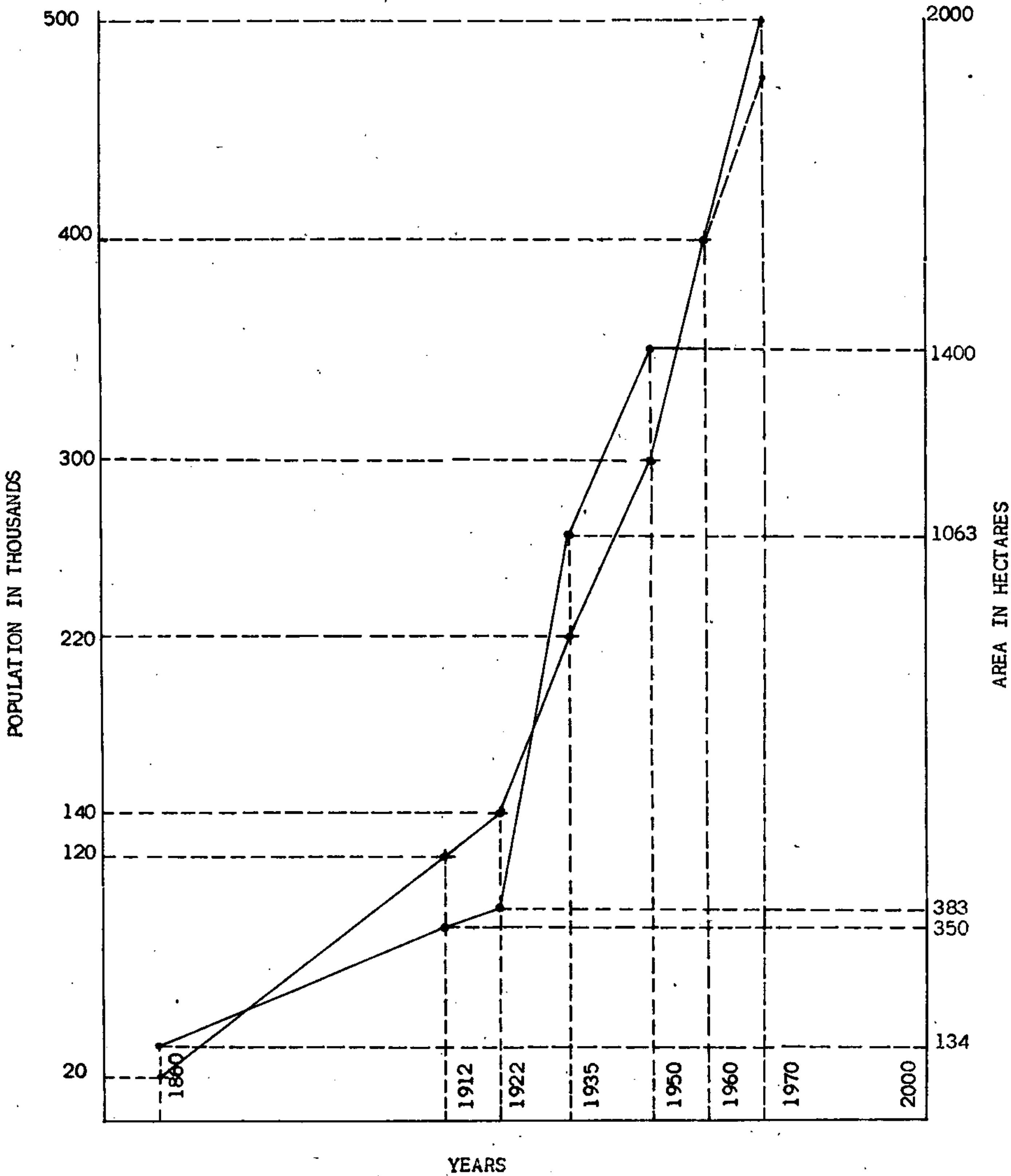


FIG. 2

NUMBER OF REGISTERED VEHICLES PER YEAR IN LEBANON

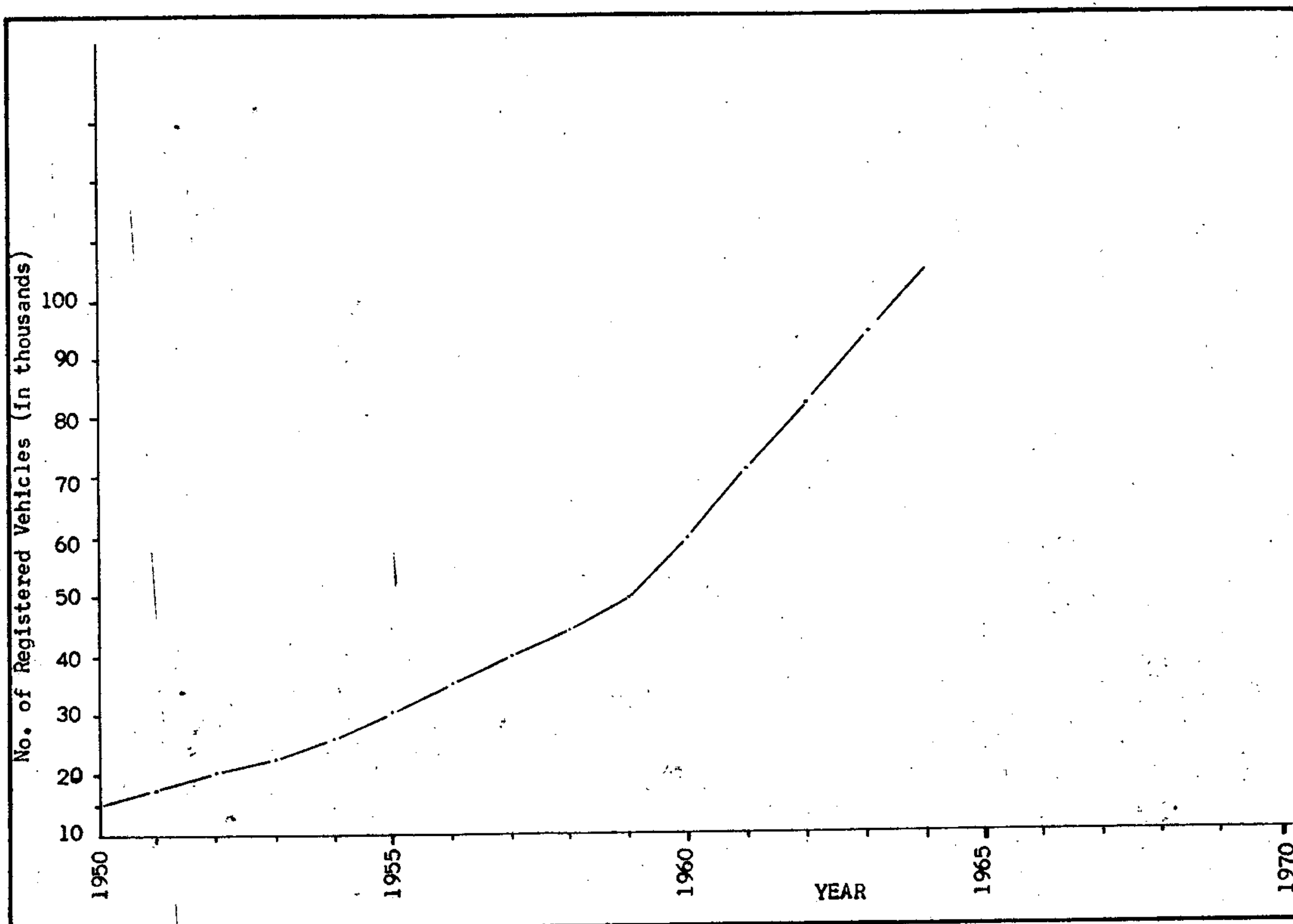


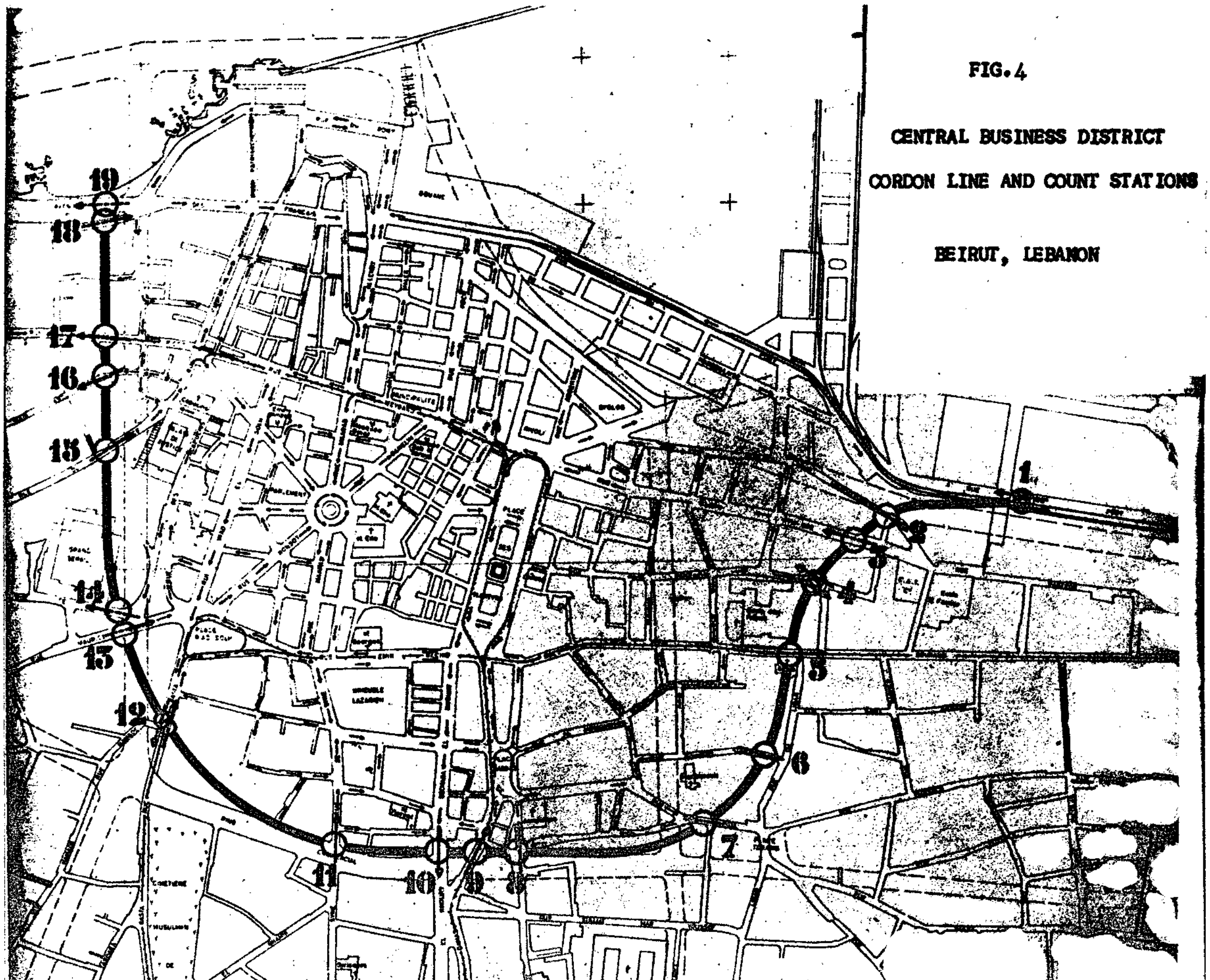
FIG. 3

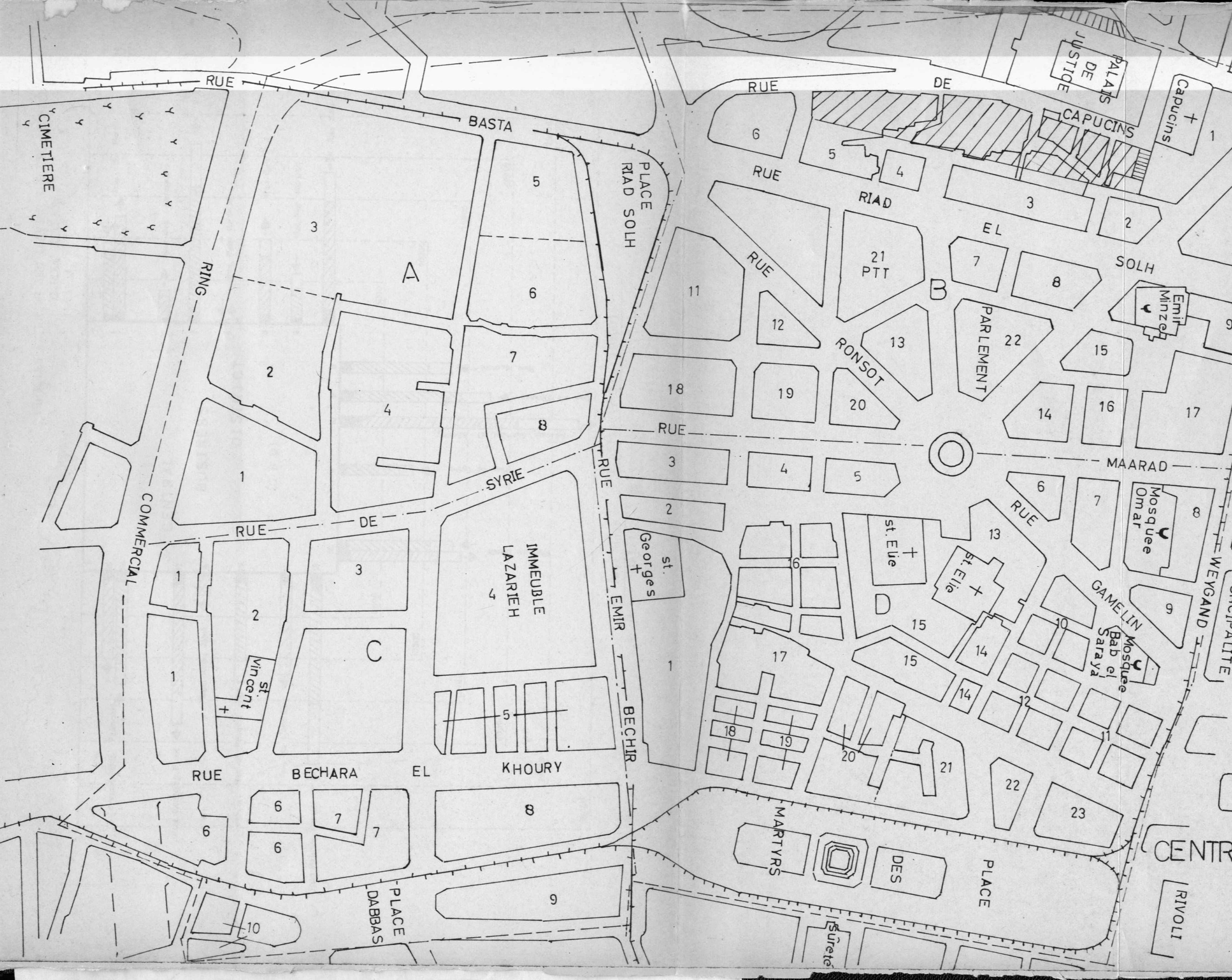
FIG. 4

CENTRAL BUSINESS DISTRICT

CORDON LINE AND COUNT STATIONS

