A STUDY OF THE INFLUENCE OF STOPPED DELAY ON DRIVER GAP ACCEPTANCE BEHAVIOUR

Thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria, in partial fulfillment of the requirements for the award of Master of Science Degree in Transportation and Highway Engineering,

BY

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D E C L A R A T I O N

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any other university or Institution. Information derived from the published and unpublished works of others has been acknowledged in the text.

C E R T I F I C A T I O N

This thesis report entitled "A STUDY OF THE INFLUENCE OF STOPPED DELAY ON DRIVER GAP ACCEPTANCE BEHAVIOUR" by George Nkeng Sama meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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D E D I C A T I O N

This work is dedicated to my mother, the memory of my father and Mr. Christopher Sama and Wife.

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A B S T R A C T

The influence of stopped delay on driver gap acceptance behaviour is investigated. Gap rejection/acceptance data collected for minor road drivers executing left-turning manoeuvres at two separate priority intersections are analysed. The mean critical gapfit (C) and its variance (O^2) are separately estimated from the aggregated data and from abstractions of the data based on the durations of stopped delay.

It has been found that at shorter durations of stopped delay by minor road drivers, the mean critical gaps obtained are higher than those obtained when minor road drivers experience higher durations of delay. A statistical comparison shows that at the %% level of significance, the mean critical gaps estimated from the disaggregated data are significantly different from the value obtained from the aggregated data, the values being in reasonable agreement when the mean delay to minor road drivers is about 30s.

The practical significance of these differences in mean critical gaps as reflected in the computed values of the minor road capacity is also investigated. It has been found that the minor road capacity will be slightly under-estimated during periods when minor road drivers experience high durations of stopped delay and seriously over-estimated at situations when durations of stopped delay are short.

Empirical equations have been derived relating the mean critical gap to the mean delay, average main flow and the minor road capacity.

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LIST OF SYMBOLS

a_n	accepted gap by n^{th} driver
α	significance level
$\alpha(t)$	gap acceptance function
B	marginal critical gap
B_1	Average service time per vehicle on main road
B_2	Minimum headway at which minor road traffic may follow each other to the major road
C	mean critical gap
Cn	Expected critical gap for n^{th} driver
d	delay to minor road traffic
E(N)	Mean vector of multinominal probit model
$K(\alpha)$	value of standard normal variate at a cumulative probability of $(1 - \alpha)$
L	Length of chart paper
mm/S	Millimetres per second
N	Number of queued minor road vehicles
n_1, n_2	Sample sizes for two situations being compared
ϕ	Unit normal distribution
Q	Minor road capacity
q	Average flow on main road
R	maximum number of rejected gaps
$r_i n$	i^{th} rejected gap by the n^{th} driver
S	start-up time of a minor road vehicle
s	seconds
σ	standard deviation of critical gaps
σ_α	Standard deviation of gap acceptance function
T	Time gap in main traffic accepted by N minor road vehicles
U	drum speed of recorder

μ_1, μ_2	means of two samples being compared
v/h	vehicles per hour
V(N)	covariance matrix of multinominal probit model
W_n	Vector of multivariate normally distributed randon variables
Y_i	critical gap of the i^{th} vehicle in a minor road queue

CHAPTER ONE

I N T R O D U C T I O N

1.1 GENERAL

The numerous publications on the subject of driver gap acceptance behaviour within the past three or so decades is indicative of the interest shown by traffic engineers and mathematicians alike in the study of gap acceptance characteristics of drivers executing crossing and/or merging manoeuvres at roadway intersections. It is interesting to note that whereas the mathematicians have been mainly interested in the general application of theoretical techniques and/or analogies, the traffic engineers have been more concerned with both the practical applications and implications of driver gap acceptance characteristics as they affect traffic merging and crossing problems.

To better understand how this phenomenon of gap acceptance applies to different forms of intersection control, a brief discussion on the principles of intersection design and operation may prove useful. In most instances in urban areas, highway network links are located in the same horizontal plane. Most of these links often intersect, creating areas of conflict between various traffic flows, which invariably leads to delays, loss in highway capacity and accidents.

The essential features of intersection design and control are thus geared towards resolving the potential conflicts. Such design must generally be based on how

both drivers and pedestrians are likely to behave at such locations rather than how they should behave. Traffic engineers are thus continually faced with the problem of studying such behaviour in order to effectively control traffic flows and to improve the safety as well as the overall performance of the highway network; though this is further complicated by the fact that each intersection has unique characteristics of physical layout, flow rates, pedestrian activity and turning movements. All these factors influence intersection performance.

The most appropriate type and degree of control exercised for a particular intersection will thus be assessed on the bases of the intersecting flows, turning movements and the values placed on the resulting delays, loss in capacity and accidents. Traffic volumes change with time and continuous studies and monitoring of intersection performance are essential in updating designs and control devices. The present study is focussed on an aspect of intersection performance for at-grade intersections.

From a control point of view, at-grade intersections may be classified into three different groups, namely: uncontrolled and priority intersections, space sharing intersections and time sharing intersections. These are briefly described in the following subsections.

1.2 UNCONTROLLED AND PRIORITY INTERSECTIONS

An uncontrolled intersection, as the name suggests is one whereby no form of control is exercised. Ideally, this is allowed when the intersecting roads are of relatively equal importance and traffic volumes are so low that no form of control appears necessary. However, when two opposing vehicles arrive at an uncontrolled intersection simultaneously, the rules of the road require that preference be given to the vehicle on the right. At such intersections, each flow must seek gaps (the time between two successive vehicles) in the intersected traffic streams. By simple intuition, when flows are low, gaps of reasonable size and frequency are expected, such that drivers do not have to wait for a long time before manoeuvring. However, when intersecting flows increase, the intersection needs some form of control to avoid confusion and unnecessary delays.

Priority intersections on the other hand occur when one of the intersecting roads (major road) is given definite priority over the other(s) (minor road(s)). The minor road approaches are thus controlled by some form of marking or sign such as "STOP, YIELD, or GIVE WAY" to ensure that vehicles on the main road are not delayed. It is thus clear that the minor road vehicles are those seeking gaps. They are normally required to come to a full stop and wait for an acceptable gap before merging or crossing as the case may be. There is thus an inherent assumption that

virtually no delay occurs to the main traffic; the main aspect of performance being the effects of such control on minor road traffic. These effects could be quantified in terms of the average delay to minor road traffic and the capacity of the minor road approach.

Such statistics are related to the average time gap a side street driver thinks he needs to cross or merge safely with the main traffic stream (Tanner; 1962) and the number of gaps equal to or larger than this required, acceptable or critical gap. Where a large gap presents itself when there is a queue of minor road vehicles, one or more vehicles may accept the gap. This phenomenon is more explicitly described as queue acceptance of large gaps and it is further explained in chapter two.

1.3 ROTARY INTERSECTIONS

Rotaries are a form of channelized intersection wherein vehicles are guided on to a one way roadway and required to move in an anticlockwise direction (in a drive right system) about a central island. They are specialised forms of at-grade intersection design and are best suited for intersections with five or more approaches, though they have also been useful at three and four leg intersections. In general, they are most suitable where the entry volumes from the various intersection approaches are approximately equal, and weaving traffic equals to, or exceeds through traffic.

Originally, rotary designs were intended to permit continuous movement of all intersecting flows. This phenomenon is better described as weaving rather than gap acceptance. However, the introduction of the priority rule of "Give way to the vehicle on the left" at rotaries implies that each approach operates in a similar manner to a major/minor road T-junction; circulating traffic having priority over entry traffic. The entry traffic thus has to evaluate time gaps in the priority stream (circulating flow) before moving in. Since relative speeds are generally low, entry drivers tend to accept shorter gaps as traffic circulates around the central island; though as Agili (1981) points out, this priority pattern is sometimes reversed as merging drivers force themselves into the circulating stream.

1.4 TIME SHARING INTERSECTIONS

Time sharing intersections occur where the control mechanism alternates the right of way in some sequential manner. The right of way is first assigned to one set of movements and then to another in a sequence according to demand and intersection geometrics. This form of control is achieved by automatic signals and police direction.

Warrants for the installation of traffic signals can be found in most traffic engineering texts. However, the design must be based on a careful study of the intersection, since experience has shown that unwarranted and improperly installed signals can lead to excessive delay, disobedience

of signal indications, increase in accident frequency, and sometimes the use of less adequate routes by motorists in order to avoid the signal.

Though conflicts are separated by time, it will be realised that the gap acceptance phenomenon is still applicable here if a special phase is not provided for right turning traffic; since they must have to merge with the through cross stream traffic.

From the discussions, it is apparent that the gap acceptance phenomenon is basic to drivers at almost all at-grade intersections and freeway entry ramps. Even a pedestrian waiting to cross a traffic stream has to decide if a gap is sufficiently large to allow a safe crossing. Thus, this phenomenon is not only applicable to drivers but to pedestrians as well; though most of the research on the subject seems to have been centred solely on driver characteristics.

At rotaries, Agili (1981) indicates two strategies by which an entry/circulating flow relationship can be predicted from a knowledge of the geometric layout of the roundabout. These are the gap acceptance and empirical approaches.

The gap acceptance approach requires the establishment of a model of vehicle - vehicle interaction that takes place at the roundabout entry, and to compute the entry/circulating flow relationship from the model before calibrating the parameters of the relationship in terms of the roundabout geometry. The second approach is an empirical method which

directly determines the entry/circulating flow relationship on the basis of the geometric parameters.

While Agili acknowledges the gap acceptance mechanism as an important element in the vehicle-vehicle interaction at roundabouts, he points out that it is unlikely to be a complete and sufficient determinant of the capacity; because in reality, the process at entries to roundabouts is more interactive than conventional assumptions of gap acceptance allow. For example, the merging behaviour at high circulating flows often leads to the "locking" of the roundabout, and secondly, the behaviour of individual drivers often causes circulating flow to slow down, sometimes creating short periods of priority reversals whereby circulating flow has to wait until normal priority is restored.

With such complex interactions, a gap acceptance model seems practically difficult to apply at roundabouts. Thus, the capacities of roundabouts have been mostly modelled using the empirical approach based on the formula developed by the Transport and Road Research Laboratory (1965). However, at conventional T-junctions, the gap acceptance approach is applicable, since the derivation of the formulae for the estimation of the capacity of uncontrolled intersections and the average delay experienced by minor road drivers (Tanner; 1962) show that besides depending on such other factors as the major flow and the minimum headway at which minor road traffic can follow each

other to the major road, the minimum acceptable gap is also a very important parameter. A clear knowledge of the gap acceptance behaviour of drivers at such intersections is thus imperative for the accurate computations of capacity and delay. Since delay and capacity are major inputs in the appraisal of the efficiency of a highway network, this may be a logical explanation for the interest so far shown in driver gap acceptance characteristics at uncontrolled and priority intersections. The present research is based on the phenomenon.

The next chapter gives a brief review of the models and analytical procedures that have been utilised in studies of this phenomenon. Chapter three outlines the main objectives of the study, the assumptions made and the study methodology. A description of the field studies and subsequent analyses are presented in chapters four and five respectively. The sixth and last chapter presents the results of the study, deductions, discussion of the results, recommendations and a conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL

Gap acceptance characteristics of drivers have influence on the design, operation and degree of control exercised at roadway intersections. Gap acceptance parameters of drivers are needed in assessing both the average delay experienced by minor road drivers and the capacity of uncontrolled and priority intersections. This is important, since the operation of intersections may often be a critical factor in determining the overall performance of a highway network.

Gap acceptance studies at priority intersections have usually been in one of two model forms, namely:

(a) Studies relating the length of each accepted gap in the major road traffic to the number of minor road vehicles merging into it; known as queue acceptance, and

(b) Studies relating the lengths of gaps in the major traffic to their probabilities of acceptance by each minor road driver, and the estimation of gap acceptance parameters for the population of drivers.

2.2 QUEUE ACCEPTANCE STUDIES

Queue acceptance can be defined as the acceptance of a large gap in the major road traffic stream by two or more waiting minor road vehicles, where the minor road queue is not exhausted. Queue acceptance studies are geared towards predicting the capacities of junctions based

on the distribution of gaps in the main flow by establishing a relationship between the number of queued vehicle (N) that would enter a gap of size T seconds in the main traffic stream.

Studies of this type have been reported by several authors. By first studying the start-up times for vehicle queues at the minor road, Uber (1978) derived a linear relationship between the median number of vehicles (N) that would merge into a gap of size T seconds when the queue of minor road vehicles is not exhausted.
The relationship obtained is:

$$N = 0.286T - 0.74 \quad \ldots\ldots\ldots \quad (2.1)$$

Cooper and Wennel (1978) however pointed out the implication of normality assumptions of most linear regression models used by previous authors in deriving queue acceptance relationships, and the uncertainty of whether it is more appropriate to regress N on T or vice versa. Treating N as the independent variable, they proposed an explanatory model which they used in deriving queue acceptance relationships for crossing and merging manoeuvres at two different intersections. They chose to initiate their time measurements by vehicle arrivals rather than departures and classified the intervals between the events in the sequence into three, namely: the start-up time of the first turning minor road vehicle from when a major road vehicle last arrived at the junction; the move up times of the subsequent vehicles, and the residual lag which is rejected. By choosing the median

values for the distributions, they derived the following equation:

$$T = S + N.M + R \quad \ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

where,

T is the time gap in seconds accepted by N vehicles

S is the median start-up time

M is the median move-up time for each of the next N vehicles.

R is the median residual lag which is rejected.

From empirical results for the distributions at two separate T-junctions, they applied the above equation to derive the following relationships:

$$T = 3.0N + 3 \text{ for merging} \quad \ldots\ldots\ldots \quad (2.3a)$$

$$T = 2.4N + 2.9 \text{ for crossing} \quad \ldots\ldots\ldots \quad (2.3b)$$

In conclusion, the authors indicated that the explanatory model is more useful than the direct linear model, first because the former makes better use of available data, and secondly, it enables the effects of changes in individual components of queue acceptance (i.e. N, S and R) on the overall relationship to be evaluated, and thirdly, it does not contain bias effect due to main flow.

In their own paper, Maher and Dowse (1983) introduced yet another approach to derive the N/T relationship. They first proposed a deterministic model in which the number of vehicles N entering a gap of length T seconds

will be K if:

$$C + (K-1)\,B < T \leq C + K\,B, \quad K=1, 2, \ldots \ldots \quad (2.4)$$

with N = 0 for $T < C$ where

C is a critical gap

B is a marginal critical gap, defined as an increase in gap length necessary to allow one more vehicle entry into the junction.

The authors outlined five different methods by which least square regression could be used to estimate the parameters C and B in the model. In a similar manner to Cooper and Wennel, they pointed out that the assumptions of independent normally distributed errors with zero means and constant variance made in least square regression do not strictly hold; and subsequently introduced a maximum likelihood method for the estimation of model parameters.

They thus proposed yet another model which they referred to as a renewal model for the application of maximum likelihood estimation. This model supposes that if there is a gap size of length T seconds, and that if the first driver in the minor road queue has a critical gap of Y1, he will enter the gap if $T > Y_1$. If the second driver in the queue has a marginal critical gap of Y_2, he can only enter the gap if $T - Y_1 > Y_2$, while the third vehicle enters if $T-Y_1-Y_2 > Y_3$, and so on, such that K vehicles will enter if:

$Y_1+Y_2+Y_3+ \ldots\ldots + YK \leq T \leq Y_1+Y_2+Y_3+\ldots\ldots+YK+1 \ldots\ldots$ (2.5)

with K = 0 for $T \leq Y_1$; where,

Y_iS are independent random variables, with Y_1 being the critical gap with mean C and $Y_i (i \geq 1)$, the marginal critical gap with mean B. This then is the renewal model which can be written as:

$$SK = Y_1 + Y_2 + Y_3 + \ldots\ldots\ldots YK \quad \ldots\ldots\ldots \quad (2.6)$$

It should be noticed that if the Yis in equation 2.5 are constants, then it reduces to the deterministic model as given by equation 2.4.

By assuming the Yis in equation 2.6 to be normally distributed i.e.

$Y_1 \sim N(C, \sigma^2)$, $Yi \sim N(B, \sigma^2)$ $i \geq 1$, it follows that $Sk \sim N(C+(K-1)B, K\sigma^2)$ and the probability relationship in equation 2.7 is established.

$$P(N = K/T) = \phi \left(\frac{T-C-(K-1)B}{\sigma\sqrt{K}}\right) - \phi\left(\frac{T-C-KB}{\sigma\sqrt{(K+1)}}\right)$$

$$\text{with } P(N=O/T) = 1 - \phi\left(\frac{T-C}{\sigma}\right) \quad \ldots\ldots\ldots\ldots \quad (2.7)$$

where,

ϕ is the unit normal distribution.

It follows from the above that the log-likelihood function can be written as follows:

$$\text{Log}(C, B, \sigma) = \sum_{i=1}^{N} \log \left[\phi\left(\frac{Ti-C-(Ki-1)B}{\sigma\sqrt{K}}\right) - \phi\left(\frac{Ti-C-KiB}{\sigma\sqrt{(Ki+1)}}\right)\right] \quad \ldots(2.8)$$

and $\phi = \left(\frac{Ti-C-(ki-1)B}{\sigma\sqrt{ki}}\right) = 1$ for Ki = O

By maximising the log-likelihood function above for C B and σ, the authors obtained maximum likelihood estimates of the three parameters and their 95% confidence intervals from their data as follows:

$\hat{C} = 4.26 \pm 0.22$, $\hat{B} = 2.64 \pm 0.21$, $\hat{\sigma} = 0.89 \pm 0.11$ which corresponds to a fitted straight line given by:

$$N = 0.38T - 1.61 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.9)$$

which they compared with results obtained by previous authors as follows:

N = 0.28T - 1.07 (Pearson and Ferreri; 1961)

N = 0.286T - 0.74 (Uber; 1978)

N = 0.33T - 1.00 (Copper and Wennel; 1978)

N = 0.39T - 1.00 (McDonald and Armitage; 1978)

It is obvious from all the results that N and T are positively correlated in that N increases with T. Also, all the researchers cited chose linear models for the data analyses and the main point of contention is on the methods of estimation of model parameters. Whereas the maximum likelihood estimation method indicated above is a more efficient and unbiased method, the least square regression method has been used more extensively because of the availability of computer packages for carrying out such computations.

With recent developments of computer programs for maximum likelihood estimation such as "chomp" (Daganzo and Schoenfeld; 1978) it is hoped that researchers of queue acceptance characteristics of drivers, will have fast and efficient tools at their disposal for data analysis.

2.3 GAP ACCEPTANCE STUDIES

Studies of this type are focussed on the behaviour of individual drivers at intersections when they merge or cross the main traffic stream. The analysis involves the estimation of gap acceptance parameters (the mean and variance of critical gaps and the variance of the gap acceptance function) over the population of drivers. To do this some idealised criteria have been formulated to explain how individual drivers decide whether to accept or reject a gap of a given size. Such formulations have generally taken the form of a gap acceptance function. This function relates the duration of a time gap in the main traffic stream to its probability of acceptance by a minor road driver.

In the establishment of delay models and the computations of the capacities of uncontrolled and priority intersections, driver gap acceptance behaviour has had to be described on the basis of one of two hypotheses. These are consistent driver behaviour and inconsistent driver behaviour or in the terminology of Cooper *et al* (1976), the time hypothesis and the modified time hypothesis respectively.

The consistent behaviour hypothesis assumes that each driver has a fixed critical gap (i.e. his gap acceptance function is a step function) and he will always accept all gaps larger than this and reject all gaps smaller than this critical gap; though different drivers necessarily have different critical gaps.

If the gap acceptance function for a given driver is denoted by $\alpha(t)$, then the idealized assumption of consistent behaviour can be represented by a Heavyside unit step function as follows:

$$\alpha(t) = \begin{cases} 0 \text{ for } t < C \\ 1 \text{ for } t \geq C \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.10)$$

where,

$\alpha(t)$ is the probability that a minor road driver accepts a gap of duration t seconds in the main traffic stream and C is the driver's critical gap.

It is implied from equation 2.10 that the driver rejects all gaps less than the critical gap C, and accepts all gaps greater than C seconds. Hence the critical gap can be defined as that gap size for which the probability of acceptance by a minor road driver changes from zero to one.

The inconsistent behaviour concept however assumes that each driver has a variable critical gap which can be described by some distribution such that the same distribution is applicable to all drivers. Though the exact form of the distribution may not be known, data analyses by Ashworth and Bottom (1977) suggest a cumulative normal or log-normal distribution. Daganzo (1981) also indicates that the errors to be introduced by assuming such a distribution are likely to be of second order since satisfactory results had been reported by previous authors such as Miller (1971) (quoted by Daganzo; 1981). However, the shifted negative exponential distribution has also been commonly used to describe inconsistent driver gap acceptance

behaviour. This can be expressed as follows:

$$\alpha(t) = \begin{cases} 0 & \text{for } t < T \\ 1-\exp(-B(t-T)) & \text{for } t \geq T \end{cases} \quad \ldots\ldots\ldots (2.11)$$

where,

$\alpha(t)$ is as defined earlier

B and T are constants for a given driver but can both vary over the population of drivers.

Equation 2.11 thus allows some variability in the driver's critical gap. Accordingly, the probability of a minor road driver accepting a gap size less than a threshold value of T seconds is always zero, while there is a steadily increasing probability of acceptance with a gap size t greater than T.

While equation 2.10 is a simplistic way of describing the gap acceptance behaviour of a driver, equation 2.11 is a more realistic representation, since it takes care of the fact that the critical gap C in equation 2.10 can vary for a given driver (i.e. within driver variability). Secondly, since the value of C can vary over the population of drivers (i.e. between driver variability), Ramsey and Routeledge (1973) propounded a method for determining the probability structure of critical gaps over the population of drivers from the histograms of all offered gaps and rejected gaps. This method was reviewed and its limitations pointed out by Troutbeck (1975),

Earlier studies by Herman and Weiss (1961) and analysis of variance on Ashworth and Bottom's data (1977) on 19 drivers by Blumenfeld and Weiss (1979) gave a within driver variance of 1.50 s^2 and a between driver variance of 0.31s^2. This thus led Blumenfeld and Weiss to suggest that if a simplification in gap acceptance representation is needed, it is more accurate to assume that drivers are inconsistent but identical in behaviour than that they are consistent but different in behaviour. However, the same authors showed that though predicted delays are dependent on which of the assumptions used, the errors introduced in the computations of delay statistics and other quantities of traffic engineering concern, such as the capacity of the minor road by assuming that drivers behave consistently are sufficiently accurate for practical purposes.

Whereas such variables as approach speed (Cooper et al, 1976), intersection sight distance and visibility have been shown to influence the gap acceptance behaviour of drivers, Adebisi (1982) pointed out that the assumptions and indeed most studies on driver gap acceptance behaviour have tended to neglect drivers' sensitiveness to available gaps. From an intuitive approach, he suggested two variables which can be used as indirect measures of driver sensitivity to available gaps. These variables are the main flow and the duration of stopped delay experienced by the minor road driver at the time the gap becomes available.

By the analyses of both aggregated and disaggregated data, he investigated the influence of the former on the gap acceptance parameters of drivers and the implications on the computed values of the average delay and the capacity of the minor road. And indeed he showed that driver sensitiveness to flow on the main road affects their critical gaps and their probability distributions. In the same work, he assumed a negative exponential distribution for headways on the main road for the equations derived by Tanner (1962) to compute the capacity of the minor road and the expected delay to minor road drivers. The equations are as follows:

$$Q = q\ (1-B_1\ q)/\exp(q(C-B_1)\ (1-\exp(-B_2 q)) \quad \ldots\ldots \quad (2.12)$$

$$E(d) = \frac{\exp(q(C-B_1)}{q(1-B_1\ q)} - C - \frac{1-B_1 q+B_1^2\ q^2}{q(1-B_1\ q)} + \frac{\frac{1}{2}\ B_1^2\ q^2}{(1-B_1 q)^2} \quad \ldots(2.13)$$

where,

Q is the capacity of minor road

q is vehicular flow on main road

C is mean critical gap

B_2 is the minimum headway at which minor road traffic may follow each other to the major road.

B_1 is average service time per vehicle on main road.

d is delay to minor road traffic.

On a general note he recommended that if flow on the main road is neglected in the study of gap acceptance characteristics of drivers, any deductions from the study should be limited to flows within half a standard deviation

of the observed average main flow (i.e. within $\bar{q} \pm \frac{\sigma}{2}$).

It would thus appear that some form of correction has to be applied to the computed values of the average delay and capacity deduced for average flows outside these limits. While such a correction has not been specifically determined, it would be worthwhile to investigate in a more or less similar fashion the influence of the duration of stopped delay which was also suggested as a measure of drivers' sensitivity on their gap acceptance characteristics and the traffic engineering implications. That in effect is the main objective of this study; which is to quantify "The influence of stopped delay on driver gap acceptance behaviour".

2.4 ESTIMATION OF GAP ACCEPTANCE PARAMETERS

In the study of gap acceptance characteristics of drivers as described in section 2.3, the gap acceptance parameters (the mean critical gap and its variance and the variance of the gap acceptance function) necessarily have to be estimated. Various methods have been suggested and utilised by researchers for this purpose. Some of these methods are briefly described below.

Adebisi (1982) and Polus (1983) utilised a graphical method based on the intersection of plots of cumulative numbers of rejected and accepted gaps to estimate the critical gaps from their independent data sets. This method assumes that the critical gap is that gap size for

which the number of rejected gaps greater than its value equals the number of accepted gaps less than this critical gap.

Ashworth and Bottom (1977) and Cooper et al (1976), by assuming a normal gap acceptance function chose probit analysis for the estimation of the parameters. This is done by plotting the probit of percentage acceptance against the gap size or tabulating the probit and gap sizes, the linear relationship established by regression analysis. The mean critical gap obtained when the probit acceptance is 5 and the standard deviation being the reciprocal of the slope of the regression line.

However, Daganzo (1981) criticised these methods of estimation on two main grounds. First is that only the average across the population of the mean of the gap acceptance function is estimated with the majority of the methods and secondly, that much data is lost by treating only the first gap considered by each driver. He thus proposed a maximum likelihood framework for estimating the gap acceptance parameters. By assuming a normally distributed gap acceptance function, he showed that the observed pattern of gaps rejection/acceptance is multivariate normally distributed. He then utilised a multinomial probit model in a computer program (CHOMP) to estimate the mean critical gap, its variance and the variance of the gap acceptance function, from a string of gaps rejection/acceptance data of 203 drivers. This approach has been adopted for the present analysis. Further discussions of the approach are therefore included in chapter five.

CHAPTER THREE

OBJECTIVES AND SCOPE OF STUDY

3.1 GENERAL

One obvious implication of drivers' inconsistency in their gap acceptance behaviour is that a given driver could reject a gap larger than one he would eventually accept. A driver who has waited for a long time at the stop line of a priority intersection, for example, may become impatient and thereby accept a gap shorter than one of those he had previously rejected.

Because of such a daring tendency of drivers attempting to accept short gaps, one would expect that for longer durations of stopped delay there would be a higher probability of short critical gaps and vice versa. This is important, since if drivers tend to accept short gaps, major traffic may be forced to reduce speed (intimidation of main road traffic) or collisions may occur. If this hypothesis holds true, a potentially high degree of hazard thus exists when minor road drivers have to wait for a long time before undertaking a basic manoeuvre. This may warrant a more positive means of assigning right of way, such as traffic signals. It is realised of course that signal control will lead to increased delay to major road traffic but it will almost certainly reduce minor stream delay.

A pertinent question at this point would be "When does a driver start feeling he has waited for a long time?". While it is obvious that some drivers are apt to be more aggressive than others, it is one of the primary objectives

of this study that some average duration of stopped delay will be discerned for which drivers start exhibiting impatient behaviour and begin to take risks.

3.2 COMPONENTS OF VEHICLE DELAYS AT UNCONTROLLED INTERSECTIONS

At uncontrolled intersections, delay to minor road traffic normally includes the following main components:

a) Delay due to time spent in the queue before reaching its head; and,

b) Delay at the head of the queue while waiting for an acceptable gap.

If a minor road vehicle arrives at the stop line without being delayed in a queue of turning vehicles, a situation referred to as undelayed lag by Uber (1978), then the first delay component above will be zero. On the other hand, a minor road vehicle can arrive at the head of the queue and accept the remaining part of a gap (lag acceptance), in which case the second delay component will be zero for the particular driver. It is thus possible to have four instances of delay occuring as explained below:

i) No delay at all. Theoretically, this is when a minor road vehicle arrives at the intersection when there is no queue and accepts a lag. However, since minor road vehicles would normally slow down, while assessing the traffic situation before moving in, some amount of delay is experienced in reality.

ii) Delay while waiting for an acceptable gap alone: This is when a minor road driver arrives at the stop line when there is no queue, but has to wait for an acceptable gap in the main traffic stream before moving in.

iii) Delay due to time spent in the queue alone: This occurs when the minor road vehicle after spending sometime in the queue, on moving up to the stop line accepts a lag.

iv) Delay due to a combination of (ii) and (iii) above: This is when after spending sometime in the queue, the minor road driver moves to the head of the queue, rejects one or more gaps before crossing and/or merging as the case may be.

To study the third and fourth cases given above will require some sophisticated equipment to monitor vehicle arrivals at the intersection. This would necessarily include photographic techniques and/or video recording equipment which could be used to film the intersection and the resulting video tapes later analysed to produce lists of events and their times of occurence. Besides being an expensive and time consuming procedure, it is also very cumbersome. The present study is thus focussed on situations where there is little or no queue build up. Essentially, therefore, delay due primarily to the lack of acceptable gaps in the main traffic stream is the main interest of this study. The main thrust of the work done is to investigate the influence of such delays on drivers' gap acceptance behaviour.

3.3 OBJECTIVES

The main interest of this research is to study the influence of the duration of stopped delay (a measure of driver sensitivity) experienced by minor road drivers on their gap acceptance parameters; and the implication of such reactions to delay on the capacity of the minor road. The main objectives of the study, therefore, are:

1. To estimate gap acceptance parameters separately for each group of drivers who experience similar durations of stopped delay and to compare with the estimated parameters when the data are aggregated.

2. To undertake a statistical comparison of the means of critical gaps obtained for the different durations of stopped delay with the mean critical gap obtained for the aggregated data so as to find out if there are any significant differences, and whether any pattern emerges for which a relationship could be established between the mean critical gap and the duration of stopped delay, such that an average delay for which drivers start becoming impatient could be deduced.

3. To compute the capacity of the minor road from the estimated mean critical gaps for each duration of stopped delay and compare with the capacity computed with the aggregated data.

4. To estimate the average flow on the main road that corresponds to an average delay to minor drivers that equals the duration of stopped delay for which the latter start becoming impatient. Such a flow can be considered a critical flow for which alternative forms of control may be sought.

3.4 ASSUMPTIONS

In order to simplify the analyses, the following idealizations are assumed:

1. Traffic on the main road is random, such that gaps in the flow are negative exponentially distributed.
2. Minor road drivers act independently in their assessment of gaps and their critical gaps are normally distributed.
3. Average processing time to major road traffic is zero. This is consistent with the operational requirement of no delay to major road traffic at priority intersections.
4. The minimum headway at which minor road traffic may follow each other to the main road is 2.0s. A minimum headway implies capacity limitations. The assumed value of 2.0s corresponds to an average main flow of 1800 v/h which is a reasonable value for the capacity.
5. The effects of sight distance, visibility and pedestrian activity on the studied phenomena are negligible. A careful choice of observation points had to be made to ensure compliance.
6. The minor road vehicles studied are first in line when they arrive at the stop line of the intersection. The data collection is such that any minor road vehicles

delayed in a queue were not considered part of the data as explained in Section 3.2.

3.5 METHODOLOGY

Field observations were made on the gap acceptance behaviour of minor road drivers executing left turning movements at priority intersections. The gaps rejection/acceptance pattern, the time of arrival at the intersection and time of departure of individual drivers were recorded. Gaps rejection/acceptance data and the duration of stopped delay experienced by each minor road driver were extracted from the field recordings. The procedure is described in Section 4.2. The data was further segmented on the basis of delays experienced while executing the manoeuvre.

Gap acceptance parameters were determined for each duration of stopped delay and for the aggregated data. To estimate these parameters, the "CHOMP" computer program developed by Daganzo and Schoenfeld (1978) was utilised in maximising the log-likelihood function of obtaining the parameters. This gave the likelihood estimates of the mean critical gap (C) and the variance (σ^2). The program is described in appendix A while a listing is given in appendix C.

After obtaining estimates of the gap acceptance parameters, a statistical comparison of the means of critical gaps for the different durations of stopped delay to that obtained when the data are simply aggregated was carried out by assuming a normal distribution, since the sample sizes

are large (>25). Standard testing techniques were adopted.

Thus, if:

$$\frac{/(u_1 - u_2)/}{\left(\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right)^{\frac{1}{2}}} > \begin{matrix} K(\alpha) \text{ for one tail test} \\ K(\frac{\alpha}{2}) \text{ for two tail test} \end{matrix} \quad \ldots (3.1)$$

then the difference between the means is significant at the α% level of significance.

where,

$K(\alpha)$ is the value of the standard normal variate at cumulative probability of $(1-\alpha)$

u_1 is the mean of the first sample.

u_2 is the mean of the second sample,

σ_1 and σ_2 are the respective standard deviations,

n_1 and n_2 are the respective sample sizes for the two situations being compared.

The means of critical gaps were tested at the 10%, 5% and 1% levels of significance.

The average main flows corresponding to the mean delay for each group was estimated by iteration from equation 2.13 given earlier. Since B_1 has been assumed to be zero, the equation reduces to:

$$\bar{d} = q^{-1} (\exp(q\mathbf{C}) - 1 - q\mathbf{C}) \quad \ldots (3.2)$$

where,

$\bar{d}$ is the average delay for each group

q is the corresponding average main flow to be estimated

$\hat{C}$ is the estimated mean critical gap.

Also, equation 2.12 was utilised to compute the capacity of the minor road (Q) from the mean critical gaps estimated for both the disaggregated and aggregated data. Since B_1 and B_2 have been respectively assumed as 0.S and $2s$, the equation reduces to:

$$Q = q \exp(-q\hat{C})/(1-\exp(-2.0q)) \quad \ldots\ldots\ldots (3.3)$$

CHAPTER FOUR

FIELD WORK

4.1 CHOICE OF SITES

The intersections studied were chosen after a careful preliminary observation of traffic behaviour and roadway geometrics at a number of T-junctions in and around Zaria. The criteria for selection were such that the site conditions reflected the study objectives and accommodated the stated simplifying assumptions to the utmost. The key factors are:

(a) Pedestrian activity is minimal and is of no consequence to the studied phenomena.

(b) There is little or no queue build up at the minor road approach during studied periods.

(c) The main traffic is heavy enough that an appreciable number of minor road drivers experience some delay while evaluating gaps. For this, it was necessary to study left turning vehicles rather than those merging as has been the case with most gap acceptance studies. This is because most of the candidate intersections have flarred entries for right turners who could gently merge with the major flow without necessarily stopping. However, since left turning vehicles are affected by main flow in both directions, they had to stop, assess the traffic situation in both directions before turning.

(d) Adequate sight distance exists to render its effect on the studied phenomena insignificant. The minor road approaches were approximately perpendicular to the major road with clear vision of at least 75m on each

side of the intersection approach.

(e) Left turning vehicles from the major road are few, if not negligible and are of minimal consequence to the studied phenomena.

(f) There is no form of control (such as police or traffic signals) in the vicinity of the intersections.

After a consideration of the above criteria, two T-junctions were finally selected for the study. At both locations, the major road is a two-lane two way highway with a median of approximately 1.5m average width and traffic lanes of about 4m width each. The selected intersections are the old Kano and new Kano junctions along Sokoto Road in Zaria Metropolis. These are respectively referred to as intersections A and B.[1] See Fig. 3.1 and map at back.

4.2 DATA COLLECTION

The field observations were carried out on clear week days between 9 a.m. and 12 noon. This was done in the month of March, 1986 and as it is, at this time of the year visibility was good.

A chart recorder equiped with three event pens of different colours was used for field observations. The recorder has a revolving drum (with grooves into which chart paper could be fitted), which rotated at a chosen speed. The speed was selected as a compromise between accuracy of measurements and economy of chart paper. Naturally, the faster the drum, the more accurate the results, but the more chart paper that is used and vice

1 The minor road at intersection A serves mostly residential areas around Zaria, while that at B connects neighbouring cities.

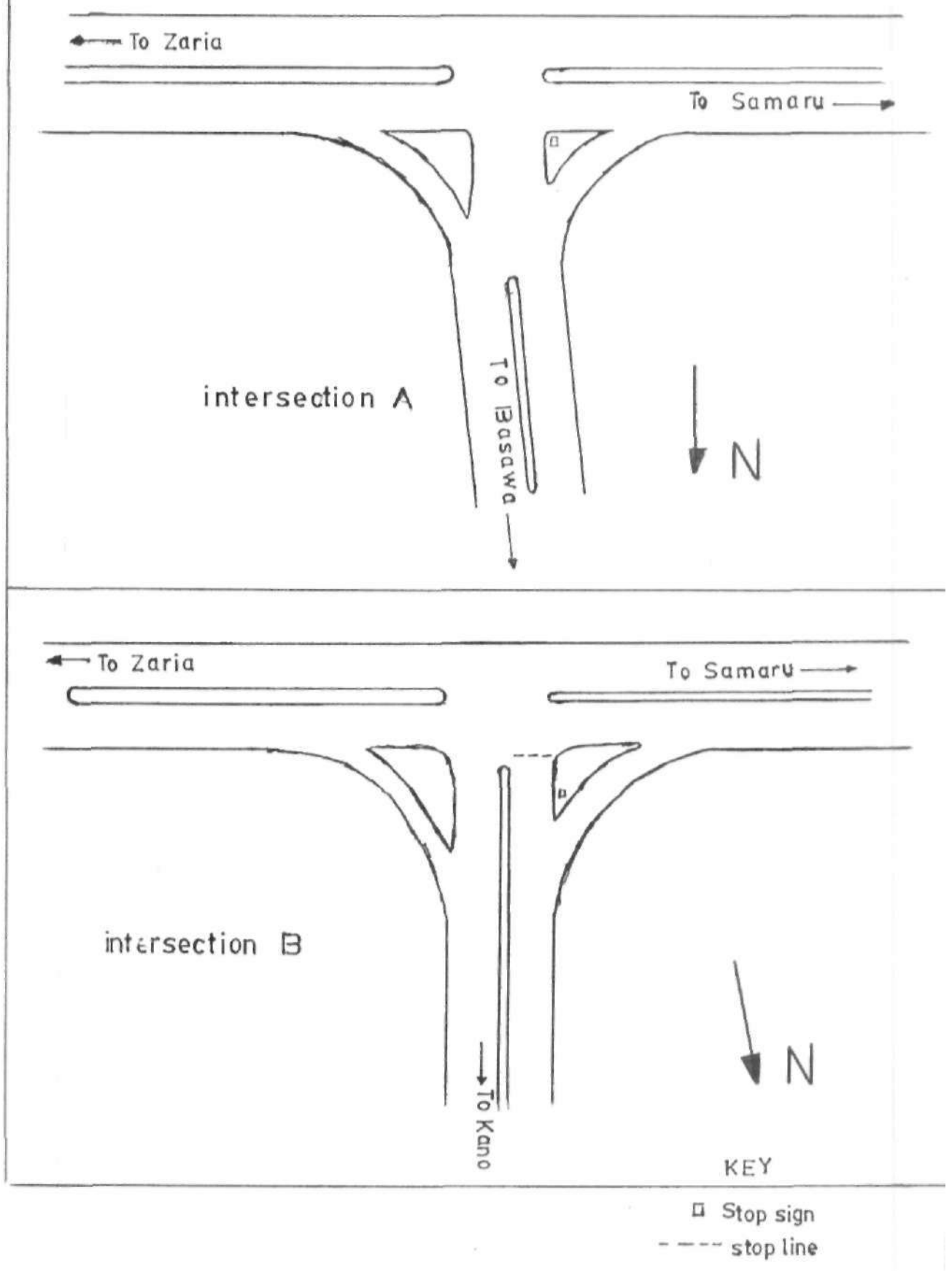


Fig. 3.1 Sketches of intersections A and B

versa. After some trial recordings, the speed was finally set at 5mm/s.