BEIRUT, LEBANON





THE STUDY AREA

CORE OF

CENTRAL BUSINESS DISTRIC

BEIRUT

Scale 1:2000

Fig. 5

VEHICLES ENTERING AND LEAVING THE CBD AT EACH GORDON STATION

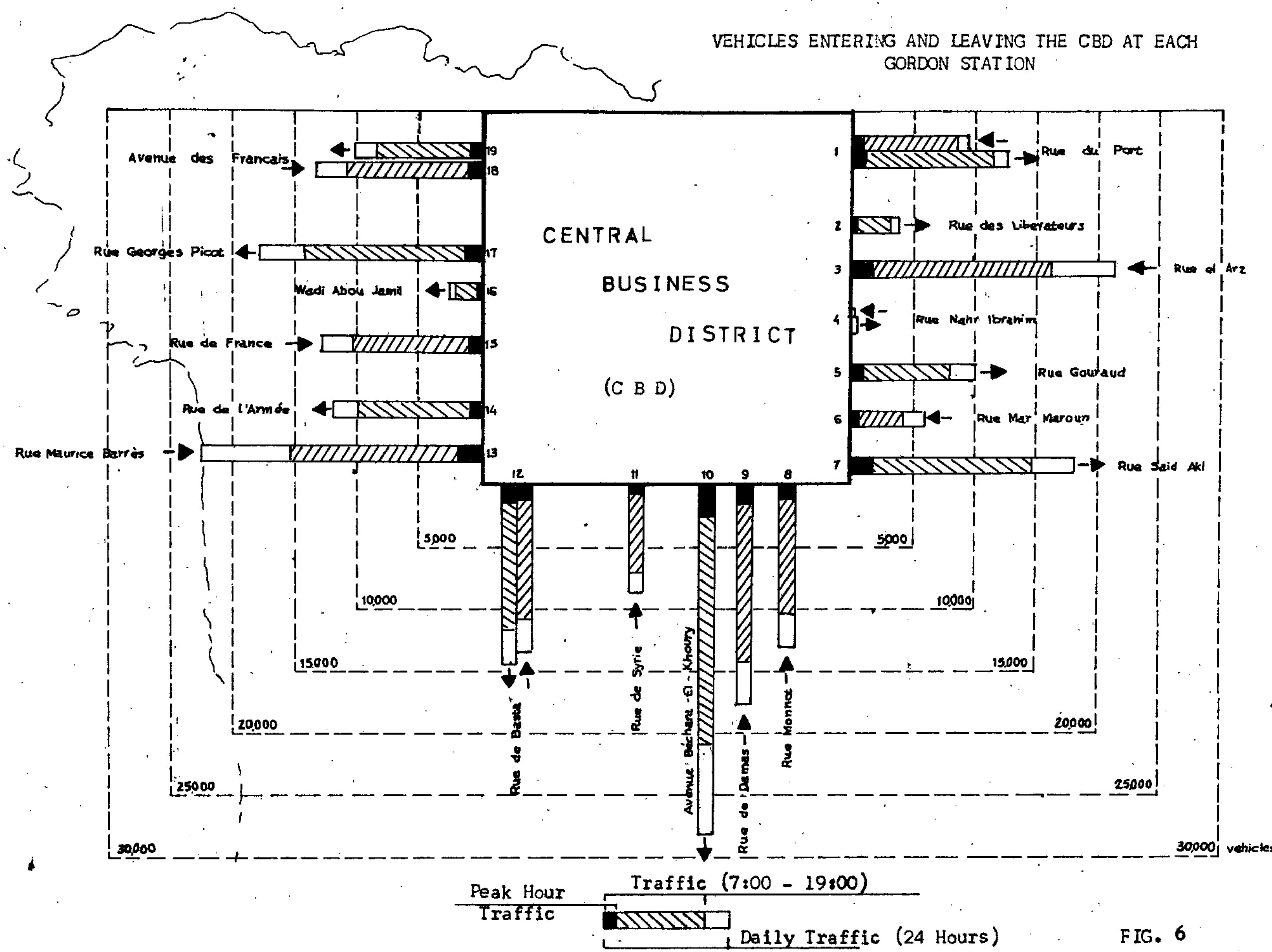


FIG. 6

NUMBER OF PERSONS BY 30 MINUTE
PERIODS ENTERING AND LEAVING
THE C B D.