The first pen of the recorder was connected via an automatic counter to a pneumatic tube stretched across the far traffic lane and secured to the carriageway by clips. One end of the tube was sealed while the other was attached to a pressure-actuated diaphram switch incoporated in the counter housed at the roadside. The passage of a vehicle over the tube (detector) caused a pulse of air to travel along the tube moving the diaphram outwards against a contact point thereby completing an electrical circuit which actuated both the counter and pen. This constituted a count and also caused the pen to move to and fro on the revolving chart paper creating a signal, thus providing information on vehicle arrivals and headways on the far lane of the major road.

The tube detector could have been used to monitor vehicle arrivals in both directions by mounting the recorder on the median. However, this was not done for the near side traffic because of two main reasons. First, the mere presence of such equipment on the median could arouse driver curiousity and thus influence their behaviour. Secondly, since the recorder needed to be connected to the mains supply, mounting the equipment on the median would have meant erecting a pole to deliver a power cable for the recorder; which presented a practical difficulty. Even if a small generator had been used, it would have also aroused driver curiousity. Hence the near lane traffic was manually monitored.

The second pen of the recorder was connected to a portable battery with a manually operated switch. When a vehicle on the near traffic lane on the major road arrived at the intersection, the battery was instantly switched on and off, creating a voltage pulse from the battery which activated the second pen, thus giving signals for arrivals and thus headways for the near traffic lane.

The third pen was connected to a similar battery. This was used to monitor both the arrival and departure of minor road vehicles. On the arrival of such a vehicle at the stop line, the battery was switched on and off activating the pen, thereby giving a signal indicating the time of arrival of the particular vehicle. By the same token, when the particular minor road driver just started accelerating into an accepted gap, the battery was again switched on and off to indicate the time of entry into the intersection. The letters "A" and "D" were marked with a pencil against the signals to indicate the arrivals and departures respectively. When a minor road vehicle was delayed in a queue before arriving the stop line, it was ignored and not recorded as part of the data as explained in Section 3.2.

4.3 DATA EXTRACTION AND PREPARATION

At the end of each day's observation, all the recordings on the chart sheets were extracted. This was done by measuring the distances between signals in millimetres and recording them on some ruled sheets. These were later divided by the

drum speed to give the lengths of all rejected gaps, the accepted gap, and the duration of delay for each minor road driver in seconds. The data was further categorised on the basis of delays experienced while executing the left turning manoeuvre, such that those with delays within 0-5.0S, 5.1-10.0S, 10.1-15.0, 15.1-20.0, 20.1-25.0, 25.1-30.0, 30.1-35.0S, 35.1-40S, 40.1-60.0S and 60.1S where in the same group. Altogether 10 such groups were established. Only sixteen drivers experienced a delay of more than 60.2 seconds. Though the sample was small, it was still considered a group.

The main traffic flow was deduced from the number of signals recorded for each traffic lane, the chart speed and the length of chart paper for each day's observation as follows:

$$q = N/L \times u \times 3600 \quad v/h \quad \ldots\ldots\ldots \quad (4.1)$$

where,

q is the main traffic flow in vehicles per hour

L is the length of chart paper in millimetres

N is the total number of signals (vehicles) for the particular lane.

U is the drum speed in millimetres per second.

The observed flows are given in table 4.1

INTERSECTION	OBSERVATION DATE	NEAR LANE FLOW v/h	FAR LANE FLOW v/h	TOTAL FLOW v/h	AVERAGE FLOW v/h
A	13/3/86	574	613	1187	1004
	14/3/86	555	559	1114	
	17/3/86	362	446	808	
	18/3/86	439	504	943	
	19/3/86	490	474	964	
B	20/3/86	537	504	1041	1075
	22/3/86	508	605	1113	
	24/3/86	493	526	1019	
	25/3/86	512	614	1126	

TABLE 4.1: Observed main flows

CHAPTER FIVE

A N A L Y S I S

As indicated in Section 2.4. the maximum likelihood method was employed for the estimation of the gap acceptance parameters. A summary of the theoretical background of the technique is thus presented here.

In proposing this approach, Daganzo (1981) made two major assumptions; which are that the critical gap (Cn) is a random variable which is normally distributed across the population of drivers with mean C and variance σ^2 and related to the gap acceptance function as:

$$Cn = \int_{-\infty}^{\infty} t \, d\alpha n(t) \quad \ldots\ldots\ldots\ldots\ldots \quad (5.1)$$

where,

Cn is the expected critical gap for the nth driver

$\alpha n(t)$ is the gap acceptance function of the n^{th} driver; and that the variance of the gap acceptance function (σ_α^2) is identical for all drivers in the population. Studies by Ashworth and Bottom (1978) (quoted by Daganzo, 1981) indicate that the variance of the gap acceptance function is minimally correlated with critical gaps. Daganzo however indicates this to be of second order effect and he ignored it for the analyses.

By conditioning the probability density of a driver's gaps rejection/acceptance pattern on the unknown parameters C, σ and σ_α and further assuming that drivers act independently and do not become impatient he derived the likelihood function for the population of drivers as:

$$L(\bar{C}, \sigma, \sigma_\alpha) = \prod_{n=1}^{N} \Pr(n^{th} \text{ driver pattern}/\bar{C}, \sigma, \sigma_\alpha) \quad .. \quad (5.2)$$

and showed that for normal gap acceptance functions the log-likelihood function can be expressed in terms of the multivariate normal cumulative function as:

$$\text{Log } L(\bar{C}, \sigma, \sigma_\alpha) = \sum_{n=1}^{N} \log \Pr(W_n < (0....0)/\bar{C}, \sigma, \sigma_\alpha) \quad ....(5.3)$$

where,

Pr is the probability mass of obtaining the observed gap rejection/acceptance pattern.

$\bar{C}$ is the mean critical gap for the population of drivers

σ is the variance of critical gaps over population of drivers

σ_α is the variance of the gap acceptance function.

N is the number of observations (i.e. the number of minor road drivers who evaluated gaps).

W_n is a vector of multivariate normally distributed (MVN) random variables with mean vector and covariance matrix given respectively by:

$$E(W_n) = (r_{in}-\bar{C},\ r_{2n}-\bar{C},\ \ldots.\ r_{nrn}-\bar{C},\ \bar{C}-a_n) \quad \ldots\ldots\ldots\ (5.4a)$$

and

$$\text{Cov}(W_n) = \begin{bmatrix} \sigma^2+\sigma_\alpha^2 & \sigma^2 & \ldots\ldots & \sigma^2 & -\sigma^2 \\ \sigma^2 & \sigma^2+\sigma_\alpha^2 & \ldots\ldots & \sigma^2 & -\sigma^2 \\ \ldots & \ldots & \ldots\ldots & \ldots & \ldots \\ \sigma^2 & \sigma^2 & \ldots\ldots & \sigma^2+\sigma_\alpha^2 & -\sigma^2 \\ -\sigma^2 & -\sigma^2 & \ldots\ldots & -\sigma^2 & \sigma^2+\sigma_\alpha^2 \end{bmatrix} \quad \ldots\ldots\ (5.4b)$$

where,

r_{in} is the i^{th} rejected gap by the n^{th} driver

a_n is the accepted gap by the n^{th} driver.

The maximum number of rejected gaps was specified as R and the number of alternatives (See Appendix A) as R+2 and the gap acceptance parameters can on the basis of the above derivation be estimated from a multinominal probit estimation program "CHOMP". The input of the multinominal estimation program for the particular problem is a specification indicating how the mean vector $E(N)$ and the covariance matrix $V(N)$ depend on the parameters ϵ, σ and σ_α while the output gives the likelihood estimates $\hat{\epsilon}$, $\hat{\sigma}$, $\hat{\sigma}_\alpha$ and an estimate of the covariance matrix of the estimator Σ as given by minus the inverse Hessian[1] of the log-likelihood function at $\hat{\epsilon}$, $\hat{\sigma}$ and $\hat{\sigma}_\alpha$.

The specification for $E(N)$ and $V(N)$ in terms of the multinominal probit model are thus given by:

$$E_1^n = 0$$

$$E_{i+1}^n = r_i^n - \epsilon, \quad i=1, 2, 3.....R$$

$$E^n_{R+2} = \epsilon - a^n_{R+1} \qquad \text{(5.5a)}$$

and

$$V(n) = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ 0 & & & \\ \vdots & & \text{Cov } (W_n) & \\ 0 & & & \end{bmatrix} \qquad \text{(5.5b)}$$

where,

r_i^n is the i^{th} rejected gap by the n^{th} driver.

R is the maximum number of rejected gaps.

---

1. The Hessian Matrix is given by the second derivatives of the log-likelihood function.

a^n is the accepted gap by the n^{th} driver.

Cov (W_n) is an $(R+1)x(R+1)$ version of equation 5.4b.

When the estimation package was used to estimate $\mathbf{c}$, σ and σ_α for field data on 203 drivers in California, Daganzo (1981) initially obtained a value of zero for the variance of critical gaps. This is contrary to the assertion of Ashworth and Bottom (1977) who showed that there is some variability in driver critical gaps. In order to correct this anomaly, he thus introduced a two stage estimation process whereby the variance of the gap acceptance function (σ_α^2) is either assumed or first estimated from the data before the MNP model can be recalibrated to estimate $\mathbf{c}$ and σ. He then assumed a value of 1.0S which was obtained by Ashworth and Bottom for σ_α.

However, he also proposed an alternative method for estimating the variance of the gap acceptance function from the data. This involves initially setting the critical gap Cn of each driver to the average of the accepted gap and the largest rejected gap. Thus if the gap accepted by the n^{th} driver is a_n and the largest rejected gap is maxi (rin), then:

$$Cn = \tfrac{1}{2}\,(a_n + \text{Maxi}(rin)) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5.6)$$

Hence,

$$Pr\ (\text{observed pattern}/Cn, \sigma_\alpha) = \prod_{i=1}^{nr} \phi\left(\frac{cn-rin}{\sigma_\alpha}\right) \phi\left(\frac{an-Cn}{\sigma_\alpha}\right) \quad -(5.7)$$

The log-likelihood of eq. 5.7 could again be estimated with CHOMP. Once the value of α_k is known, it can be used in equation (5.5b) in conjuction with equation (5.5a) in recalibrating the multinomial probit model for the estimation of ϵ and σ. This is described in the documentation of the program given in Appendix A.

CHAPTER SIX

RESULTS AND DISCUSSIONS

6.1 PRESENTATION OF RESULTS

The printouts of the various computer runs are given in Appendix B. The outputs give the observed choice of each driver, the attribute vector of his gap rejection/ acceptance pattern and the estimated gap acceptance parameters. PAR. No.1 gives an estimate of the mean critical gap ($\mathfrak{C}$), while PAR. No.2 gives an estimate of the standard deviation (σ). A summary of the results on the aggregated data is presented in Table 6.1a.

Data Type	No. of Samples	Mean Critical gap ($\mathfrak{C}$) (s)	Standard deviation (σ) (s)
Intersection A	377	9.99	1.71
Intersection B	391	10.21	1.99
Combination of A and B	768	10.44	1.81

Table 6.1a: Estimated gap acceptance parameters from the aggregated data for intersections A and B.

The average traffic flow on the main road was found to be 1040 v/h. From table 4.1, this value is an average of the observed mean flows at the two intersections. It was found at the 5% level of significance that there is no statistical difference between the mean flows at the two intersections. Thus their average value could be used for the joint aggregated data. Table 6.1b gives the

average main flow and the computed capacity of the minor road for each of the intersections and the joint aggregated data. The minor road capacity was computed from equation 3.3 as explained earlier.

Data Type	Mean Critical gap ($\frac{C}{s}$)	Average main flow(q) v/h	Minor road capacity(Q) v/h
Intersection A	9.99	1004	144
Intersection B	10.21	1076	113
Combination of A and B	10.44	1040	116

Table 6.1b: Average main flow and computed minor road capacity for intersections A and B and joint aggregated data.

A statistical comparison of the mean critical gaps for intersections A and B was undertaken along the lines explained in section 3.5. The test statistics corresponding to the 1%, 5% and 10% levels of significance are summarized in table 6.1c.

	Test Statistics		
K(.990)	K(.950)	K(.900)	$\frac{\lvert(CA - CB)\rvert}{(\frac{\sigma_A^2}{nA} + \frac{\sigma_B^2}{nB})^{\frac{1}{2}}}$
2.33	1.64	1.29	1.65

Table 6.1c: Test statistics for comparing mean critical gaps obtained at intersections A and B.

It is inferred from table 6.1c that at the 1% level of significance, there is no statistical difference between the mean critical gaps obtained at the two separate intersections studied. This is not surprising since both intersections are along the same major road. However, at less strict significance levels of 5 and 10% the mean critical gap obtained for intersection B (New Kano Junction) is significantly higher than the value for intersection A (Old Kano Junction). This slight difference might be due to the fact that most of the minor road drivers at the Old Kano Junction are regular users of the intersection since they are residents of Zaria and are more familiar with the intersection, while those at the New Kano Junction are "out-of-towners" who are occasional users of the intersection. As explained earlier, the minor road at the Old Kano Junction serves mostly residential areas around Zaria, while that at the New Kano Junction connects neighbouring towns.

The results above indicate that the two data sets obtained at the two separate intersections could be pooled without introducing any significant errors. Thus the disaggregated data was jointly extracted from that collected at both intersections.

Table 6.2a gives a summary of the estimated gap acceptance parameters for the different durations of delay.

Duration of delay	Mid value of delay group	Mean delay for group (s)	No. of samples	Mean critical gap (C) (s)	Standard deviation (σ) (s)
$\leq$ 5.0		3.23	91	20.99	2.36
5.1-10.0	7.55	7.46	209	18.72	1.94
10.1-15.0	12.55	12.01	91	17.58	1.86
15.1-20.0	17.55	16.52	61	16.31	1.75
20.1-25.0	22.55	21.65	104	9.87	1.74
25.1-30.0	27.55	27.53	66	10.46	1.83
30.1-35.0	32.55	32.74	76	8.62	1.96
35.1-40.0	37.55	36.78	48	8.29	1.72
40.1-60.0	50.05	46.66	42	6.78	1.26
$\geq$ 60.1		75.85	16	5.32	1.65

Table 6.2a: Estimated gap acceptance parameters for different durations of stopped delay

Table 6.2b gives the average main flows and computed minor road capacity for the different durations of delay. The minor road capacity was computed from equation 3.3. given earlier. In order for the equation to be applied it is necessary to estimate the average main flow (q) for each duration of stopped delay. For this purpose, the estimated critical gap and mean delay for each group were substituted into equation 3.2 and the value of q determined by an iterative process.

Duration of delay (s)	Mean delay ($\bar{d}$) (s)	Mean critical gap ($\bar{C}$) (s)	Computed average main flow (q) v/h	Computed minor road capacity (Q) v/h
≤ 5.0	3.23	20.99	48	1380
5.1-10.0	7.46	18.72	122	984
10.1-15.0	12.01	17.58	198	723
15.1-20.0	16.52	16.31	280	546
20.1-25.0	21.65	9.87	725	300
25.1-30.0	27.53	10.46	754	245
30.1-35.0	32.74	8.62	1085	178
35.1-40.0	36.78	8.29	1206	154
40.1-60.0	46.66	6.78	1750	104
≥ 60.1	75.85	5.39	2816	56

Table 6.2b: Computed average main flow and minor road capacity for different durations of delay.

A statistical comparison of each of the estimated mean critical gaps for the different durations of stopped delay with that estimated from the aggregated data was also undertaken. The one tail test statistics corresponding to the 1%, 5% and 10% levels of significance are summarized in Table 6.3.

Since the sample size of the last entry is just 16, a t- test should have been appropriate. However, since the calculated test statistic is quite high, the use of the normal distribution would not affect the conclusion arrived at from the test.

Duration of delay (s)	Mean delay($\bar{d}$) (s)	Test Statistics			
		K(.990)	K(.950)	K(.900)	$\frac{\lvert(\bar{c}i-\bar{c})\rvert}{\left(\frac{s_i^2}{ni}+\frac{s^2}{n}\right)^{\frac{1}{2}}}$
≤ 5.0	3.23				41.23
5.1-10.0	7.46				55.37
10.1-15.0	12.01	2.33	1.64	1.29	34.72
15.1-20.0	16.52				25.15
20.1-25.0	21.65				3.12
25.1-30.0	27.53				0.09
30.1-35.0	32.74				7.78
35.1-40.0	36.78				8.37
40.1-60.0	46.66				17.85
≥ 60.1	75.85				12.26

Table 6.3: Test statistics for comparing mean critical gaps obtained from aggregated data and those for different durations of delay.

6.2 OBSERVATIONS AND DEDUCTIONS

It is evident from table 6.2a that the mean critical gaps obtained from the disaggregated data show a general decrease with an increase in mean delay to minor road drivers. The implication of this variation in mean critical gaps is reflected in the computed values of the minor road capacity as inferred from table 6.2b. The results indicate that the minor road capacity decreases severely with a decrease in mean critical gap (i.e. increase in mean delay).

It is observed from table 6.3 that the mean critical gaps obtained for the different durations of stopped delay are statistically different at the 1% level of significance from the value obtained from the aggregated data except for those drivers who experienced delays of between 25.1s and 30.0s. The indication then is that the mean critical gap from the aggregated data corresponds to this group of drivers and it is within this region that the two results are comparable. The results indicate that the mean critical gaps obtainable when the average delay to minor road traffic is less than 25.1s would be higher than that obtainable from an aggregated data analysis. The reverse situation obtains when average delay to minor road traffic is more than 30.0s. It is evident that drivers exhibit significant changes in their gap acceptance behaviour when the average delay is out of this range. The indication from the results then is that when mean delay to minor road traffic exceeds 30s, the intersection has to be controlled somehow. Incidentally, the Highway Capacity Manual (1985) allows an upper limit of delay of 60s for signal control to be considered. This will suggest that signal control is most suitable when the average delay to minor road traffic is between 30s and 60s.

From the results presented in Tables 6.2a and 6.2b and from a trial by error basis, the relationships between the mean critical gap ($\bar{c}$) and the mean delay ($\bar{d}$), mean critical gap and average main follow (q), mean critical gap and minor road capacity (Q), were found to be of the following form:

$$\mathcal{E} = \alpha_1 - \alpha_2 \bar{d} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6.1)$$

$$\ln(\mathcal{E}) = \alpha_3 - \alpha_4 \, q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6.2)$$

$$\mathcal{E} = -\alpha_5 + \alpha_6 \ln(Q) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6.3)$$

where,

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ and α_6 are constants to be determined by an empirical calibration of the models. These models were calibrated by using the "Statistical Package for the Social Sciences (SPSS)". The following relationships were then established:

$$\mathcal{E} = 18.64 - 0.226\bar{d} \quad (r^2 = .772) \ldots\ldots\ldots\ldots \quad (6.4)$$

$$\ln(c) = 2.867 - 0.00051q \quad (r^2 = .878) \ldots\ldots\ldots\ldots \quad (6.5)$$

$$\mathcal{E} = -17.851 + 5.281 \ln(Q) \quad (r^2 = .955) \ldots\ldots\ldots\ldots \quad (6.6)$$

The results including the values obtained from the aggregated data are displayed in Figs 6.1, 6.2 and 6.3 respectively. It is inferred from Fig. 6.1 that for situations where minor road drivers experience shorter durations of stopped delay, mean critical gap deduced from the aggregated data will underestimate actual critical gap for the group, while for longer durations, the mean critical gap value will be overestimated.

The average main flow corresponding to a mean delay of 30s can be inferred from Fig. 6.2 using the corresponding mean critical gap value of 10.46s as 800 v/h. This flow can be interpreted as representing the average main traffic flow beyond which resultant delay to minor road drivers turning left would cause them to become impatient and start taking risks by accepting shorter than normal gaps. It must be appreciated that the assumption of purely random arrivals

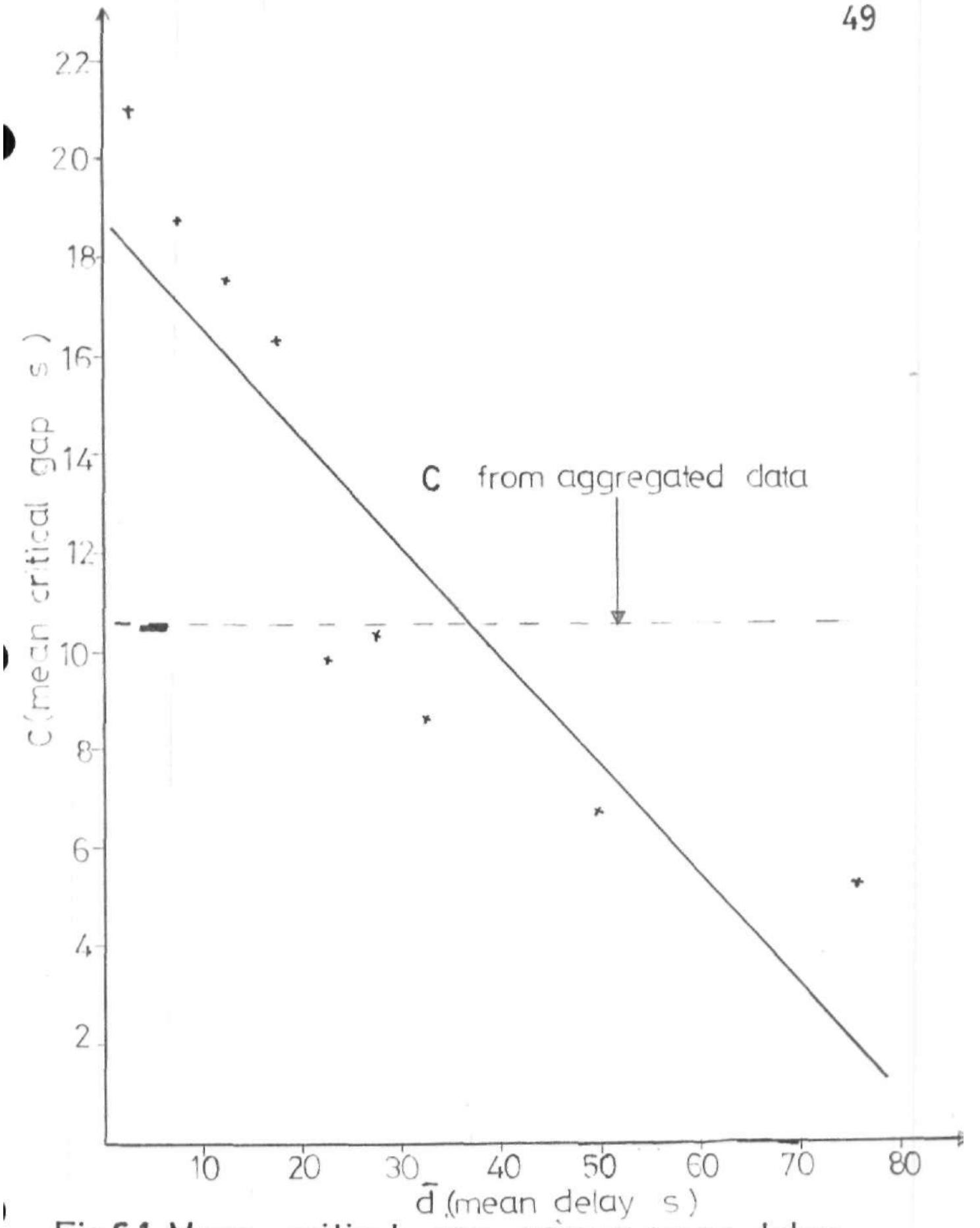


Fig.6.1. Mean critical gap versus mean delay.

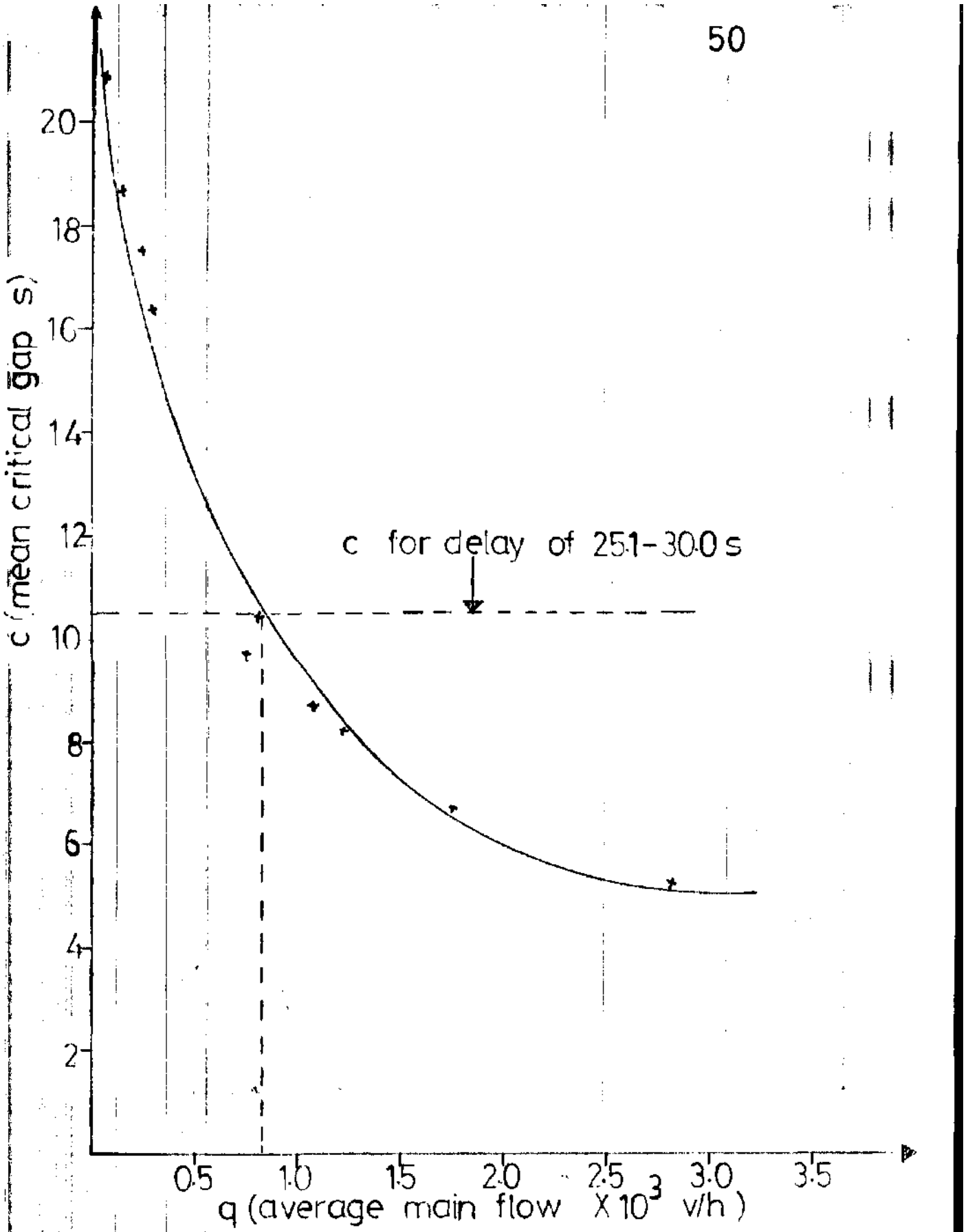


Fig.6.2 Mean critical gap versus average main flow.

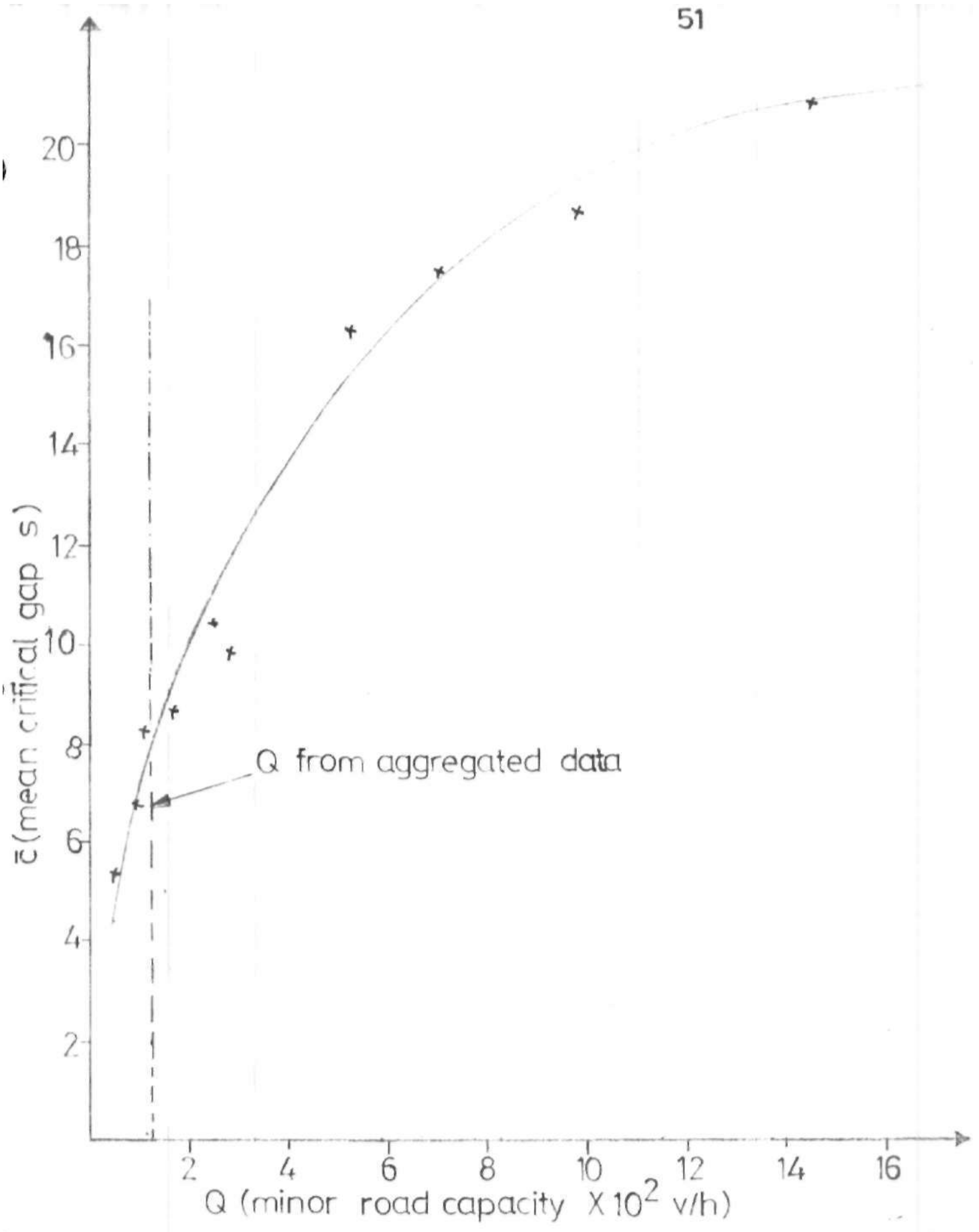


Fig.6.3 Mean critical gap versus minor road capacity

on the main road must be valid for the assertion to be strictly true.

It is evident from Fig. 6.3 that the computed values of the minor road capacity can be seriously underestimated at periods when minor road drivers experience short durations of delay (i.e. high mean critical gaps), but mildly overestimated at periods of high durations of delay (short mean critical gaps).

Equations 6.4 and 6.5 thus reveal that the mean critical gap can be considered as consisting of two components. A first component which is constant and a delay/main flow component. The r^2 values imply that equation 6.5 is more reliable than equation 6.4 if used in the estimation of critical gaps. However it must be appreciated that the average mainflow values presented were deduced from the mean critical gap values. However, since on the highway, it is usual and more conventional to measure the average mainflow than the average delay to minor road traffic, equation 6.5 will be more practical in predicting the mean critical gap. Thus once the mean critical gap has been estimated, the value could be used in equation 6.6 to obtain an estimate of the left-turning capacity of the minor road.

6.3 DISCUSSIONS

The value of 10.44S for the mean critical gap for the aggregated data obtained in this study can be compared with values reported by some earlier researchers. Cooper et al, (1976) got a value of 5.3S, Daganzo (1981) reported a value

of 6.0s, Polus (1983) obtained values of 5.2s and 7.74s at two separate intersections, while Adebisi (1982) reported a value of 4.95s for studies around Zaria. Apparently, there is a significant difference between the value reported here and those got by previous authors in that the value obtained here is much higher. However, whereas the studies cited were based on right turning movements (merging behaviour) of minor road drivers, the present study has investigated left-turning manoeuvres which involve minor road drivers cutting one traffic stream and merging with another.

It is relevant to note that from a study of two separate intersections in Israel, Polus (1983) observed that higher critical gaps are to be expected when drivers execute left turning manoeuvres. He obtained the following critical gaps at the two separate intersections: 5.2s (right merge), 6.82s (left turn) and 7.47 (right merge), 7.72s (left turn). His results indicate higher critical gaps for the left turn, but the mean value is still less than the value of 10.44s obtained in this study. It should be pointed out however, that he placed a restriction on his data in that all gaps greater than 16.0s were eliminated and not used in the analyses. No such restriction were introduced in the present study. Secondly, his sample size was limited to a maximum of 87 drivers while more than 750 drivers were studied in the present case. Such restrictions must have biased his values resulting in shorter mean critical gaps.

In general, the higher mean critical gap value for left turning drivers as compared to values for merging drivers

implies that driver assessment of gaps in the crossing manoeuvre differs from the simple merging situation. The difference in mean critical gaps could then be due to the additional time required by minor road drivers when they have to cut one traffic stream and merge with another.

The range of values of mean critical gaps obtained for the different delay situations studied in this work appears to compare favourably with the range of values reported for merging behaviour by Adebisi (1982) for different major flow regimes around Zaria. He got a minimum value of 4.3S for a major flow of 1360 v/h and a maximum value of 10.6S for a main flow of 138 v/h. The corresponding minimum and maximum values got from the present study are 5.32S and 20.99S for average delays to minor road drivers of 75.85S and 3.23S respectively. The present results are thus in agreement with Adebisi's in the sense that the mean critical gap is generally overestimated during periods of low main flows and underestimated for periods of high main flows; since minor road drivers would experience shorter durations of delay during periods of low main flows and longer durations during periods of high main flows. The implication then is that if gap acceptance data are collected during peak periods, one would expect higher probabilities of short critical gaps and lower probabilities of long critical gaps and vice versa.

The observed trend of longer mean critical gaps for shorter durations of stopped delay and shorter mean critical gaps for longer durations as depicted in figure 6.1 could thus be attributed to driver sensitivity to delay. The highest value of mean critical gap resulted from drivers who experienced an average delay of 3.23s, some of who accepted lags. Such drivers are likely to be more relaxed in their assessment of gaps than drivers who have had to wait for a longer period.

On the other hand, the shortest mean critical gap was obtained when the minor road drivers experienced the highest average delay. This is most likely due to the fact that some minor road drivers having rejected some longer gaps finally accepted gaps of a much shorter duration. It will be recalled that a major assumption made in choice models is that individuals are rational in behaviour and thus select the most attractive alternative. In gap acceptance description, one would naturally expect the most attractive alternative to be that offered gap with the largest size. However, a glance at the data in Appendix B reveals that not all drivers did accept the largest offered gap.[1]

A plausible explanation then could be that, unlike other choice problems where the choice maker is likely to assess the various alternatives at a point in time and with some certainty, the gap acceptance situation is such that on most occasions, by the time a minor road driver rejects a gap of a certain duration, he is unaware of the sizes

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1 The accepted gap is the last attribute.

of future gaps. This may tend to introduce some aspect of regret on his part for having rejected some longer gaps; since once a decision (to reject or accept a gap) is taken, it cannot be revoked. The tendency then is that once a driver has waited for a long time, he becomes not just alert, but impatient and more "aggressive" in his gap acceptance behaviour and likely to accept shorter gaps. Instances of intimidation of main road drivers cannot be ruled out during these periods. Daganzo (1981), in deriving the gap acceptance model employed, assumed that drivers do not become impatient; but this as can be deduced from the present study, is not strictly the case.

The trend of short mean critical gaps for longer durations of stopped delay could be partly explained on the basis of driver start-up times. Drivers who have stopped for some time at the intersection, will generally have shorter start-up times since they must have observed traffic conditions on the main road and are able to anticipate the arrival of an acceptable gap and are prepared to move in rapidly. This stresses the importance of good intersection sight distances, since if these are poor, such anticipation of gaps will be difficult.

The mean critical gaps obtained thus appear reasonable for the studied turning movements and delay situations. However, it is worthwhile to note that choice models are usually specified in terms of explanatory variables of both the various alternatives and characteristics of the choice maker. A modal split problem for example will have as attributes of the different alternatives (modes), such

variables as travel time and cost by each mode, while the characteristics of the choice maker will be specified in terms of his income, family size and other pertinent characteristics.

In applying the multinomial probit approach to driver gap acceptance behaviour, only attributes (gap sizes) of the various alternatives are specified in the model, though one would naturally expect characteristics of the choice maker (minor road driver) such as age, sex and experience to influence his driving behaviour and hence his gap acceptance characteristics.

Apparently, the cited characteristics of drivers have seldom been included in the analysis of gap acceptance data. However, the rather low standard deviations of mean critical gaps obtained are indicative of the limited significance of these attributes. Nonetheless, less variability would result if the variables are incorporated in the model. The observed variability could also be as a result of judgement errors due to a variability in the approach speed of the main road traffic and the direction of travel of vehicles opening and closing the gap, since the left turning driver conflicts with two traffic streams. Another important factor is the difficulty of capturing relevant variables for each minor road driver during field observations. However, since gap acceptance parameters estimated in previous studies without considering such variables have received widespread acceptance and the indication from the present results is that introducing them would bring minimal improvement, it is strongly felt that ignoring

driver characteristics would not materially affect the reliability of gap acceptance studies.

6.4 CONCLUSION

The results from the study presented thus indicate that the duration of stopped delay experienced by minor road drivers influences their gap acceptance behaviour. Drivers are more relaxed and less sensitive to gaps when they suffer minimial delays but are more sensitive to gaps after waiting for a longer time. A driver's response (to accept or reject a gap of a particular duration) is thus affected by the length of time he has had to wait before such a gap is presented. Since the average delay to minor road drivers is dependent on average main flow, equation 6.5 relating the mean critical gap to the average main flow can be used to indirectly account for delay when estimating the mean critical gap from gap acceptance data collected during periods of known average main flows.

When minor road drivers experience long delays, they become impatient. This leads to poor gap acceptance decisions resulting in low mean critical gap values, increased conflicts with the major road traffic and intimidation of the latter. At high main flow speeds, the risk can be severe since major road traffic may have to use abnormal deceleration rates. Some control measures are thus required in such situations. The study reveals that

drivers are more erratic in their gap acceptance behaviour when they have been delayed for more than 30S. This finding, coupled with the recommendations in the Highway Capacity Manual is the basis for recommending traffic signals to cater for situations when the average delay to minor road traffic is between 30S and 60S. However, the design and installation must be based on a careful study of the particular intersection.

In summary then, it can be generally concluded that minor road drivers are sensitive to the duration of stopped delay experienced when deciding on whether to reject or accept a gap of a particular duration. From the study however, such driver reactions to delay may not be enough for a universally valid relationship to be established between the mean critical gap and the duration of stopped delay, since only unsaturated conditions at the minor road approaches were investigated. Though the empirically derived equations provide a quicker means of accounting for delay when estimating mean critical gaps and minor road capacity from observed average main flows, they should be considered applicable only for the range of delay and particular turning behaviour investigated. It is hoped that conclusive findings can be established if and when the study can be extended to include the queuing situation.

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APPENDIX A

PROGRAM DOCUMENTATION FOR "CHOMP"

"CHOMP" is a choice modelling program with three options. It can estimate both multinomial probit and logit models, and predict with multinomial probit models. CHOMP is the main program which controls the execution of all the three options mentioned above. In the estimation option, the program essentially employs an iterative procedure to search for the maximum of the log-likelihood function to obtain the likelihood estimates of the parameters in question that best fit the observed data.

The program is useful in other transportation problems such as modal split and traffic assignment. Directives for the use of the program are given in the user's manual (Daganzo and Schoenfeld; 1978). However, the relevant information to be supplied by the user and a summary of the functions of each of the ten sub-routines are explained herein in line with their application in the determination of gap acceptance parameters.