LEGEND

- Persons entering the CBD
- Persons leaving the CBD
- Accumulation of Persons

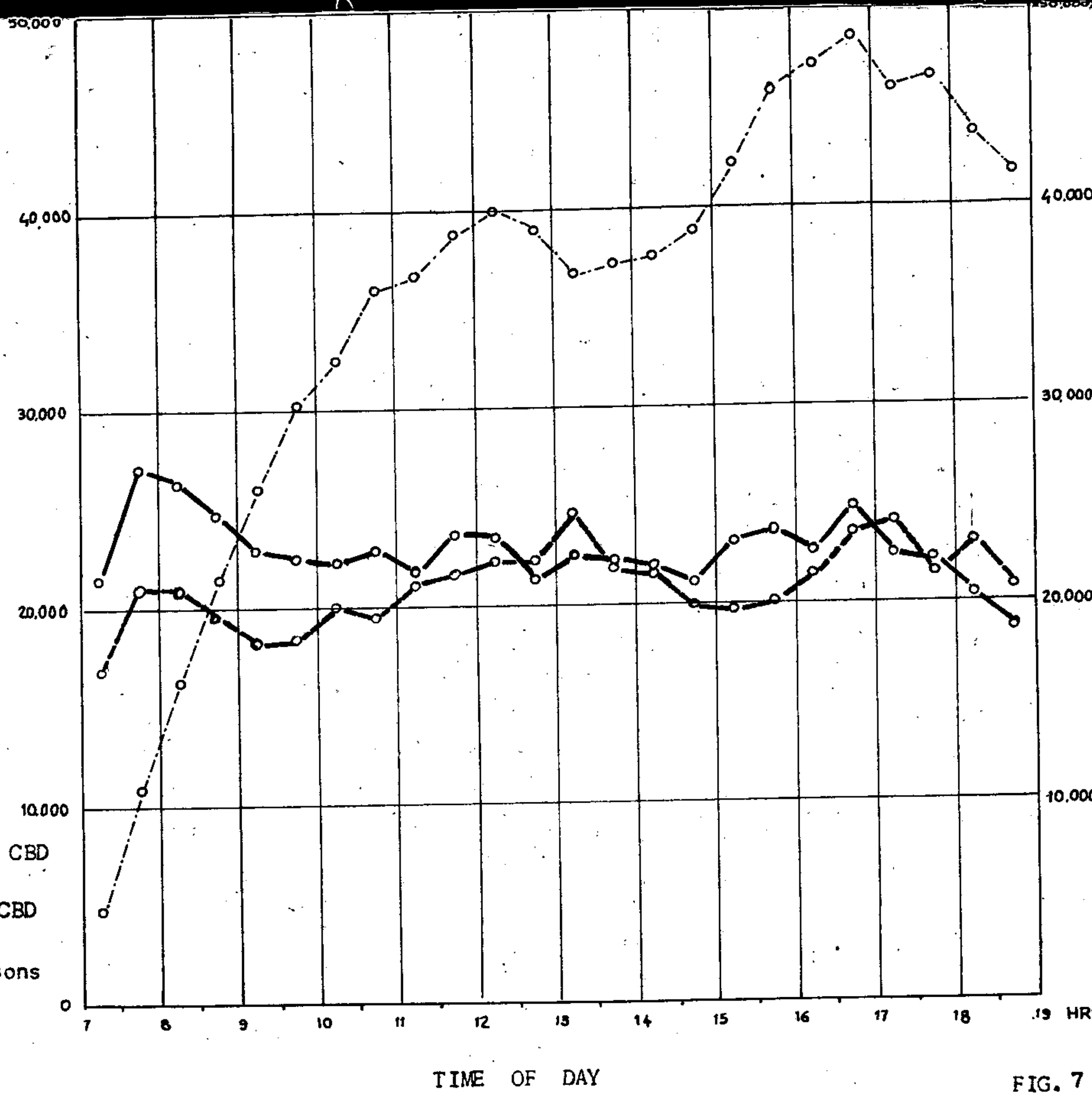
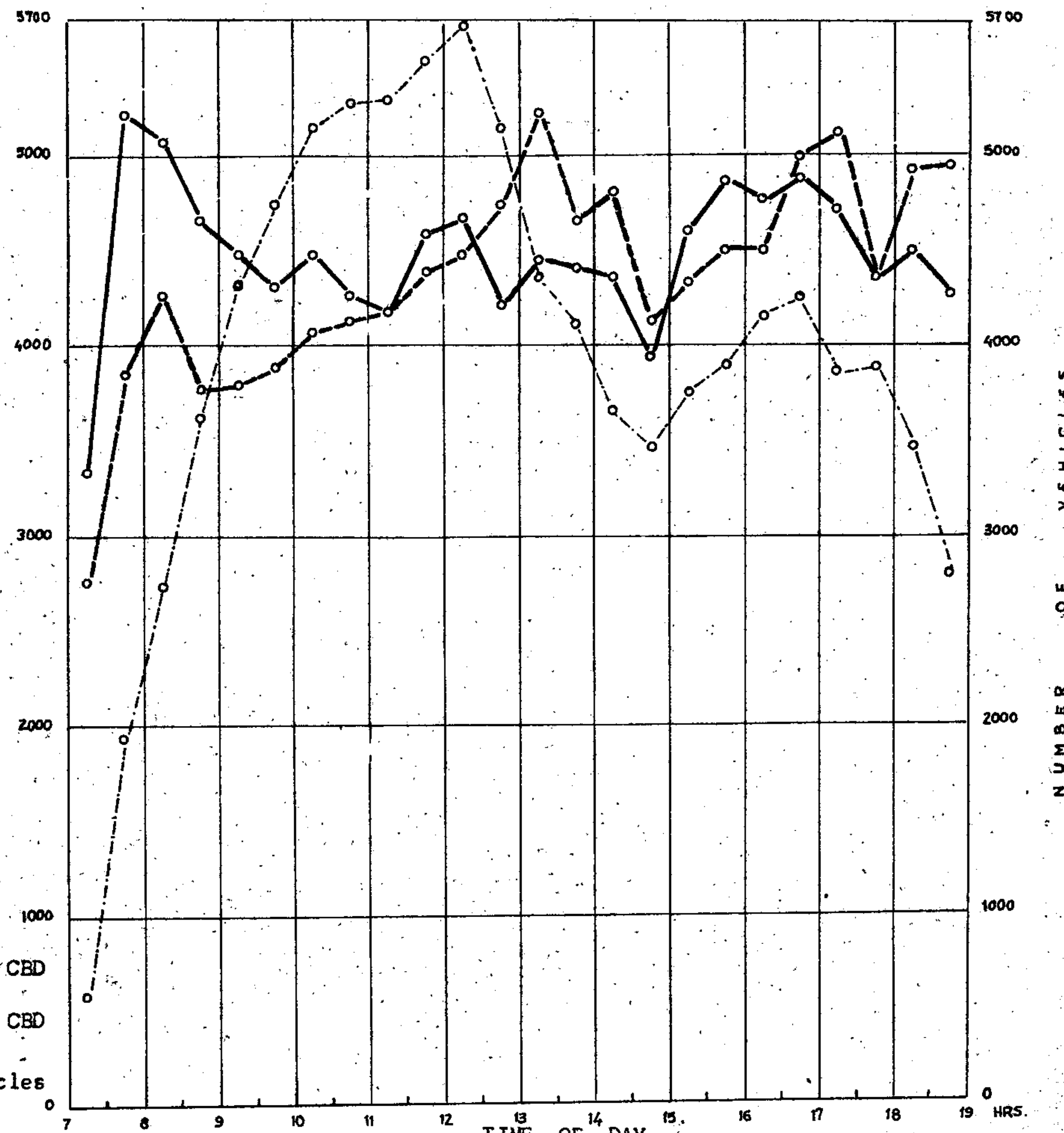


FIG. 7

NUMBER OF TOTAL VEHICLES
(Private Cars + Taxis & Services + Buses + Trucks)
BY 30 MINUTE PERIODS ENTERING AND LEAVING THE CBD.



LEGEND

o——o Vehicles Entering the CBD

o— — —o Vehicles Leaving the CBD

o-·-·-·o Accumulation of Vehicles

FIG. 8.

NUMBER OF PRIVATE VEHICLES BY 30 MINUTE PERIODS ENTERING AND LEAVING THE CBD.