B.1 CONTROL VARIABLES

These consist of a control card with the relevant information in an appropriate format for controlling the program according to the user's particular needs. The card contains the following information in the format shown:

COLUMNS	VARIABLE NAME	FORMAT
1 - 10	NATTR	I 10
11 - 20	NPAR	I 10
21 - 30	NSAMP	I 10
31 - 40	IALT	I 10
41 - 50	EPSIL	F 10.5
51 - 60	ALPHA	F 10.5
61 - 70	NITERA	I 10
71 - 75	ID	I 5
76 - 80	IHESS	I 5

where,

NATTR -is the number of attributes in the specification of the model. Observations on each driver will thus consist of NATTR attributes (offered gaps) and an observed choice (accepted gap). Where the number of rejected gaps for a particular driver is less than the specified maximum number of rejected gaps, the extra attribute values are each assigned a negative number that is large in absolute value. A value of -100.0 was used (Daganzo, 1981).

NPAR - gives the number of parameters to be calibrated in the model.

NSAMP - specifies the number of observations in the sample.

IALT - specifies the number of alternatives in the choice set. As indicated earlier, the number of alternatives is equal to (R+2). For a maximum number of rejected

gaps of five, the alternatives were defined in terms of gap sizes as follows:

ALTERNATIVE	GAP RANGE (S)
1	0.0 - 3.0
2	3.1 - 6.0
3	6.1 - 9.0
4	9.1 - 12.0
5	12.1 - 15.0
6	15.1 - 18.0
7	≥18.1

EPSIL - is a number (at least two or three times larger than the increments used to calculate partial derivatives) that controls the initial step size of the bracketing procedure preceding the Fibonacci search. A value of 0.05 was used.

ALPHA - is a parameter that controls the progress of the bracketing mechanism and is usually set equal to 3.0.

NITERA - specifies the maximum number of iterations that will be allowed before program execution is terminated. Where convergence is achieved, the following message is printed: "OPTIMUM REACHED *** END EXECUTION BY TRANSFER TO LINE 600 FROM LINE 74". Where any other message is reported, then convergence has not been attained. In such a case, the feasible

region (i.e. initial values) can be redefined.

ID - is a dummy variable which indicates whether the user wants probit, logit calibration, or probit prediction. It is set to zero or blank for probit calibration, one for logit calibration and two for probit prediction. In the present study, it was set to zero, since probit calibration is required.

IHESS - is another dummy variable which specifies if numerical evaluation of the inverse Hessian of the log-likelihood function is desired. IHESS is set to one if evaluation is required and to zero if otherwise. In this case it was set to one.

B.2 DATA CARDS

This set of cards, comes immediately after the control variables card. The set contains one card for each individual observation (minor road driver); thus giving exactly NSAMP cards in the group. The information on each card is shown below in the appropriate format.

COLUMN	VARIABLE NAME	FORMAT
1 - 10	ICH(K)	I 10
11 - 20	T (I,K)	F 10.5
21 - 30	T (2,K)	F 10.5
31 - 40	T (3,K)	F 10.5
.	.	.
.	.	.
.	.	.
	T (NATIR, K)	F 10.5

where,

ICH(K) - is the choice made by the K^{th} observation represented by an integer going from 1 to IALT. For example, if ICH(2) = 4, it means that the gap accepted by the second driver is in the fourth range, i.e. it lies between 9. and 12.0 seconds as specified in the table of alternatives given earlier.

T (J,K) - is the value of the J^{th} attribute (offered gap) for the K^{th} observation. For example, if T(2,1) = 12.0, it means that the size of the second gap offered to the first driver equals 12.0. If the number of attributes (NATTR) exceeds 7, the remaining attributes are entered on additional cards with an F 10.5 format starting on columns 1, 11, 21, etc.

B.3 INITIAL VALUE CARDS

This set of cards comes immediately after the last data card. The set contains information relevant to the parameters to be estimated. This group contains NPAR cards with the following information for the i^{th} parameter.

COLUMN	VARIABLE NAME	FORMAT
1 - 10	PAR (J)	F 10.5
11 - 20	XMN PAR (I)	F 10.5
21 - 30	XMX PAR (I)	F 10.5
31 - 40	XINC (I)	F 10.5

where,

PAR (I) - is the initial value of the i^{th} parameter. For example, if PAR(2) = 3.0 it means that the initial value assigned to the second parameter is 3.0.

XMNPAR(I) - is the minimum allowable value of the i^{th} parameter.

XMXPAR(I) - is the maximum allowable value of the i^{th} parameter.

XINC(I) - is the increment that will be used to calculate partial derivatives needed for the search process for the optimum of the log-likelihood function.

B.4 SUBROUTINES

The subroutines are specific in function. The functions are briefly described.

FIBBO - This subroutine is called by CHOMP at each iteration to perform a one-dimensional Fibonacci search for the maximum of the log-likelihood function. FIBBO thus calls YLIKE to obtain the log-likelihood function.

DFP - This is called by CHOMP to compute corrected search directions, thereby reducing the number of steps required for convergence.

YLIKE - This is the controlling subroutine for calculating the value of the log-likelihood function in the probit option. For each sample point, YLIKE calls SPEC to obtain the vector of means and covariance matrix for the observation. The ROTA, to re-index the chosen alternative to the last

position and CLARK to calculate the probability that the last alternative is chosen. The logarithm of the probability of choice for each observation is summed to obtain the log-likelihood function.

ROTA - This is called by YLIKE to switch the indices of the chosen alternative to the last position. This is done because CLARK evaluates the probability that the last alternative is chosen.

CLARK - The subroutine CLARK calculates the probability that the last alternative was chosen in the probit option. Values of the standard normal function are evaluated directly within CLARK if the argument is greater than 8.64361, otherwise MERFC is called.

MERFC - This is called by CLARK to evaluate the complementary normal function, $1-\phi(x)$, where $\phi(x)$ is the standard normal distribution function, if an approximation is not evaluated within CLARK.

LOGIT - This is called by CHOMP if logit estimation is specified by the user. It evaluates the log-likelihood function for a given vector of parameters. LOGIT thus serves the same purpose as YLIKE, ROTA, CLARK and MERFC in the probit option. LOGIT calls SPEC first, to obtain the mean vector, then directly calculates the probability that the observed alternative was chosen. Then sums the logarithm of the choice probabilities to obtain the log-likelihood value.

HESS - If specified on the control card, execution transfers to the HESS subroutine at the final iteration of the parameter estimation process, to calculate the covariance matrix of the estimated parameters, by computing the inverse of the negative of the Hessian matrix at the solution point. The derivatives are computed using finite difference techniques while the matrix inversion is accomplished by use of row reduction operations.

PRED - If probit prediction is specified by the user, CHOMP calls PRED to calculate the choice probabilities of each of the alternatives. The means and covariance matrix of the perceived utility vector have to be specified as the input to the program.

SPEC - This subroutine specifies the form of the model. In the probit estimation option which has been adopted for this work, SPEC defines the values of the means and covariance matrix of the alternatives as a function of the parameters and attributes. This subroutine thus has to be supplied by the user of CHOMP. The arguments of SPEC in the probit option are the attribute array, T; the parameter vector, PAR; the observation number, K; the vector of measured utilities (gaps), E and the covariance matrix, V.

The first three statements are thus:

```
SUBROUTINE SPEC( T, PAR, K, E, V)
DIMENSION T (20,1000), PAR (20)
DIMENSION E(20), V(20,20), with the following
statements specifying the elements of E and V in
```

terms of PAR and T.

```
E(1)  =
E(2)  =
  !
E(IALT) =
V(1,1)  =
V(1,2)  =
  !
V(1,IALT) =
  '
  '
  '
V(IALT,IALT) =
```

Then the following two cards to end the subroutine:

```
RETURN
END
```

where,
IALT is the number of alternatives in the choice set.

Since the number of attributes (maximum number of offered gaps) is not the same for the different directions of stopped delay, different specification subroutines were supplied for each group. A typical case in which the maximum number of rejected gaps is five is presented here for illustrative purposes by focussing on the estimation of the mean and variance of critical gaps.

From equation 5.5b and using the numerical value of the variance of the gap acceptance function (σ_α^2) as Z^2 as indicated in Chapter Five, the covariance matrix (V^n) is thus given by:

$$V^n = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \sigma^2 + Z^2 & \sigma^2 & \sigma^2 & \sigma^2 & \sigma^2 & -\sigma^2 \\ 0 & \sigma^2 & \sigma^2 + Z^2 & \sigma^2 & \sigma^2 & \sigma^2 & -\sigma^2 \\ 0 & \sigma^2 & \sigma^2 & \sigma^2+Z^2 & \sigma^2 & \sigma^2 & -\sigma^2 \\ 0 & \sigma^2 & \sigma^2 & \sigma^2 & \sigma^2+Z^2 & \sigma^2 & -\sigma^2 \\ 0 & \sigma^2 & \sigma^2 & \sigma^2 & \sigma^2 & \sigma^2+Z^2 & -\sigma^2 \\ 0 & -\sigma^2 & -\sigma^2 & -\sigma^2 & -\sigma^2 & -\sigma^2 & \sigma^2+Z^2 \end{bmatrix} \quad \ldots A.1$$

Hence from equations 5a and A.1 the specification subroutine for the estimation of the mean ($\bar{c}$) and variance (σ^2) of critical gaps is:

```
SUBROUTINE SPEC (T, PAR, K, E, V)
DIMENSION  T(20,1000), PAR (20)
DIMENSION  E(20),  V(20,20)
E(1) = 0
E(2) =  T(1,K) - PAR(1)
E(3) =  T(2,K) - PAR(1)
E(4) =  T(3,K) - PAR(1)
E(5) =  T(4,K) - PAR(1)
E(6) =  T(5,K) - PAR(1)
E(7) =  PAR(1) - T(6,K)
V(1,1) = 0, V(1,2) = 0, V(1,3)=0, V(1,4)=0, V(1,5)=0
V(1,6)=0, V(1,7)=0
V(2,1)=0, V(2,2)= PAR(2)**2+Z**2, V(2,3)=PAR(2)**2
```

```
V(2,4)=V(2,3), V(2,5)= V(2,3), V(2,6)=V(2,3),V(2,7)=-V(2,3)
V(3,1)=0, V(3,2)=V(2,3),V(3,3),=V(2,2), V(3,4) = V(2,3)
V(3,5)=V(2,3), V(3,6)-V(2,3), V(3,7) = V(2,7)
V(4,1)=0,V(4,2)=V(2,3),V(4,3)=V(2,3),V(4,4)=V(2,2)
V(4,5)=V(2,3),V(4,6)=V(2,3),V(4,7)=V(2,7)
V(6,1)=0,V(5,2)=V(2,3),=V(2,3),V(5,4)=V(2,3)
V(5,5)=V(2,2),V(5,6)=V(2,3),V(5,7)=V(2,7)
V(6,1)=0,V(6,2)+V(2,3),V(6,3)=V(2,3),V(6,4),=(2,3)
V(6,5)=V(2,3),V(6,6)=V(2,2),V(6,7)=V(2,7)
V(7,1)-0,V(7,2)=V(2,7),V(7,3)=V(2,7),V(7,4)=V(2,7)
V(7,5)=V(2,7),V(7,6)=V(2,7),V(7,7)=V(2,2)
RETURN
END
```

When the above subprogram is merged with the main program (CHOMP) and executed with various data sets, the maximum likelihood estimates of the mean (**C**) and standard deviation of critical gaps are obtained respectively as PAR(1) and PAR(2).

PARAMETER NO. 1

NITIAL VALUE= 9.00300
IN. ALLOWABLE VALUE= 1.00100
AXIMUM ALLOWABLE VALUE= 20.00001

ARAMETER INCREMENT= .01000

PARAMETER NO. 2
NITIAL VALUE= 2.00300
IN. ALLOWABLE VALUE= .20100
AXIMUM ALLOWABLE VALUE= 17.00001

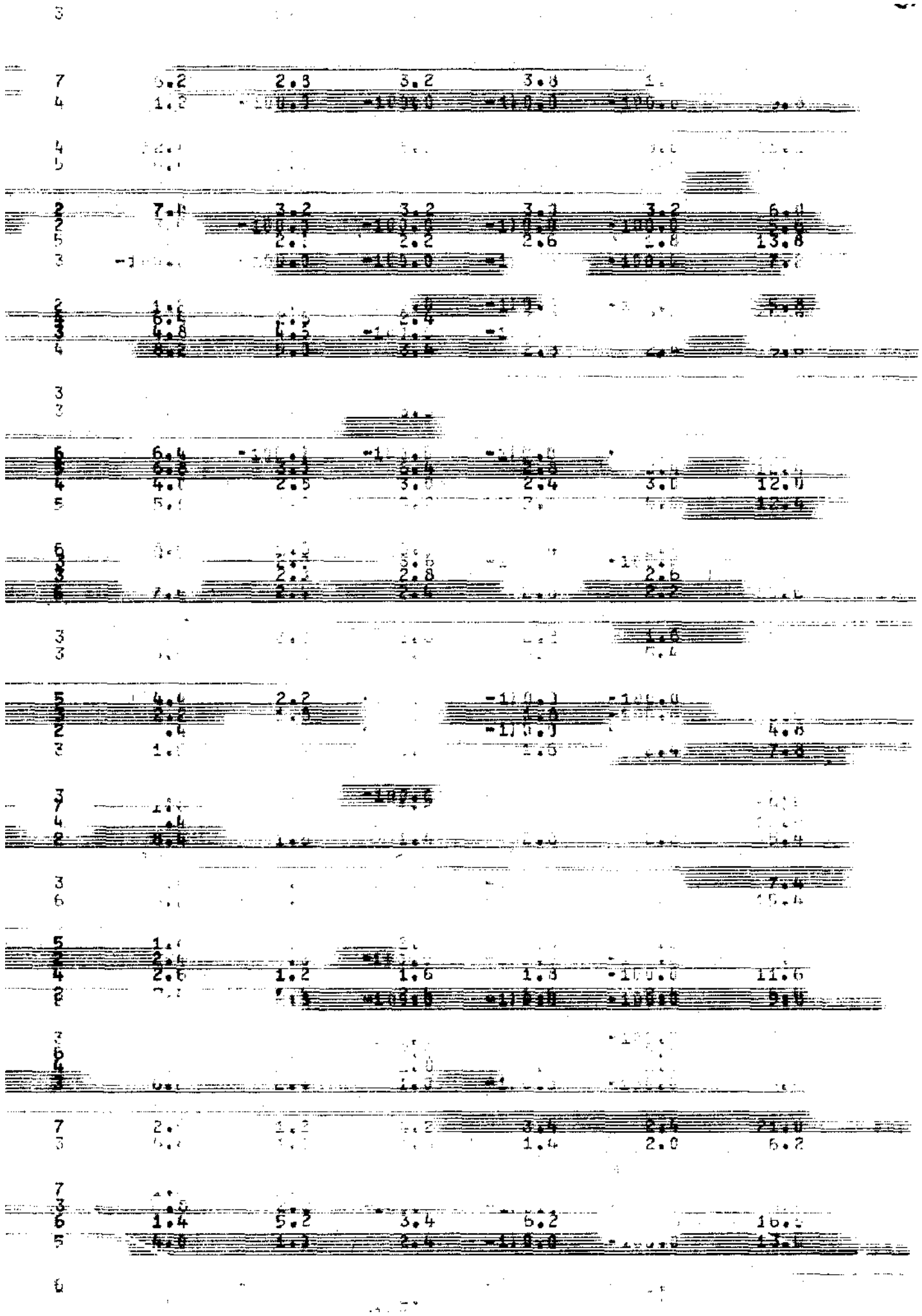
ARAMETER INCREMENT= .01300
SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2,...

3	4.4	2.3	1.6	2.3	1.2	7.4
6	-100.0	-100.2	-100.0	-100.0	-100.0	17.0
2	2.8	2.0	2.2	1.4	1.8	4.2
4	2.8	.4	-100.0	-100.0	-100.0	9.2
1	9.0	2.3	4.0	3.0	3.6	2.4
3	12.2	.5	-100.0	-100.0	-100.0	6.6
5	5.6	.5	2.6	-100.0	-100.0	13.2
1	8.6	3.3	-100.0	-100.0	-100.0	2.2
6	1.0	-100.0	-100.0	-100.0	-100.0	15.2
3	6.8	2.0	1.4	1.2	2.2	6.2
1	3.0	1.2	-100.0	-100.0	-100.0	1.6
4	8.8	1.2	-100.0	-100.0	-100.0	11.6
1	12.0	2.2	-100.0	-100.0	-100.0	3.0
1	5.6	2.8	1.8	3.6	4.6	2.2
4	3.2	2.2	3.2	-100.0	-100.0	9.6
1	2.4	2.0	2.2	-100.0	-100.0	3.0
2	2.4	1.2	-100.0	-100.0	-100.0	5.8
2	4.4	2.2	1.8	1.4	2.6	5.2
5	5.6	-100.0	-100.0	-100.0	-100.0	6.4
3	1.6	-100.0	-100.0	-100.0	-100.0	6.4
6	5.8	.5	-100.0	-100.0	-100.0	17.2
6	5.6	2.2	-100.0	-100.0	-100.0	15.4
3	6.0	3.0	-100.0	-100.0	-100.0	6.2
3	7.2	4.4	3.0	4.0	3.4	8.2
3	3.6	2.2	3.4	-100.0	-100.0	9.6
2	3.4	1.5	2.4	3.0	2.0	4.7
5	1.2	1.2	-100.0	-100.0	-100.0	13.8
1	7.6	1.8	3.4	1.8	2.6	2.4
5	6.2	1.5	-100.0	-100.0	-100.0	12.2
5	5.8	2.1	.8	5.4	4.4	13.2
2	8.2	7.3	4.6	5.8	4.8	4.6
3	2.2	1.4	.8	-100.0	-100.0	9.0
4	4.0	3.8	2.2	-100.0	-100.0	12.0

2	4.6	.8	1.2	1.8	-100.0	4.0
5	8.6	6.4	1.6	2.8	2.0	14.0
1	6.4	1.6	2.0	2.4	-100.0	2.8
5	3.0	2.2	2.4	1.2	1.6	13.0
1	3.8	2.4	2.8	3.6	3.0	2.4
3	9.0	2.8	2.0	2.4	5.8	7.0
7	5.2	2.2	2.4	-110.0	-100.0	10.8
2	2.4	2.2	2.2	-110.0	-100.0	5.0
5	3.6	1.4	2.4	2.6	-100.0	12.8
5	4.8	-100.0	-100.0	-110.0	-100.0	14.8
6	6.6	2.2	-100.0	-110.0	-100.0	15.6
4	4.8	2.0	2.0	2.4	1.6	3.4
2	3.4	.8	1.0	3.0	1.6	4.4
4	4.0	3.0	1.0	2.0	1.0	10.0
2	4.6	-100.0	-100.0	-110.0	-100.0	4.8
3	2.0	1.4	2.8	2.4	-100.0	6.4
4	10.0	4.0	1.2	1.3	2.4	9.6
2	7.6	2.2	.8	2.4	-100.0	4.0
2	3.6	2.2	3.0	2.0	2.0	3.2
6	3.2	2.6	2.0	2.2	-100.0	15.2
5	2.8	1.2	4.2	2.8	-100.0	9.2
3	-100.0	-100.0	-100.0	-110.0	-100.0	8.2
1	6.0	2.2	-100.0	-110.0	-100.0	2.4
2	.4	2.4	3.2	3.4	100.0	3.2
4	3.8	2.0	1.2	-110.0	-100.0	8.2
1	-100.0	-100.0	-100.0	-110.0	-100.0	2.0
2	2.0	1.2	1.6	1.8	-100.0	5.4
3	3.2	.8	.6	.8	.6	7.2
2	2.6	1.2	1.2	-110.0	-100.0	4.4
2	3.0	-100.0	-100.0	-110.0	-100.0	5.6
3	.6	2.4	2.6	-110.0	-100.0	6.8
5	6.0	2.4	3.2	1.2	1.0	12.6
3	1.0	.8	-100.0	-110.0	-100.0	8.4
3	3.0	.8	1.4	2.0	2.2	7.4
2	8.2	3.0	2.0	2.2	4.8	3.4
7	8.0	1.0	-100.0	-110.0	-100.0	31.2
3	-100.0	-100.0	-100.0	-110.0	-100.0	7.4
3	.8	-100.0	-100.0	-110.0	-100.0	8.0
7	2.8	-100.0	-100.0	-110.0	-100.0	19.0
2	3.6	1.8	2.8	2.0	2.6	3.2
5	6.2	3.2	2.6	5.0	4.2	15.4
3	6.0	1.4	3.4	2.8	1.4	9.0
4	3.0	-100.0	-100.0	-110.0	-100.0	9.0
3	4.6	4.0	-100.0	-110.0	-100.0	8.0
2	7.2	4.4	3.0	-110.0	-100.0	6.0
3	-100.0	-100.0	-100.0	-110.0	-100.0	6.4
5	7.0	2.4	2.8	2.8	2.2	5.6
2	6.8	4.8	2.2	2.2	3.4	6.0
1	2.8	2.0	1.2	-110.0	-100.0	2.8