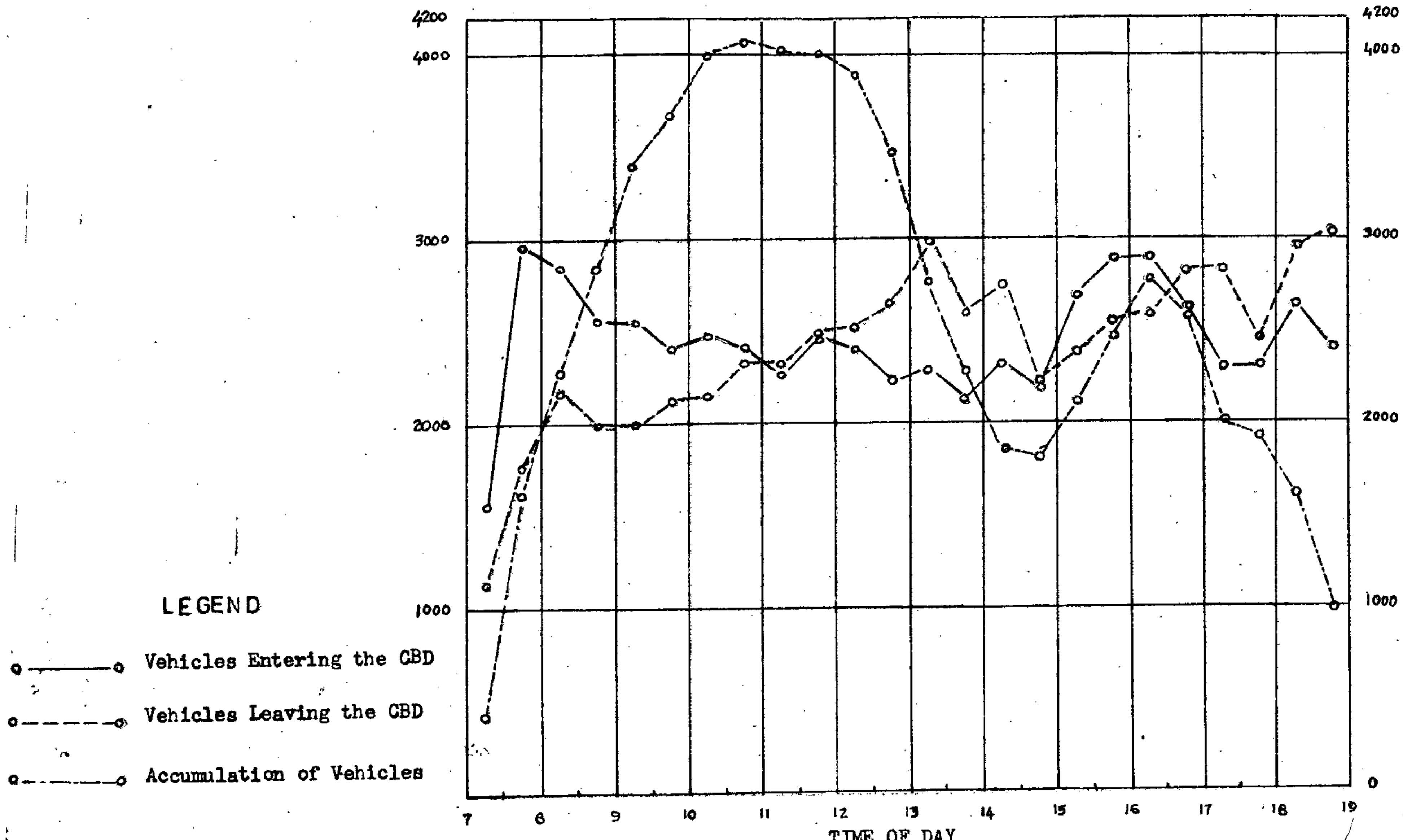
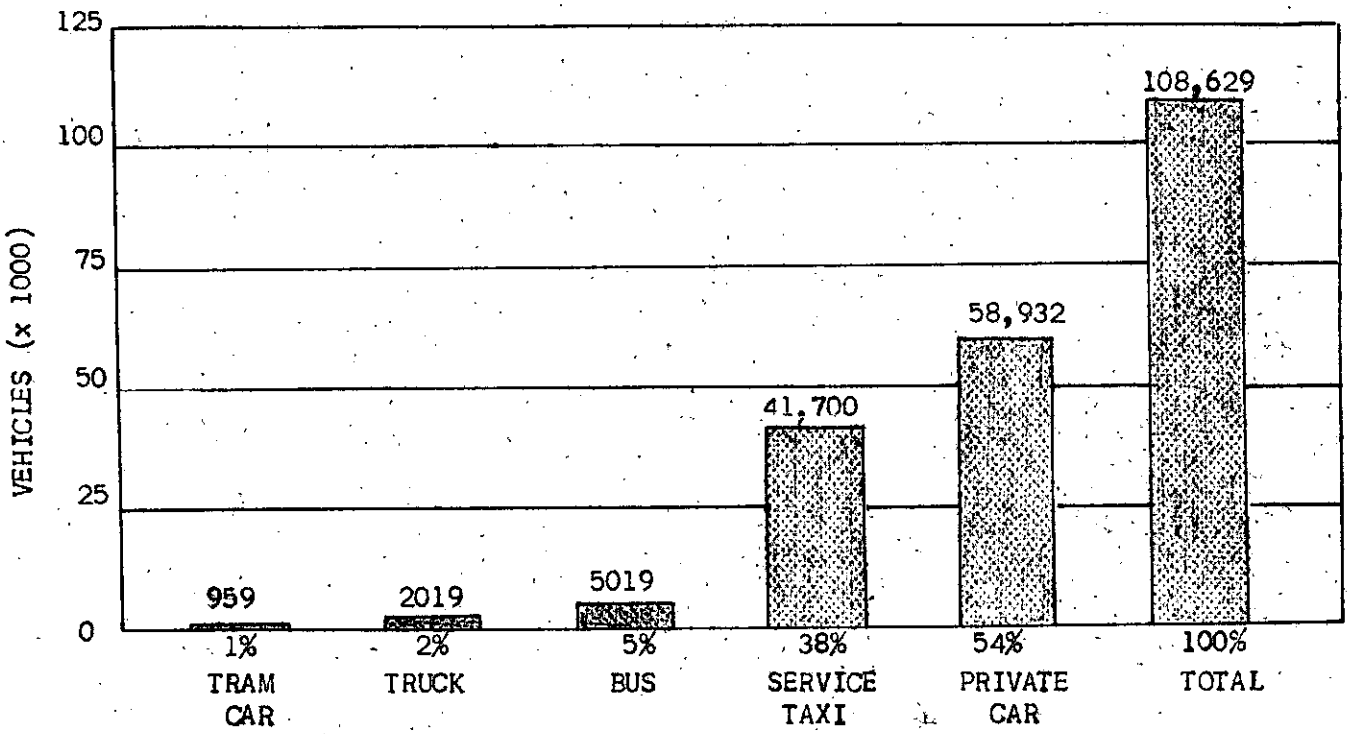


Fig. 9

PROPORTION OF VEHICLES OF VARIOUS TYPES
ENTERING THE CENTRAL BUSINESS DISTRICT
(7 A.M. - 7 P.M.)



PROPORTION OF VEHICLES OF VARIOUS TYPES
ENTERING THE CENTRAL BUSINESS DISTRICT
(8-8:30 A.M.; 1-1:30 P.M.; 4:30-5 P.M.)

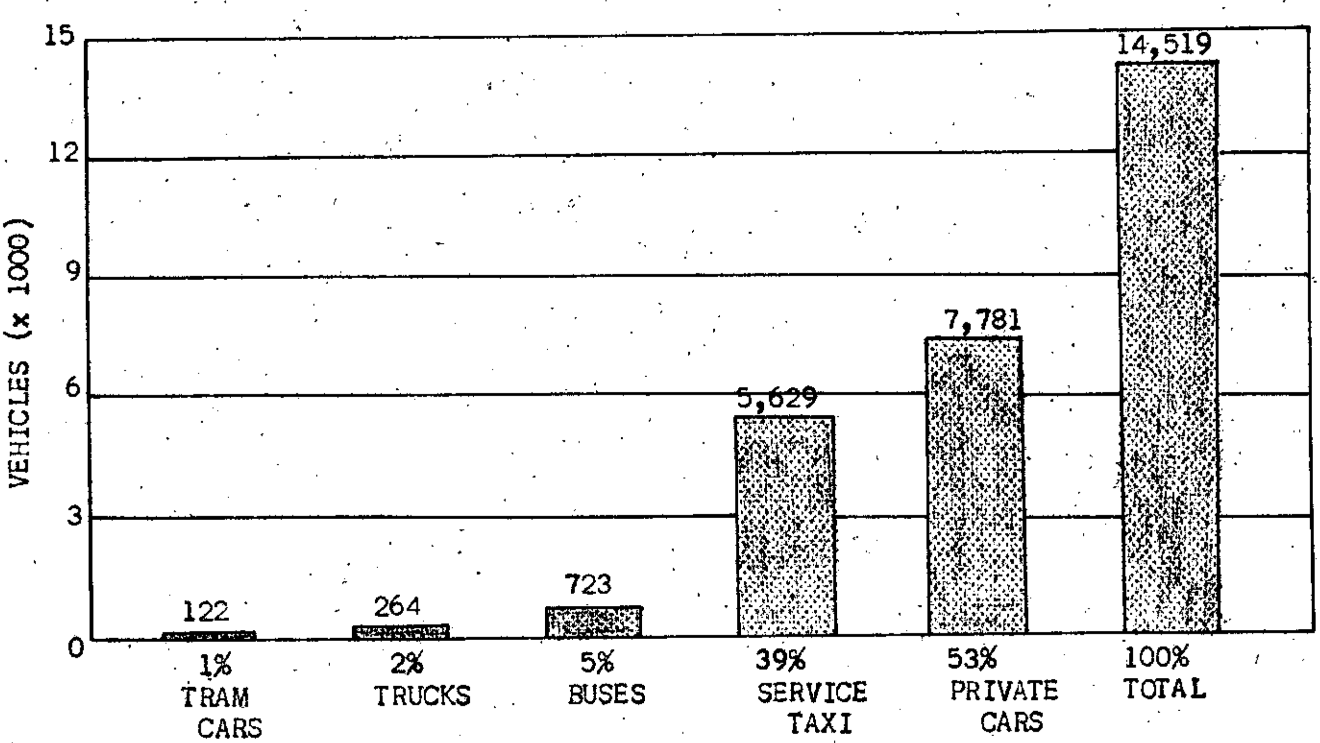
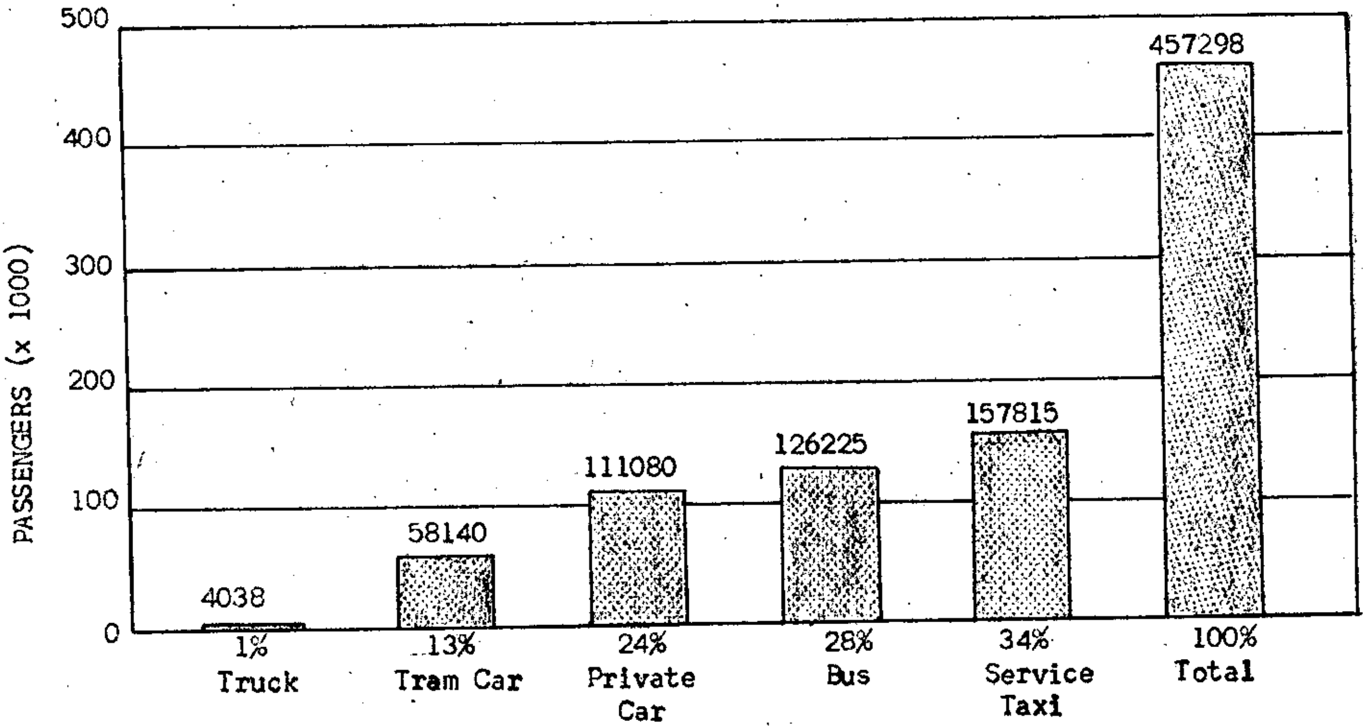


Fig. 10

PROPORTION OF PASSENGERS BY TRAVEL MODE
ENTERING THE CENTRAL BUSINESS DISTRICT
(7:00 A.M. - 7:00 P.M.)