4	4.0	2.4	2.0	4.4	3.6	11.0
3	2.6	2.5	4.2	3.2	1.2	6.2
7	2.8	2.2	-100.0	-100.0	-100.0	19.2
3	2.8	1.2	3.2	2.4	4.2	5.2
6	1.8	-100.0	-100.0	-100.0	-100.0	15.6
7	5.4	2.8	.8	1.2	2.6	21.6
2	-100.0	-100.0	-100.0	-100.0	-100.0	4.0
7	1.0	3.2	2.4	3.4	2.2	38.8
5	-100.0	-100.0	-100.0	-100.0	-100.0	11.2
4	2.6	2.4	1.2	2.4	3.2	9.4
2	-100.0	-100.0	-100.0	-100.0	-100.0	6.0
2	4.2	-100.0	-100.0	-100.0	-100.0	4.6
2	4.2	1.4	3.6	1.6	2.8	3.4
1	2.0	-100.0	-100.0	-100.0	-100.0	2.8
7	5.6	2.5	-100.0	-100.0	-100.0	24.8
6	3.4	1.8	1.2	2.2	3.2	16.2
7	2.4	1.2	1.8	2.0	-100.0	19.2
2	1.4	-100.0	-100.0	-100.0	-100.0	5.4
3	11.2	7.0	7.6	2.0	2.8	7.4
3	.8	-100.0	-100.0	-100.0	-100.0	8.4
2	8.2	1.2	1.6	2.4	-100.0	4.8
7	1.4	-100.0	-100.0	-100.0	-100.0	23.0
3	8.4	1.2	3.2	4.4	3.2	8.2
5	.6	-100.0	-100.0	-100.0	-100.0	14.4
4	4.4	1.4	2.6	2.4	1.2	10.2
2	-100.0	-100.0	-100.0	-100.0	-100.0	4.4
2	.6	1.2	1.2	3.4	2.2	5.2
4	14.0	3.0	3.0	3.4	3.0	12.4
3	-100.0	-100.0	-100.0	-100.0	-100.0	7.8
2	5.6	1.2	2.0	2.6	1.8	5.6
5	4.4	5.2	5.8	-100.0	-100.0	15.4
3	3.4	-100.0	-100.0	-100.0	-100.0	8.4
7	2.8	1.5	1.2	3.2	2.4	23.6
7	8.8	3.2	5.8	3.4	4.0	19.0
5	1.4	-100.0	-100.0	-100.0	-100.0	12.4
7	1.2	2.5	2.4	4.2	2.2	18.4
6	5.2	-100.0	-100.0	-100.0	-100.0	16.8
5	8.2	7.5	2.2	6.2	5.6	14.8
5	9.4	4.8	4.4	7.4	4.4	14.6
3	5.8	-100.0	-100.0	-100.0	-100.0	6.8
7	4.2	2.2	1.8	2.4	2.6	27.4
6	3.8	-100.0	-100.0	-100.0	-100.0	16.4
7	8.0	1.5	3.0	-100.0	-100.0	23.6
7	4.2	4.3	.8	2.3	-100.0	25.4
3	3.6	-100.0	-100.0	-100.0	-100.0	6.8
2	13.4	2.2	3.2	7.8	3.6	5.8
6	12.8	.8	-100.0	-100.0	-100.0	15.2
2	4.0	2.2	3.4	3.2	2.6	4.4
2	2.4	2.0	-100.0	-100.0	-100.0	3.2
7	10.0	5.4	5.4	3.4	5.8	25.6
3	-100.0	-100.0	-100.0	-100.0	-100.0	6.4
7	5.2	1.2	1.6	1.2	-100.0	28.8

4	3.2	-100.0	-100.0	-100.0	-100.0	13.8
7	6.8	1.5	.8	-100.0	-100.0	26.8
1	3.6	2.2	2.0	3.2	2.2	3.1
5	-100.0	-100.0	-100.0	-100.0	-100.0	14.4
5	10.8	0.2	5.2	2.2	1.2	12.8
3	4.0	2.0	1.2	-100.0	-100.0	9.0
2	4.0	2.5	1.2	-100.0	-100.0	3.8
2	4.2	3.2	4.2	4.0	2.4	6.0
3	4.8	3.0	2.6	-100.0	-100.0	9.0
3	8.6	5.5	1.0	2.2	2.4	8.2
3	-100.0	-100.0	-100.0	-100.0	-100.0	6.2
3	9.2	3.5	1.4	3.0	3.8	6.6
2	12.2	1.0	2.2	1.8	2.2	4.2
7	2.8	2.1	-100.0	-100.0	-100.0	16.2
6	5.6	-100.1	-100.0	-100.0	-100.0	12.2
2	7.4	2.4	2.2	3.6	2.8	3.8
2	3.0	2.0	1.4	1.2	-100.0	5.2
6	1.8	-100.1	-100.0	-100.0	-100.0	15.0
4	6.0	1.2	2.0	2.8	2.8	12.0
2	6.0	3.4	3.6	3.6	3.8	4.2
5	4.8	-100.0	-100.0	-100.0	-100.0	14.8
3	5.2	1.2	3.2	4.2	2.6	8.8
4	4.2	3.4	-100.0	-100.0	-100.0	9.2
3	10.0	2.5	3.2	5.4	-100.0	6.2
3	4.4	5.2	2.2	2.2	3.0	10.0
7	3.0	.5	1.4	-100.0	-100.0	18.8
2	6.2	5.5	1.6	-100.0	-100.0	5.8
5	6.2	3.0	1.8	2.0	5.8	12.2
3	6.8	1.2	3.2	4.4	2.6	8.0
2	-100.0	-100.0	-100.0	-100.0	-100.0	4.4
2	7.0	4.4	2.8	2.4	3.0	5.8
2	.6	-100.0	-100.0	-100.0	-100.0	4.4
4	2.2	-100.0	-100.0	-100.0	-100.0	16.8
3	-100.0	-100.0	-100.0	-100.0	-100.0	8.6
2	6.6	2.2	2.6	4.0	-100.0	12.4
4	4.2	2.0	1.0	1.6	4.4	11.6
4	4.6	1.2	-100.0	-100.0	-100.0	10.4
7	2.4	1.0	-100.0	-100.0	-100.0	18.4
7	10.8	2.4	1.0	4.4	2.8	23.0
6	11.2	1.4	1.8	2.0	-100.0	17.4
4	3.8	2.0	3.0	3.8	3.6	11.6
5	3.6	.8	1.8	-100.0	-100.0	13.0
6	4.8	2.8	2.0	3.2	2.2	16.4
3	3.6	-100.0	-100.0	-100.0	-100.0	6.2
4	6.4	1.2	-100.0	-100.0	-100.0	10.2
6	1.8	1.0	1.6	1.2	1.0	16.2
4	2.8	1.4	2.2	2.4	2.2	10.8
5	6.0	1.2	2.2	2.0	1.2	14.2
1	9.2	2.8	4.5	2.6	4.6	2.6
2	2.4	-100.0	-100.0	-100.0	-100.0	10.8



5	3.4	1.2	-103.0	-110.0	-100.0	14.8
5	1.0	2.4	5.4	1.2	2.2	12.6
6	8.2	3.4	3.2	2.4	3.0	15.8
3	14.1	-107.3	-102.8	-110.0	-100.0	8.8
3	3.6	.8	1.4	2.6	3.2	8.6
4	6.0	3.0	2.4	-110.0	-100.0	9.4
1	1.2	-100.0	-102.0	-110.0	-100.0	3.6
2	4.2	.8	1.4	2.4	-100.0	3.4
2	4.0	2.2	-103.0	-110.0	-100.0	4.2
7	3.8	2.4	3.0	2.0	2.6	18.2
7	3.8	1.4	2.2	-110.0	-100.0	18.6
3	5.0	2.2	1.2	2.2	2.4	7.8
5	3.6	-100.0	-103.0	-110.0	-100.0	14.6
3	6.2	1.4	2.8	1.6	-100.0	7.2
6	7.0	2.2	2.2	1.2	3.8	16.8
2	4.8	1.4	2.4	1.2	3.4	5.6
7	3.4	3.2	2.2	3.2	3.2	22.0
7	3.8	2.2	1.6	-110.0	-100.0	19.0
2	16.2	1.2	1.6	1.8	4.0	5.6
2	6.6	3.2	5.2	2.8	2.8	5.2
1	9.4	.8	1.6	3.8	1.6	3.0
3	1.4	-100.0	-100.0	-170.0	-100.0	8.6
2	6.0	2.2	-103.0	-110.0	-100.0	10.4
2	3.4	1.8	1.4	-110.0	-100.0	5.2
6	3.4	1.8	2.0	2.2	5.4	17.2
1	1.0	.8	-100.0	-110.0	-100.0	3.0
6	4.0	2.8	3.4	-110.0	-100.0	16.8
4	3.6	2.2	-101.8	-110.0	-100.0	10.0
7	.8	1.2	2.2	2.4	3.2	22.0
3	1.8	-100.0	-103.0	-110.0	-100.0	8.6
1	-100.0	-100.0	-100.0	-110.0	-100.0	3.8
1	4.0	.8	-100.0	-170.0	-100.0	3.0
2	6.4	2.4	1.2	5.2	2.4	3.8
4	2.2	1.4	1.2	2.2	.8	10.0
2	4.6	2.2	5.6	2.8	-100.0	4.4
4	1.8	.8	5.6	2.8	-100.0	10.4
6	2.8	1.8	2.2	-110.0	-100.0	16.0
3	4.0	3.5	2.6	2.4	1.6	
3	4.2	2.2	3.8	2.6	2.6	8.4
3	6.8	1.8	-102.0	-110.0	-100.0	7.4
6	7.8	2.4	1.2	3.2	5.4	16.6
4	6.6	-101.8	-103.0	-110.0	-100.0	11.2
7	3.6	2.6	2.6	3.2	3.2	19.2
2	2.4	1.8	-101.0	-110.0	-100.0	5.6
2	3.8	2.6	2.6	3.8	1.6	5.4
2	-100.0	-101.2	-103.0	-110.0	-100.0	6.0
7	4.0	1.4	3.6	1.8	-100.0	25.0
3	2.2	1.8	-103.0	-110.0	-100.0	7.4
2	2.6	2.4	3.2	5.4	4.8	5.4
7	6.0	5.0	2.8	4.2	2.4	10.2

```
 4        8.1          7.7          2.6          5.4          3.6          12.0
 2        3.8          1.5          1.2          1.2       -100.0           5.9


 3        5.4       -100.1       -100.0       -100.0       -100.0           7.2
 1        4.0          2.0          2.4          2.0          1.6           3.0

 4        3.6       -100.1       -100.0       -100.0       -100.0          11.6
 3        2.6          2.2          1.8          1.9          1.8           8.0

 5        8.0          3.8          4.8          3.8          6.2          14.6
 7        1.4          3.0          2.6          2.4          2.2          25.2
 2        6.1          1.5          2.6          2.2          3.1           5.8
 3        6.6       -100.4       -100.2       -100.4       -100.2           7.6

 7       11.2          8.7          3.2          3.9          3.2          26.2
 5     -100.1       -100.1       -100.0       -100.0       -100.1           2.6
 7        5.8          1.5          1.2          1.3          5.8          19.3
 3        4.4          1.4          1.8       -100.0       -100.0           6.2

 5        8.4          1.5       -100.0       -100.0       -100.0          13.2
 2       10.2          6.2          3.0          4.2          6.1           4.2


BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT=          -11516.67329

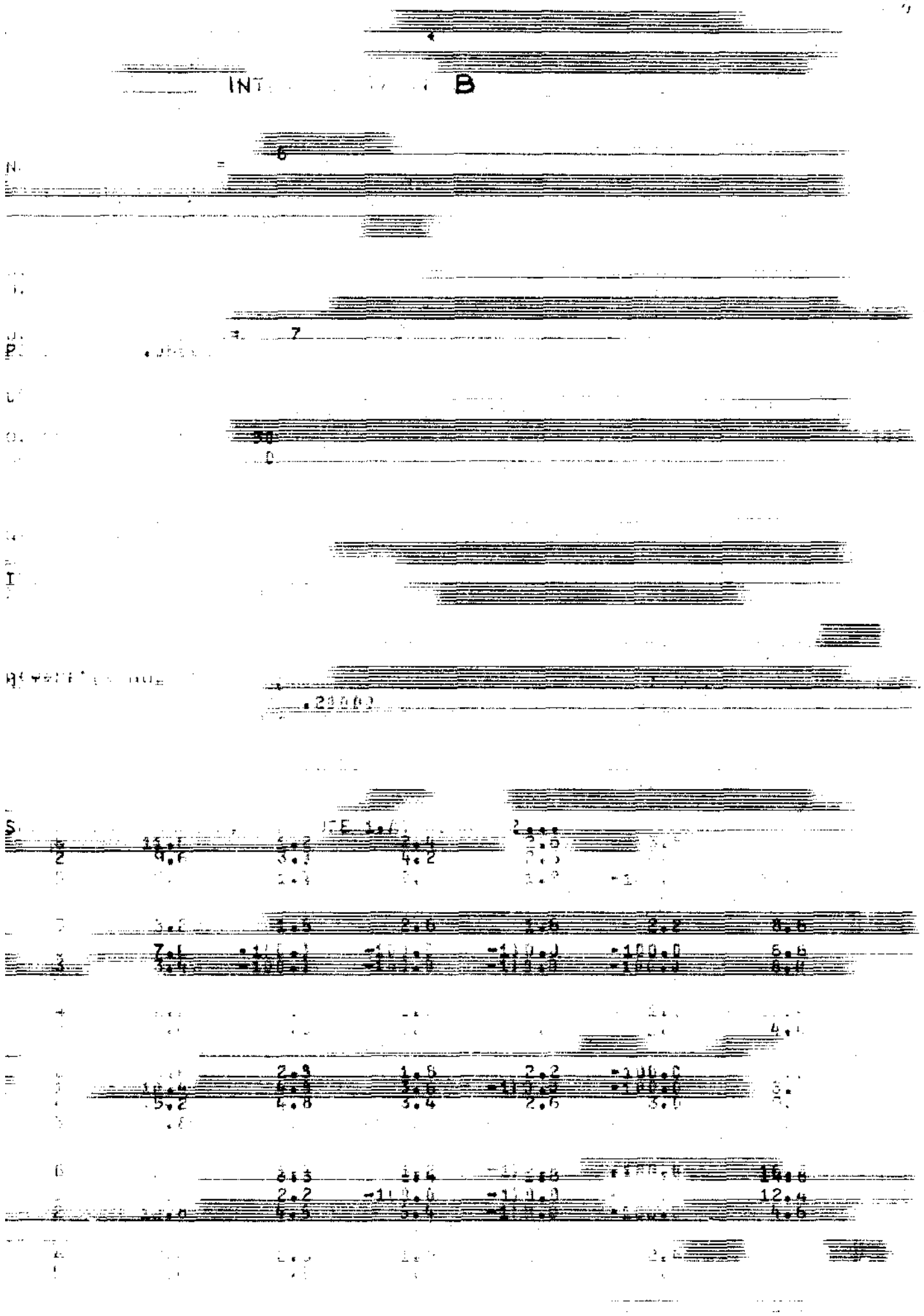
END PHASE I

LOG LIKELIHOOD AT START OF PHASE II=          -95403.69854

ITERATION  1

LOG LIKELIHOOD=       -84764.83925
PAR. NO.          PAR.VALUE
     1              9.98613
     2              1.71426

OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 603 FROM LINE  74
```



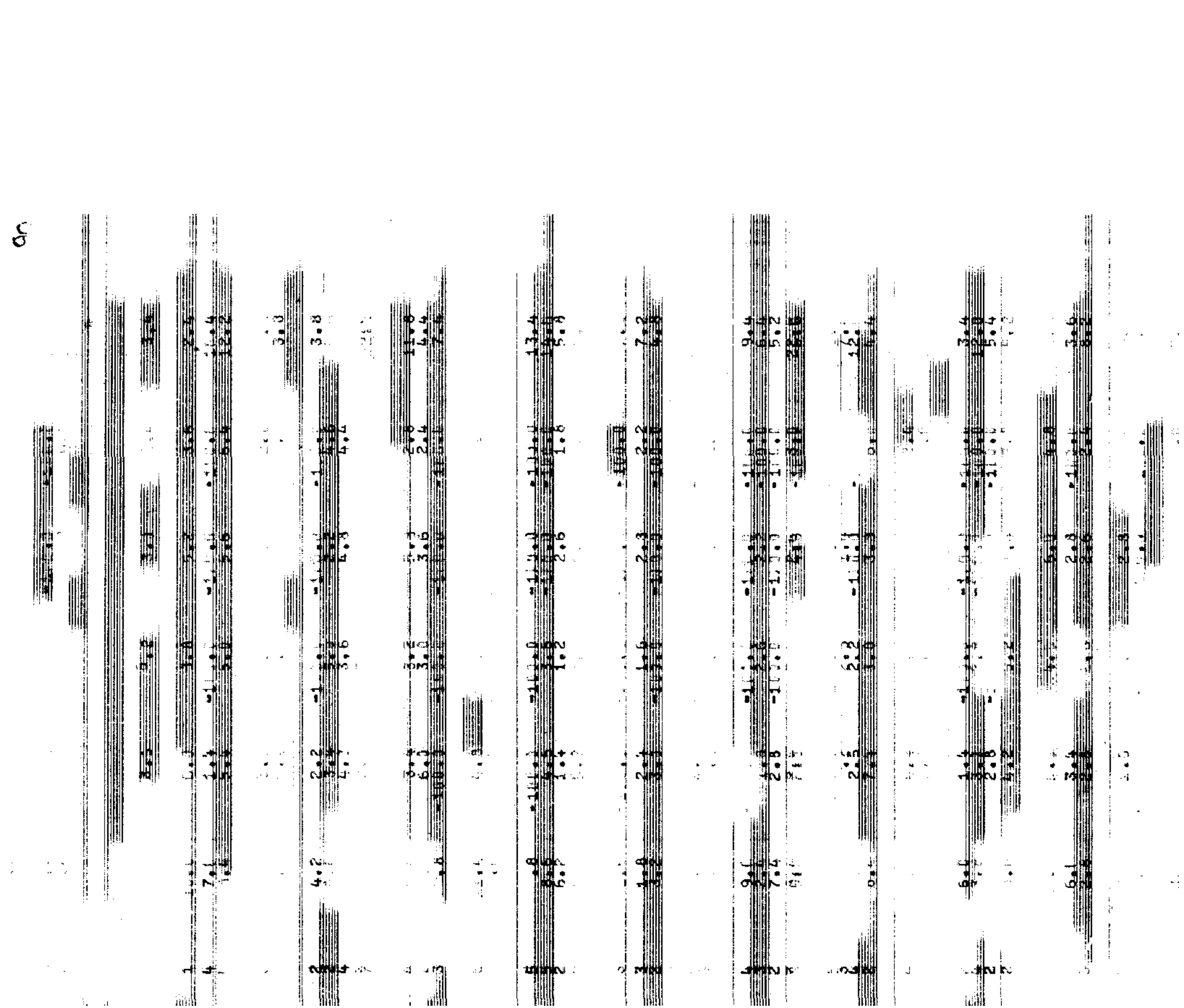
2	3.4	2.2	2.4	3.2	2.6	5.2
5	3.0	-100.0	-100.0	-100.0	-100.0	12.4
7	2.8	1.4	2.2	3.4	1.2	20.8
3	2.4	1.4	-100.0	-100.0	-100.0	9.6
3	3.2	1.8	-100.0	-100.0	-100.0	7.4
4	1.8	1.2	2.4	2.2	1.4	10.8
4	1.6	-100.0	-100.0	-100.0	-100.0	11.6
2	6.6	1.6	1.6	4.2	-100.0	4.4
4	6.2	3.8	2.4	2.2	2.4	10.8
2	6.6	1.6	2.2	4.2	3.6	3.6
1	6.2	2.0	2.2	4.2	2.0	3.0
1	3.4	2.2	2.8	-100.0	-100.0	2.8
7	3.4	2.6	2.2	.8	1.0	23.0
5	3.0	1.8	2.2	1.8	3.0	15.0
2	4.6	1.6	1.4	2.2	1.0	5.4
5	3.0	1.0	2.0	1.4	-100.0	13.6
7	6.2	3.2	2.0	1.8	-100.0	23.6
4	1.4	-100.0	-100.0	-100.0	-100.0	19.8
2	4.0	3.2	2.4	2.6	1.2	6.0
2	6.2	2.8	5.0	3.8	4.0	3.8
4	1.8	1.4	-100.0	-100.0	-100.0	10.0
4	4.4	1.8	2.0	2.2	2.8	11.4
5	3.8	3.6	1.2	2.8	3.6	13.0
7	4.4	3.2	2.6	1.8	2.0	25.0
6	7.8	1.8	1.4	2.0	2.8	16.0
5	3.2	2.2	1.8	-100.0	-100.0	12.6
2	10.2	-100.0	-100.0	-100.0	-100.0	4.8
4	2.4	2.2	2.4	-100.0	-100.0	11.4
3	2.4	1.6	2.2	-100.0	-100.0	6.8
4	9.4	2.8	1.2	2.2	2.4	10.8
2	5.6	1.2	1.0	-100.0	-100.0	4.0
2	6.6	5.8	3.2	3.2	5.0	4.4
3	11.8	3.0	4.8	3.8	3.6	6.6
3	4.0	1.2	2.2	1.0	-100.0	6.4
7	11.8	3.4	2.0	4.8	4.8	17.0
6	10.4	2.4	5.0	3.6	3.0	17.8
5	2.6	2.6	1.2	2.2	-100.0	12.8
7	3.8	-100.0	-100.0	-100.0	-100.0	18.6
2	1.2	2.4	3.2	4.2	2.4	5.6
3	4.6	3.4	3.2	3.4	2.6	8.4
3	2.4	1.4	1.6	-100.0	-100.0	7.6
3	8.4	6.2	3.4	3.4	5.8	6.4
4	2.6	.4	-100.0	-100.0	-100.0	9.8
4	5.4	3.4	3.2	3.2	3.0	10.4
7	3.0	-100.0	-100.0	-100.0	-100.0	19.8
5	6.2	2.4	1.2	2.0	-100.0	12.6