PROPORTION OF PASSENGERS BY TRAVEL MODE
ENTERING THE CENTRAL BUSINESS DISTRICT
(8-8:30 A.M.; 1-1:30 P.M.;4:30-5 P.M.)

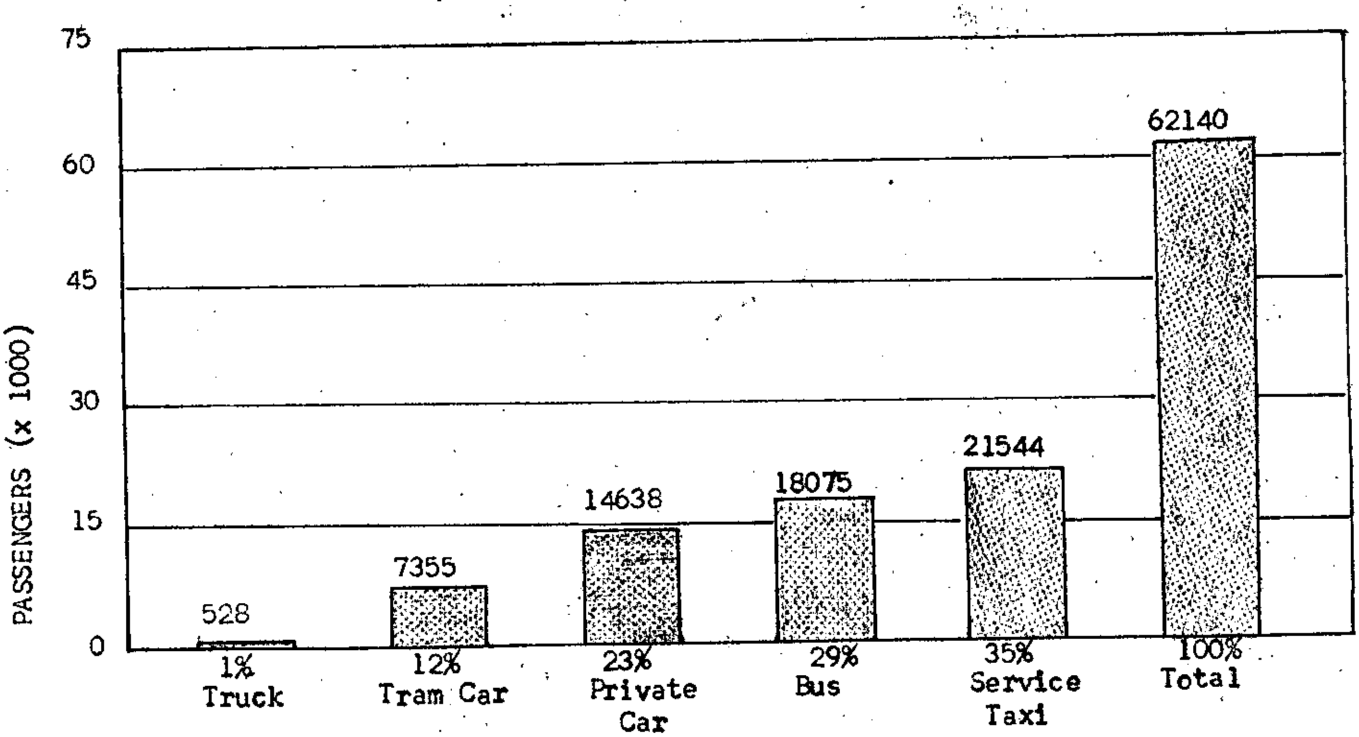
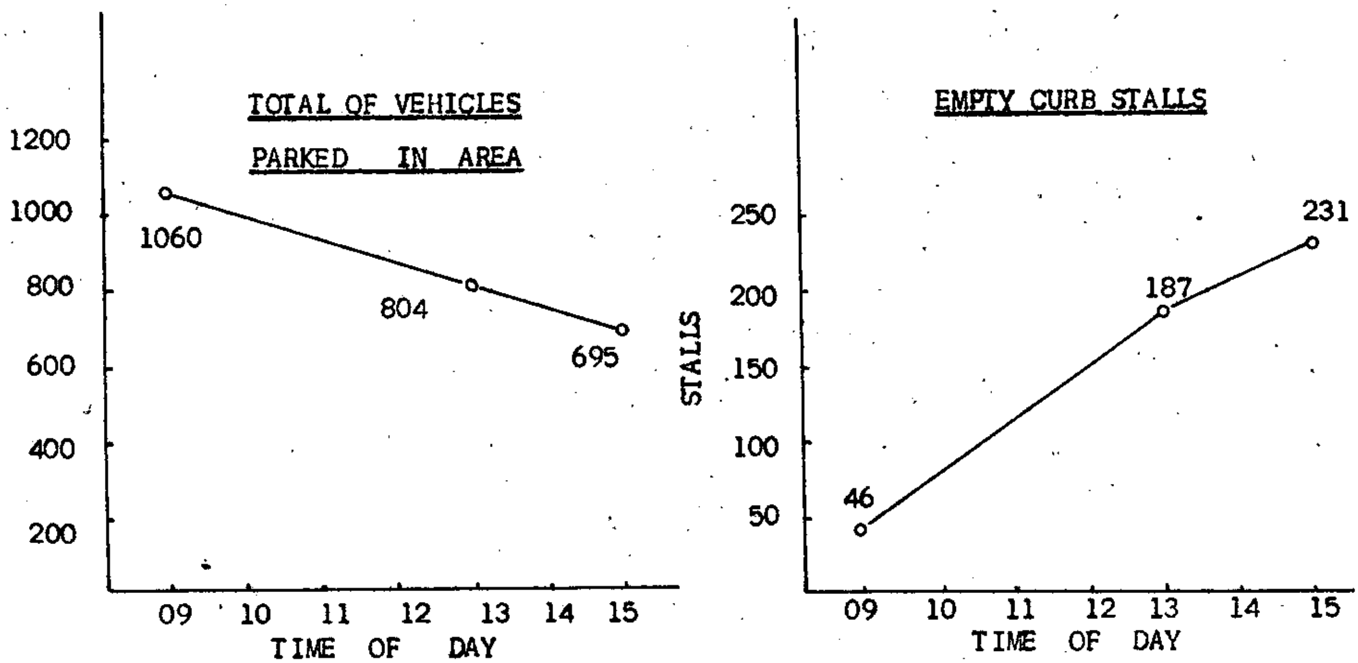


Fig. 11

CURB UTILIZATION CURVE
PARKERS DURATION CURVES



- TOTAL OF VEH. CURVE REPRESENTS ALL PARKED PASSENGER AND COMMERCIAL VEHICLES ON CURBS AND OFF-STREET.
- EMPTY STALL CURVE REPRESENTS THOSE ONLY ON CURBS WHERE PARKING IS ALLOWED - FOR PRIVATE P-VEHICLES.

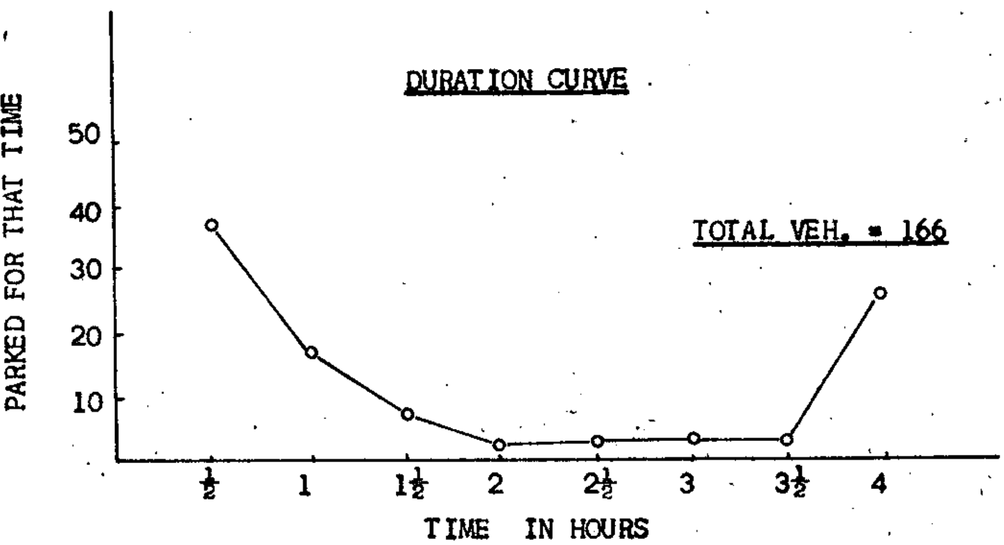


FIG. 12

APPENDIX III

THEORY AND DEFINITION OF STATISTICAL TERMS

APPENDIX III

Multiple Linear Regression Analysis

The dependent variable, y_v, —— the variable to be explained is assumed to be a linear function of certain explanatory or independent variables, $x_{1v}, x_{2v}, \ldots, x_{mv}$. The observed data is given as n sets of numbers $(x_{1v}, x_{2v}, \ldots, x_{mv}, Y_v)$ for $v = 1, 2, \ldots, n$. Where m is number of independent variables.

The assumptions underlying the regression analysis are as follows:

1. For every fixed value of $(x_1, x_2, \ldots, x_n)$, y is normally distributed.

2. The mean value of y is a linear function of $x_1, \ldots, x_n$. This function may be written

$$\eta = \mathcal{M}[y / x_1, x_2, \ldots, x_m]$$
$$= \alpha + \beta_1(x_1 - \bar{x}_1) + \beta_2(x_2 - \bar{x}_2) + \ldots + \beta_m(x_m - \bar{x}_m) \quad \ldots\ldots(1)$$

where the data clearly violate this assumption, one of the variables is transformed.

3. The variance of y is independent of $(x_1, x_2, \ldots, x_m)$

$$\sigma^2 = \mathcal{V}[y/x_1, x_2, \ldots, x_m] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

4. The independent variables are assumed to be fixed or non-random. This assumption must be made if probabilistic statements about regression coefficients are to be made.

5. The observations are stochastically independent, i.e. the values $(x_{1v}, x_{2v}, \dots, x_m, y_v)$ are stochastically independent, i.e. the values $(x_{1v}, x_{2v}, \dots, x_{mv}, y_v)$ are stochastically independent of $x_{1\mu}, x_{2\mu}, \dots x_{m\mu})$ for $v \neq \mu$.

Estimation of the parameters α, β_1 & $\beta_2, \dots, \beta_m$ and σ^2 are to be determined from the observations.

If the observations are plotted as points in a $(x_1, x_2, \dots, x_m, y)$ coordinate system the assumptions mean that the points are distributed about the plane, represented by (1), the vertical distance between the points and the plane, i.e. $y_v - \eta_v = U_v$, being independently and distributed about zero with variance σ^2.

The term U_v, called the random error term is assumed to be unrelated to the independent variables. If this assumption is violated, then the estimated regression coefficients will exhibit a specification bias.

Further it is assumed that the observations are not grouped into sets whence the variation within sets is not analyzed.

The estimates of the parameters α, β_1, β_2, ..., β_m are determined by the method of least squares, i.e. the sum of squares of the deviations between observed values and empirical regression plane, ΣU_v^2, is minimized.

The estimate of the regression equation is written

$$Y = a + b_1(x_1-\bar{x}_1) + b_2(x_2-\bar{x}_2) + \dots + b_m(x_m-\bar{x}_m) \quad \text{.............. (3)}$$

where, a, is the intercept on the Y-axis, $b_1, b_2, \dots, b_m$ are the regression coefficients and $\bar{x}_1, \bar{x}_2, \dots, \bar{x}_m$ are the mean values of $x_1, x_2, \dots, x_m$.