7	6.1	3.3	-100.0	-100.0	-100.0	19.0
2	4.6	2.3	2.8	3.3	3.0	4.2
5	5.8	4.3	3.5	3.2	1.8	13.8
3	2.2	1.8	1.6	-100.0	-100.0	8.6
4	4.4	3.4	.8	2.2	-100.0	9.4
4	4.6	2.1	-100.0	-100.0	-100.0	10.4
1	6.4	2.3	3.0	4.4	2.6	2.0
3	4.6	2.4	1.6	2.0	2.0	7.4
2	5.4	2.4	1.6	2.2	2.4	3.4
4	4.6	.8	-100.0	-100.0	-100.0	10.0
7	4.2	2.3	2.8	2.2	2.2	30.0
7	16.4	8.1	2.8	3.2	3.4	20.4
3	3.8	2.1	3.8	2.0	3.2	6.2
3	5.8	2.5	2.4	1.4	4.8	6.4
2	8.0	5.1	-100.0	-100.0	-100.0	18.8
6	4.4	2.3	3.0	3.2	2.4	15.4
6	3.2	2.4	3.0	3.2	2.4	15.4
5	2.4	1.3	1.6	2.2	-100.0	14.6
1	2.0	1.4	-100.0	-100.0	-100.0	3.0
5	.8	-100.0	-100.0	-100.0	-100.0	12.8
1	2.0	1.8	-100.0	-100.0	-100.0	3.0
4	7.6	2.2	4.8	1.0	.8	11.8
3	15.4	11.4	4.2	1.8	2.4	7.8
7	2.8	1.5	2.4	2.0	1.8	19.8
5	14.4	3.5	2.8	2.4	2.8	12.2
3	4.0	2.8	1.6	2.0	-100.0	8.4
5	6.4	2.2	-100.0	-100.0	-100.0	14.0
7	2.2	1.3	2.0	2.0	2.0	32.6
4	2.0	1.4	1.0	1.0	-100.0	10.4
6	1.6	-100.0	-100.0	-100.0	-100.0	15.6
7	1.8	-100.0	-100.0	-100.0	-100.0	26.8
3	5.2	4.2	4.6	3.0	3.2	6.4
4	1.6	2.4	3.2	2.4	6.2	11.2
8	9.6	1.3	-100.0	-100.0	-100.0	17.4
2	4.0	1.5	2.6	2.4	2.0	4.6
2	8.0	7.4	2.2	1.8	2.0	5.6
7	4.0	2.3	2.8	3.1	2.2	18.6
2	7.8	1.5	1.8	1.6	3.2	3.6
2	18.6	1.2	4.6	4.4	3.0	4.4
5	7.6	4.3	2.8	3.4	2.4	14.4
4	4.2	1.4	-100.0	-100.0	-100.0	9.8
3	2.6	2.1	-100.0	-100.0	-100.0	6.8
4	3.4	1.4	1.2	3.2	2.4	9.4
4	2.4	1.3	1.4	1.6	-100.0	9.2
3	1.8	1.4	.8	-100.0	-100.0	6.2
4	7.2	3.2	2.8	2.2	1.4	11.2
7	4.2	2.4	3.0	-100.0	-100.0	23.4

		.5	1.0	-100.0	-100.0	7.2
2	3.6	2.2	2.0	2.4	3.6	4.1
2	2.6	-100.0	-100.0	-100.0	-100.0	4.4
4	1.6	1.2	.8	-100.0	-100.0	11.6
7	6.8	2.2	.6	.8	-100.0	20.8
3	2.8	2.2	2.4	2.6	1.8	6.2
2	5.6	2.2	2.2	4.4	2.4	5.2
3	1.1	.8	.8	-100.0	-100.0	5.2
3	5.4	3.2	5.2	2.2	2.8	8.0
7	5.2	2.8	2.2	2.4	3.8	29.2
4	8.8	4.5	5.8	8.6	4.0	9.6
3	8.0	2.8	1.8	4.0	3.8	7.1
4	6.4	1.8	2.6	2.8	-100.0	10.3
6	7.4	2.2	4.8	5.8	2.4	16.0
3	6.6	.9	2.8	-100.0	-100.0	6.4
5	7.2	3.6	2.4	2.2	2.8	13.8
3	6.0	2.4	1.8	3.8	3.4	6.6
7	1.6	-100.0	-100.0	-100.0	-100.0	27.0
7	14.8	6.4	8.8	4.8	3.8	23.4
3	4.4	1.2	3.2	-100.0	-100.0	8.6
7	.8	-100.0	-100.0	-100.0	-100.0	21.2
6	5.8	3.4	4.4	4.4	3.4	15.2
1	2.8	-100.0	-100.0	-100.0	-100.0	2.4
7	4.8	3.1	-100.0	-100.0	-100.0	22.0
3	4.6	1.8	2.8	1.6	-100.0	5.2
2	10.1	1.2	1.4	1.8	-100.0	4.4
6	3.2	2.8	2.4	2.6	2.4	17.6
2	2.4	1.8	1.6	-100.0	-100.0	3.6
1	-100.0	-100.0	-100.0	-100.0	-100.0	2.8
5	4.8	3.0	3.4	1.6	2.4	13.2
2	4.2	3.4	3.2	3.2	3.6	3.8
4	5.8	2.2	4.6	2.6	2.8	3.4
3	2.8	2.4	2.2	2.8	2.2	6.8
2	4.4	2.0	3.0	3.8	-100.0	3.6
4	2.4	-100.0	-100.0	-100.0	-100.0	8.6
2	3.2	1.6	-100.0	-100.0	-100.0	3.8
7	3.8	1.8	-100.0	-100.0	-100.0	27.2
2	1.8	1.8	2.4	3.2	2.4	4.2
4	6.6	1.6	1.8	2.8	-100.0	12.6
2	3.2	2.6	-100.0	-100.0	-100.0	5.8
6	7.8	3.0	1.8	2.2	3.4	14.6
1	2.2	1.9	1.8	2.4	1.8	2.6
3	1.0	-100.0	-100.0	-100.0	-100.0	7.8
4	5.6	4.8	2.6	2.6	3.0	10.2
3	5.6	5.2	1.2	2.8	1.4	6.8
6	8.8	-100.0	-100.0	-100.0	-100.0	16.8
3	3.4	1.5	-100.0	-100.0	-100.0	8.2
3	3.0	2.2	2.4	3.2	1.4	7.4
4	1.4	-100.0	-100.0	-100.0	-100.0	

2	8.2	3.6	3.8	-100.0	-100.0	4.8
3	6.4	-100.0	-100.0	-100.0	-100.0	8.2
4	2.8	2.4	1.8	2.2	2.6	10.8
2	3.2	2.2	2.8	3.0	2.4	5.4
7	2.0	.8	1.0	1.2	-100.0	25.0
2	3.8	2.6	2.2	2.2	2.2	3.6
2	7.4	3.6	7.2	4.6	4.4	3.4
1	5.8	4.2	3.6	2.8	2.8	1.4
3	3.8	2.6	-100.0	-100.0	-100.0	6.6
3	2.2	-100.0	-100.0	-100.0	-100.0	7.4
4	7.6	6.8	5.2	5.6	4.4	11.0
1	11.2	3.6	1.8	1.2	1.4	3.0
7	4.0	1.0	1.0	1.2	-100.0	28.4
4	5.6	2.6	4.2	2.4	4.0	10.0
3	2.4	1.2	1.6	-100.0	-100.0	6.4
2	2.4	1.4	1.2	1.6	2.2	3.8
6	10.0	1.0	-100.0	-100.0	-100.0	15.2
4	6.0	5.4	3.0	2.4	2.4	9.6
1	3.6	2.6	-100.0	-100.0	-100.0	3.0
4	6.8	4.4	4.0	5.0	4.4	9.8
3	3.8	-100.0	-100.0	-100.0	-100.0	7.4
3	3.2	2.0	1.8	1.6	2.2	7.6
2	7.2	2.6	4.0	2.0	2.4	4.0
2	6.8	2.8	5.6	3.2	4.0	7.2
3	2.6	.8	-100.0	-100.0	-100.0	8.2
1	2.8	1.2	-100.0	-100.0	-100.0	3.0
1	1.2	1.1	2.2	2.4	1.6	2.4
4	3.6	1.2	2.2	1.8	2.2	10.8
2	3.4	2.6	2.8	3.0	2.8	3.6
2	6.6	3.0	3.4	-100.0	-100.0	5.4
2	4.4	3.0	2.4	-100.0	-100.0	4.2
2	1.6	.8	.8	1.2	2.2	7.0
4	5.2	4.2	3.6	3.0	3.6	11.2
2	2.0	-100.0	-100.0	-100.0	-100.0	3.0
7	3.0	-100.0	-100.0	-100.0	-100.0	24.0
5	8.2	1.0	1.2	3.4	2.2	14.2
3	2.4	1.8	-100.0	-100.0	-100.0	7.0
5	7.2	3.6	5.8	6.2	3.6	13.2
2	6.2	2.2	3.0	2.0	3.2	3.4
2	6.4	2.2	5.8	4.4	4.0	4.8
3	2.6	2.4	-100.0	-100.0	-100.0	7.0
3	-100.0	-100.0	-100.0	-100.0	-100.0	7.0
5	4.2	1.8	1.6	-100.0	-100.0	5.8
3	6.8	2.6	5.8	2.4	2.8	8.8
4	6.2	1.8	1.8	2.8	-100.0	10.4
3	2.8	-100.0	-100.0	-100.0	-100.0	7.2
3	2.4	2.6	2.0	2.2	1.8	8.8

2	6.6	4.0	5.0	4.4	5.6	4.8
2	7.4	2.5	3.0	1.8	100.0	5.2
2	4.8	2.8	1.6	2.0	2.4	4.8
1	5.4	-100.0	-100.0	-170.0	-100.0	3.0
2	7.4	2.8	4.0	2.4	3.0	5.0
5	6.1	2.8	2.4	3.4	2.8	12.4
4	7.6	2.0	3.0	2.0	3.8	9.8
2	5.2	2.5	3.8	1.8	2.2	4.4
2	7.0	4.2	4.8	3.2	3.0	5.0
2	8.6	4.8	3.6	2.5	3.6	6.8
3	3.4	2.2	2.2	2.4	2.2	7.6
2	2.2	1.5	-100.0	-170.0	-100.0	5.8
4	7.8	2.8	2.2	2.4	2.6	10.2
2	4.6	2.0	3.4	3.2	-100.0	4.2
7	4.8	3.5	-100.0	-170.0	-100.0	21.4
7	3.8	2.4	-100.0	-170.0	-100.0	25.6
2	3.6	2.5	1.8	2.0	1.4	4.8
4	4.0	2.5	3.2	3.8	4.0	10.2
4	4.6	1.3	-100.0	-170.0	-100.0	10.4
5	3.2	1.4	2.0	2.2	2.4	14.8
5	6.1	3.5	-100.0	-170.0	-100.0	13.8
2	5.8	3.0	3.6	4.8	4.2	5.4
2	4.8	3.0	4.0	2.8	2.4	4.2
2	12.6	4.8	5.6	4.8	6.4	3.8
1	8.4	7.5	3.2	3.4	4.6	3.0
5	1.6	1.2	-100.0	-170.0	-100.0	12.8
4	6.2	5.8	3.8	4.8	2.8	10.2
2	9.8	2.4	4.8	4.0	2.8	3.6
3	3.8	2.8	2.2	2.6	2.2	7.4
8	10.0	4.8	7.4	4.2	6.2	5.4
3	4.0	-100.0	-100.0	-170.0	-100.0	6.2
4	4.8	2.5	3.0	2.8	3.0	11.4
4	4.6	3.4	-100.0	-170.0	-100.0	10.8
3	8.8	4.5	1.8	1.8	2.8	8.0
4	2.4	1.2	2.4	1.6	-100.0	10.2
3	4.2	2.5	1.4	4.0	-100.0	6.2
5	12.2	6.2	5.4	4.0	4.0	13.2
4	4.2	1.5	-100.0	-170.0	-100.0	10.4
3	7.4	3.4	4.2	3.8	4.8	7.6
2	4.8	2.4	3.2	2.4	2.2	5.6
3	2.6	1.5	1.4	1.5	-100.0	6.8
3	2.4	1.8	1.4	2.2	1.4	9.8
4	1.4	1.2	-100.0	-170.0	-100.0	10.6
4	2.8	1.2	1.6	2.3	-100.0	11.0
2	4.8	3.4	3.6	4.6	1.8	5.2
3	2.0	1.5	1.5	2.2	-100.0	6.6
6	1.6	1.3	-100.0	-170.0	-100.0	17.6
2	5.6	3.3	2.2	2.4	1.2	4.2
3	3.2	-100.0	-100.0	-170.0	-100.0	8.8



2	4.6	2.9	5.2	2.6	3.0	6.8
3	2.4	.8	-101.0	-110.0	-100.0	
3	3.6	5.4	3.5	2.3	3.0	7.0
3	3.4	3.3	2.9	2.8	-100.0	8.4
3	12.8	6.5	1.8	3.2	3.6	6.8
4	4.6	2.8	4.4	3.0	2.4	11.2
3	1.8	1.3	-102.0	-110.9	-100.0	8.6
2	3.2	2.4	2.2	2.3	1.8	5.2
3	2.6	1.4	3.2	2.2	1.2	7.1
1	13.6	3.5	3.6	3.2	6.2	2.8
2	5.2	2.4	3.6	4.2	3.8	22.4
2	5.4	4.4	3.1	3.4	3.8	5.8
3	6.1	2.1	1.8	3.4	4.4	7.6
7	3.0	2.1	2.2	1.4	-100.0	20.4
3	3.8	2.8	2.6	-110.9	-100.0	7.4
4	10.1	3.2	2.4	1.6	1.2	11.4

BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT= -.10098.67284

END PHASE I

LOG LIKELIHOOD AT START OF PHASE II= -77543.60236

LOG LIKELIHOOD= -58516.93218

PAR. NO	PAR. VALUE
1	10.20375
2	1.98521

OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 611 FROM LINE 74

COMBINATION OF A AND B

NO O IT UT O

F A RAY =

O. OF PARAMETERS=

O. OF SAMPLE POINTS= 765

O. OF ALTERNATIVES= 7

PSILON= .05000

LPHA= 3.84000
O. OF ITERATIONS= 50
ROGRAM SELECTION= 2

PARAMETER NO. 1
NITIAL VALUE= 1.0000
IN. ALLOWABLE VALUE= 1.00000

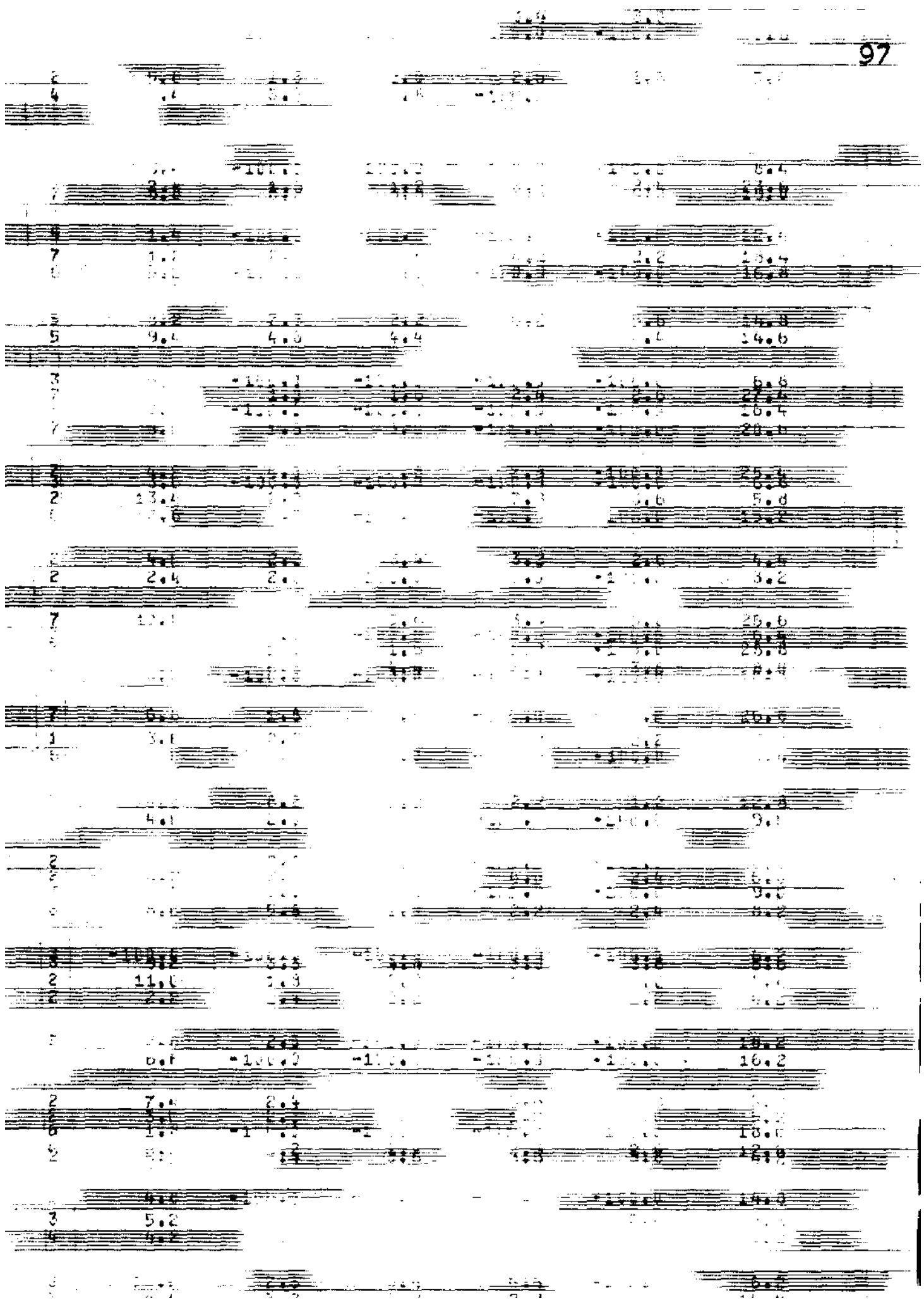
AXIMUM ALLOWABLE VALUE= 40.00000
ARAMETER INCREMENT= .1000