According to the method of least squares the estimates of the parameters are determined from the equation

$$a = \bar{y} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

and the **"normal equations"**

$$b_1 SSD_{x_1} + b_2 SPD_{x_1x_2} + \ldots\ldots\ldots + b_m SPD_{x_1x_m} = SPD_{x_1y}$$

$$b_1 SPD_{x_2x_1} + b_2 SSD_{x_2} + \ldots\ldots\ldots + b_m SPD_{x_2x_m} = SPD_{x_2y} \quad \ldots\ldots\ldots (5)$$

$$\vdots$$

$$b_1 SPD_{x_mx_1} + b_2 SPD_{x_nx_2} + \ldots\ldots + b_m SSD_{xm} = SPD_{xmy}$$

where SSD, and SPD are abbreviations for sums of squares of deviations from the means, and sums of products of the deviations.

The sums of squares $\sum(y_v - \eta_v)^2$ or U_v^2 is partitioned as follows:

$$\sum_{v=1}^{m} (y_v - \eta_v)^2 = \sum_{v=1}^{n} (y_v - Y_v)^2 + n(a - \alpha)^2 + \sum_{i=1}^{m} (b - \beta_i)^2 \, SSD_{xi} +$$

$$2 \sum_{i=1}^{m} \sum_{j=i+1}^{m} (b_i - \beta_i)\,(b_j - \beta_j) SPD_{xixj} \ldots\ldots\ldots\ldots (6)$$

Application of the partition theorem for the χ^2-distribution leads to the following results:

1. The varience

$$s^2 = \frac{1}{n - m - 1} \qquad (y_v - Y_v)^2 \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

is distributed as s^2 with parameters $(\sigma^2, n\text{-}m\text{-}1)$

2. The estimate, a, is normally distributed with mean α and varience $\frac{\sigma^2}{n}$.

3. The estimates $(b_1, b_2, \ldots, b_m)$ are normally correlated with means $(\beta_1, \beta_2, \ldots, \beta_m)$, variences

$$\mathcal{V}[b_i, b_j] = C_{ij}\,\alpha^2, \; i = 1, 2, \ldots, m \;\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

and covariences

$$\mathcal{V}[b_i, b_j] = C_{ij}\,\alpha^2, \; i \neq j, \; (i,j) = 1,2,\ldots, m \;\ldots\ldots\ldots \quad (9)$$

where the quantities C_{ii} and C_{ij} depend solely upon the coefficients of the normal equations.

4. The estimates of S^2, a, and $(b_1, b_2, \ldots, b_m)$ are stochastically independent. From this it follows, e.g. that:

$$\mathcal{V}[Y] = \mathcal{V}[a] + \sum_{i=1}^{m} \mathcal{V}[b_i]\,(x_i - \bar{x}_i)^2 + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{m} \mathcal{V}[b_i\, b_j](x_i - \bar{x}_i)(x_i - \bar{x}_j) =$$

$$\alpha^2\left[\frac{1}{n} + \sum_{i=1}^{m} C_{ii}(x_i - \bar{x}_i)^2 + 2\sum_{i=1}^{m-1}\sum_{j=i+1}^{m} C_{ij}(x_i - \bar{x}_i)(x_j - \bar{x}_j)\right] \;\ldots\ldots (10)$$

which may be used for the determination of confidence limits for η, since $(y - \eta)/S_y'$ is distributed as t with n-m-1 degrees for freedom, S_y^2 being determined from (10) by substituting S^2 for α^2.

Further we obtain as a marginal test for any specified hypothetical value of β_i:

$$t = \frac{b_i - \beta_i}{Sb_i}, \quad Sb_i = S\sqrt{C_{ii}}, \quad f = n-m-1 \;\ldots\ldots\ldots\ldots \quad (11)$$

which is distributed as t with n-m-1 degrees of freedom.

The following statistics are also of great interest.

1. Standard error of estimate or standard error of constant

$$S_a = \sqrt{\frac{S^2}{n}} \quad \text{.............................} \quad (12)$$

2. Multiple correlation coefficient is

$$R = \sqrt{1 - \frac{Sa^2}{sy^2}} \quad \text{.........................} \quad (13)$$

where Sa is standard error of constant and

s_y is standard error of dependent variable.

3. The square of multiple correlation coefficient, R^2, is called the multiple coefficient of determination, which gives a measure of the goodness of fit; namely the proportion of varience of the dependent variable explained by the linear relation to the included explanatory variables.

The following tests of significance can be applied:

1. The correlation of universe i.e. the correlation of all the variables included in the equation can be tested by means of F statistic:

$$F = \frac{R^2/(k-1)}{1-R^2/(n-k)} \quad \text{...................} \quad (14)$$

where k is the number of parameters in the regression function, n is the size of the sample and $N_1 = k-1$, $N_2 = n-k$, are respective degrees of freedom.

2. The effect of each explanatory variable on the dependent variable can be tested by means of t statistic (equation 11).

$$t = \frac{b_i - \beta_i}{Sb_i}$$

with n-m-1 degrees of freedom.

If an explanatory variable has no effect on the dependent variable, the expected value of its regression coefficient is zero. Chance factors will, however, usually lead to non-zero estimates even when no relation exists; discrepancies tend to be larger where the standard error, Sb_i, is larger. However, the greater the numerical value of the t statistic, the smaller is the likelihood that chance factors alone are responsible.

Definition of Statistical Terms

Average — The average of individual observations

$$\bar{X} = \sum_{i=1}^{n} \frac{xi}{n}$$

where x_i is an individual measurement.

Standard Deviation — A measure of general variability and the square root of the average of the squared deviations from the mean. In the sample the standard deviation is computed as

$$S = \sqrt{\frac{\sum_{i=1}^{n} fi\,(x_i - \bar{x})^2}{n - 1}}$$

For the population the standard deviation is denoted by σ.

Varience (σ^2) and (S^2) — The square of the standard deviation.

Statistical Hypothesis (H) — A statement which usually assigns one or more values to a population parameter. Other characteristics of the population are assumed.

Significance Level — The probability of the test statistic lying in the rejection region when the hypothesis is, in fact, true.

Confidence Level	The probability of the test statistic lying in the acceptance region when the hypothesis is true.
Population or Universe	The collection or aggregates of elements about which an inference is to be made.
Population Parameter	A characteristic of the population.
Range	The difference between the largest and the smallest sample values.
Sample	A number of elements selected from the population.
Normal Distribution	A certain theoretical relation between the values of the measured variable and the relative frequency of the value.
Stochastic Independence	v is said to be stochastically independent of u if the probability of the occurance of v is the same whether u occurs or not.

Specification bias

Suppose that the true relationship between some dependent variable, y, and three explanatory variables, x_1, x_2 and x_3 is given by a linear relation

$Y = a + B_1 x_1 + B_2 x_2 + B_3 x_3 + U$ where U is a random error term with mean zero and independent of the explanatory variables. Further, assume that a least squares regression of the following form is actually estimated.

$Y = a + b_1 x_1 + b_2 x_2 + V$

where V is again an error term which is assumed to be independent of the x's. The regression coefficient, b_1, is an estimate of the effect on Y of a unit change in x_1. However, the true partial effect on Y is given by B_1. It can be shown that b_1 and B_1 are related as follows:

$B_1 = b_1 - C_1 B_3$

where C_1 is obtained by estimating the following least squares regression:

$$x_3 = C_o + C_1 x_1 + C_2 x_2 + e$$

This means that b_1 will be an unbiased estimate of B_1 if and only if C_1 and/or B_3 equals zero.

Time Series

By time series is means a set of observations, $y(x_1)$, $y(x_2)$, ... $y(x_n)$ ....., where $x_1 < x_2 < \ldots\ldots < x_n < \ldots\ldots$ denote time, and $y(x)$ the corresponding observations.