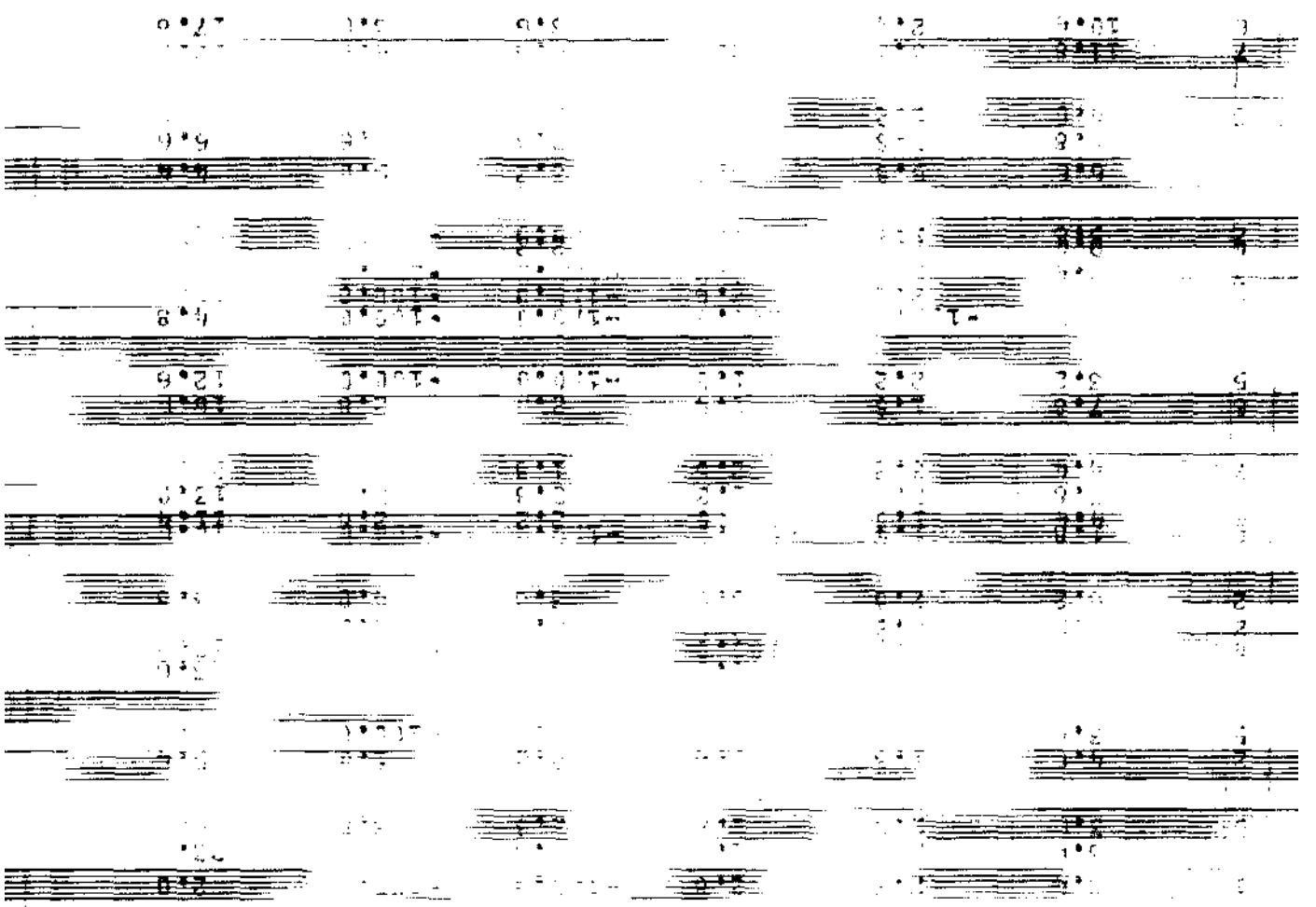
PARAMETER NO. 2
NITIAL VALUE= 2.7000
IN. ALLOWABLE VALUE= .20000

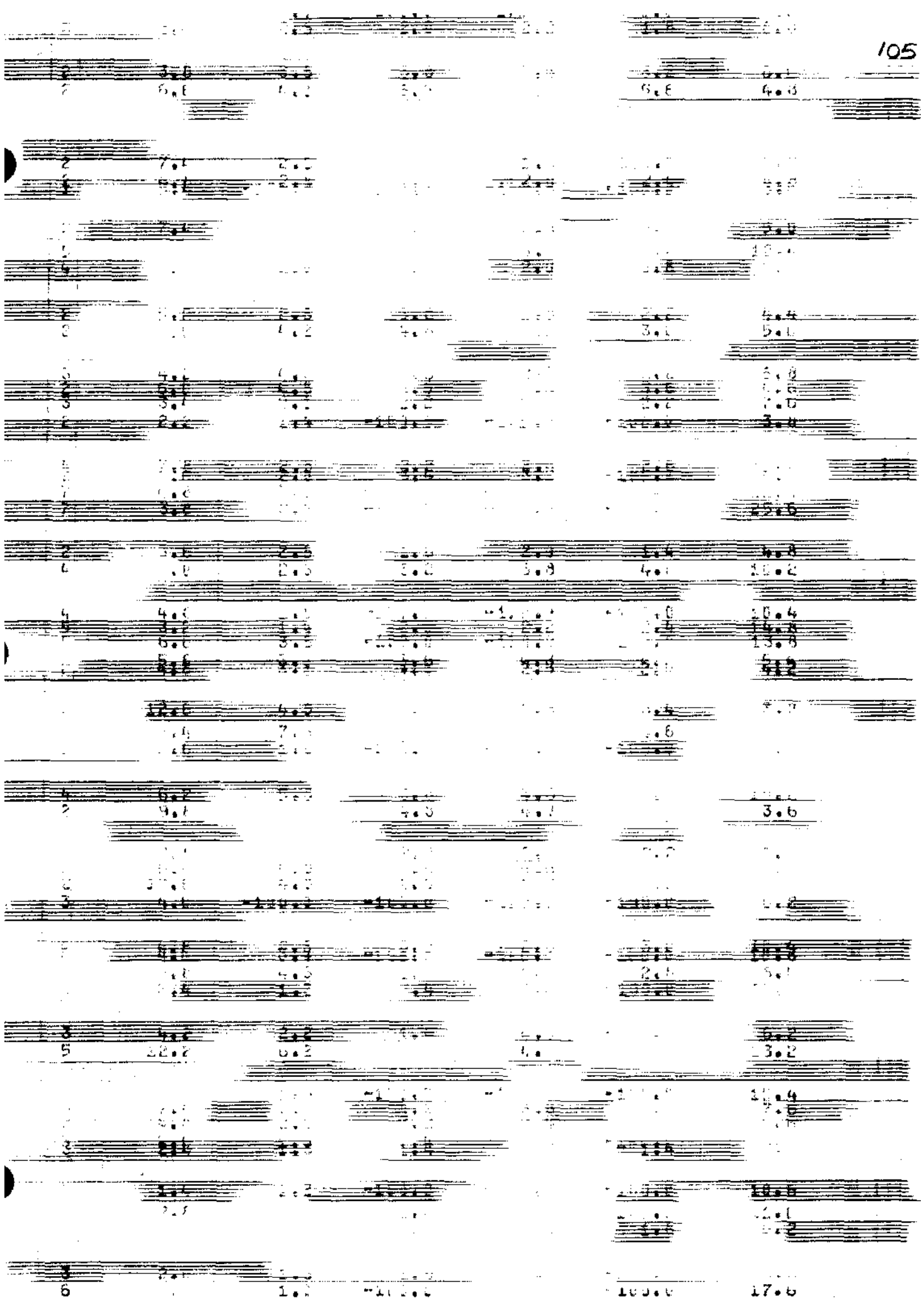
AXIMUM ALLOWABLE VALUE= 20.00000
ARAMETER INCREMENT= .10000

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2,...

3	4.4	2.3	1.6	2.3	1.2	7.4
6	-100.0	-1.0	-2.	-1.1	-2 .0	17.0
2	2.6	1.				1.
4	2.6	1.7	-100.0	-1.03	-200.0	9.2
1	3.1	0.3	1.3	1.1	0.1	2.4
3	4.6	1.8	-1.15	-1.019	-1.0015	1.12
1	3.1	3.2	-100.0	-1.03	-200.0	2.2
4	1.1	-1.1	-2.	-1.1	-2 .0	1.2
3	6.8	2.3	1.5	1.2	2.2	6.2
1	3.1	1.2	-100.0	-1.00	-200.0	1.6
4	1.0	1.2	-2.	-1.1	-2 .0	1.0







BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT= -1.1,1,0111

END PHASE 1

LOG LIKELIHOOD AT START OF PHASE 2= -1.1101.4111

LOG LIKELIHOOD= -1111.3111.

PAR. NO.	ESTIMATE
1	1.4[illegible]
2	1.71274

OPTIMUM REACHED.....END OF MINOR ITERATIONS IN LAST MAJOR ITERATION = 74

DELAY OF LESS THAN 5S.

NO. OF ATTRIBUTES= 3

O. OF PARAMETERS= 2
O. OF SAMPLE POINTS= 91
O. OF ALTERNATIVES= 4
PSILON= .05000
LPHA= 3.02000

O. OF ITERATIONS= 50
ROGRAM SELECTION= 0

PARAMETER NO. 1
NITIAL VALUE= 15.00000

IN. ALLOWABLE VALUE= .83000
AXIMUM ALLOWABLE VALUE= 40.00000
ARAMETER INCREMENT= .02000

PARAMETER NO. 2
NITIAL VALUE= 2.4
IN. ALLOWABLE VALUE= .21000

AXIMUM ALLOWABLE VALUE= 10.00000
ARAMETER INCREMENT= .01000

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2,...
3 1.0 -100.0 10.2
1 1.6 -102.2 3.4

4 -100.6 -100.0 25.4
1 .4 -100.0 3.2
2 1.2 -101.2 5.8

4 -100.6 -100.0 16.4
2 1.6 -100.0 9.8

```
 4      -100.1      -100.1        15.4
 2         1.4      -100.1         9.6

 1          .8         1.2         3.6
 2          .8      -100.1         5.6

 2         1.0      -100.1         9.4
 1         1.8          .8         4.4
 1         1.4         1.8         3.6
 4      -100.1      -100.1        17.4

 3         3.6      -100.1        11.6
 4      -100.0      -100.1        23.2
 2         3.4      -100.1         8.0

 2          .8      -100.1         7.2
 1         1.6      -100.1         4.8

 3         1.8         1.2        10.8
 3         1.6         1.4        11.6

 4      -100.0      -100.1        17.8
 3         4.0      -100.1        13.6
 3         1.4          .8        10.8

 2         4.0      -100.1         6.0
 4      -100.0      -100.1        15.4

 1         1.0          .8         3.8
 1         1.4         2.5         3.2
 4         1.6      -100.1        13.6
 3      -100.1      -100.1        12.2

 2         1.6      -100.1         5.0
 1          .8         2.5         4.4
 4          .8      -100.1        61.2

 1         1.8         1.8         4.2
 2         1.0      -100.1         7.8

 2         1.4      -100.1         9.5
 2          .6      -100.1         5.6
 2         2.2      -100.1         7.4
BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT=          -5159.3144
```

ITERATION 1

LOG LIKELIHOOD= -3680.15557

PAR. NO. PAR. VALUE

1 2.98475

2 3.85240

OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 700 FROM LINE 56

END PHASE I

LOG LIKELIHOOD AT START OF PHASE II= -13785.77782

OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 600 FROM LINE 74

O. OF SAMPLE POINTS= 209
O. OF ALTERNATIVES= 5
PSILON= .05000

DELAY OF 5.15 – 10.05.

LP IA= 3.00000

O. OF ITERATIONS= 50
RO GRAM SELECTION= 0

PA AMETER NO. 1
NITIAL VALUE= 15.00000
IN. ALLOWABLE VALUE= .01000
AX IMUM ALLOWABLE VALUE= 40.00000
AR AMETER INCREMENT= .01000

PARAMETER NO. 2

NITIAL VALUE= 2.50000
IN. ALLOWABLE VALUE= .50000
AX IMUM ALLOWABLE VALUE= 10.00000
AR AMETER INCREMENT= .10000

SA MPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2...

2	12.2	.8	-100.0	6.6
1	3.6	1.2	-100.0	1.6
1	2.4	2.2	-100.0	3.0
2	2.4	1.2	-100.0	5.3
4	5.8	.6	-100.0	17.2
4	5.6	2.2	-100.0	15.4
3	1.2	1.2	-100.0	13.3
3	4.6	3.8	2.2	12.3
1	4.4	1.8	-100.0	3.2
1	4.8	.8	-100.0	4.6
1	2.4	2.2	2.2	5.0
1	4.6	-100.0	-100.0	4.8
2	2.8	1.4	-100.0	6.4
2	2.8	1.2	-100.0	3.2
1	6.6	2.2	-100.0	2.4
2	3.8	2.0	1.2	6.2
1	2.0	1.6		
2	3.2	.8	1.0	5.4
			.6	7.2
1	2.6	1.2	1.2	4.4
2	1.8	.8	-100.0	6.4
2	4.6	4.0	-100.0	8.8
1	2.8	2.4	1.2	2.0
1	4.8	1.2	-100.0	4.8
2	3.2	1.6	-100.0	8.2
1	4.8	1.6	-100.0	4.0

2	5.4	4.2	-[illegible]	5.0
5	4.0	3.3	.0	20.0
2	1.6	1.5	-[illegible]	9.6
1	4.8	3.6	-100.0	3.2
3	4.8	1.8	-[illegible]	.2.0
1	4.0	3.2	-[illegible]	3.4
1	6.6	3.3	-[illegible]	3.4
2	4.2	2.5	-[illegible]	5.4
3	7.2	-[illegible]	-[illegible]	12.8
2	3.6	-[illegible]	-[illegible]	20.0
2	2.8	1.2	-[illegible]	8.0
1	6.0	-[illegible]	-[illegible]	5.2
1	3.4	1.0	1.8	4.0
4	1.6	-[illegible]	-[illegible]	17.3
1	4.6	3.8	1.3	3.3
2	3.2	2.5	1.5	6.4
1	4.6	-[illegible]	-[illegible]	2.4
3	5.8	[illegible]	-[illegible]	[illegible]
3	5.4	2.3	.8	11.8
1	4.2	-[illegible]	-[illegible]	4.6
4	2.4	2.3	1.8	19.2
2	8.4	-[illegible]	-[illegible]	8.2
5	2.8	1.5	-[illegible]	23.6
4	5.2	-[illegible]	-[illegible]	16.8
2	5.8	-[illegible]	-[illegible]	6.8
5	4.4	1.5	1.5	27.4
4	3.8	-[illegible]	-[illegible]	16.4
1	2.4	2.0	-[illegible]	3.2
5	5.2	1.5	1.6	38.8
5	-[illegible]	-[illegible]	-[illegible]	26.8
2	4.0	2.0	1.2	9.0
1	4.0	2.5	-[illegible]	3.8
4	6.6	-[illegible]	-[illegible]	16.2
1	7.4	-[illegible]	-[illegible]	3.8
2	2.0	1.4	-[illegible]	5.2
3	4.8	-[illegible]	-[illegible]	14.8
2	5.2	-[illegible]	-[illegible]	8.8
4	3.0	1.0	.8	18.8
2	6.8	-[illegible]	-[illegible]	8.0
2	5.4	-[illegible]	-[illegible]	5.6
4	2.4	1.2	-[illegible]	18.4
3	3.6	1.8	.8	13.8
3	6.4	1.2	-[illegible]	10.2
4	1.8	1.5	1.0	16.2
1	2.4	-[illegible]	-[illegible]	5.0
3	6.4	-[illegible]	-[illegible]	10.2
2	4.8	4.6	-[illegible]	6.4
3	2.8	-[illegible]	-[illegible]	13.8

2	2.2	2.2	1.8	6.6
4	1.8	1.8	1.2	13.6
4	3.2	-100.0	-100.0	15.4
2	2.4	.8	-100.0	5.8
3	2.6	1.8	1.6	12.6
2	1.6	1.4	-100.0	7.6
3	4.0	2.4	1.0	13.0
4	1.0	-100.0	-100.0	16.2
2	1.4	-100.0	-100.0	6.6
3	3.4	1.2	-100.0	14.8
2	5.6	-100.0	-100.0	8.2
2	3.6	.8	-100.0	8.6
1	4.0	2.2	-100.0	4.2
2	5.0	2.0	-100.0	7.8
3	3.6	-100.0	-100.0	14.6
4	3.8	2.2	1.6	19.0
4	2.4	2.2	-100.0	18.2
2	3.6	2.2	-100.0	10.0
5	.8	-100.0	-100.0	12.0
1	4.0	.8	-100.0	3.2
1	6.4	-100.0	-100.0	3.8
2	2.2	2.2	1.4	10.0
1	1.8	1.4	-100.0	3.6
2	2.2	1.8	-100.0	7.4
2	2.6	2.4	-100.0	5.4
3	4.2	-100.0	-100.0	11.6
2	3.8	1.6	1.2	5.4
2	5.4	-100.0	-100.0	7.2
2	6.4	-100.0	-100.0	7.6
2	4.4	1.8	1.4	6.2
5	7.0	-100.0	-100.0	6.6
3	2.2	1.8	1.2	10.4
4	2.0	1.4	1.2	16.2
2	4.8	-100.0	-100.0	5.2
3	2.4	2.2	-100.0	19.6
5	2.8	1.4	-100.0	20.8
2	2.4	1.4	-100.0	9.0
2	3.2	1.8	-100.0	7.4
3	3.0	2.0	1.4	13.6
2	1.8	1.4	-100.0	10.0
2	2.4	2.2	1.6	6.8
1	5.6	1.2	1.0	4.0
3	2.0	-100.0	-100.0	12.8
4	3.8	-100.0	-100.0	18.6
2	2.4	1.6	1.4	7.0
2	2.6	.4	-100.0	9.8
4	3.6	-100.0	-100.0	19.0
2	2.2	1.8	1.6	8.6
3	4.0	2.0	-100.0	10.4
2	4.0	.8	-100.0	10.0

1	2.2	2.7	1.0	5.0
3	2.4	2.4	-100.0	12.4
1	4.2	2.2	-100.0	3.8
1	3.4	.5	-100.0	3.8
2	6.2	-100.0	-100.0	5.8
2	1.6	-100.0	-100.0	7.3
1	3.2	3.0	-100.0	4.8
4	4.2	2.3	-100.0	16.4
2	2.4	1.8	-100.0	6.4
2	5.0	-100.0	-100.0	9.6
2	4.4	-100.0	-100.0	7.4
3	.8	-100.0	-100.0	11.2
3	1.4	1.2	-100.0	12.2
2	3.2	2.8	-100.0	5.4
2	1.6	-100.0	-100.0	6.0
2	3.1	-100.0	-100.0	7.8
2	5.6	1.2	-100.0	7.2
2	2.4	2.2	1.0	6.8
2	3.2	1.5	-100.0	7.2
3	2.4	1.5	.6	10.8
2	1.8	1.5	-100.0	8.6
4	1.6	2.8	1.0	12.2
4	1.6	1.2	1.0	15.4
2	1.8	1.4	-100.0	7.4
3	6.4	-100.0	-100.0	18.8
2	4.6	-100.0	-100.0	7.0
1	4.0	1.1	-100.0	5.0
2	2.6	1.8	-100.0	7.0
2	5.6	1.2	-100.0	6.0
2	1.0	-100.0	-100.0	6.0
2	2.0	1.8	1.4	5.2

BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT= -4733.67967

ITERATION 1

LOG LIKELIHOOD= -4463.92402

PAR. NO.	PAR.VALUE.
1	18.71662
2	1.97551

```
  E        2
IT RATION

LOG LIKELIHOOD=     -4354.11954

PAR. NO.              PAR.VALUE
     1                  18.72214
     2                   2.35224

END PHASE I

LOG LIKELIHOOD AT START OF PHASE II=        -30055.72192
```

DELAY OF 10.1S- 15.0S

NO. OF ATTRIBUTES= 4

O. OF PARAMETERS= 2
O. OF SAMPLE POINTS= 91

O. OF ALTERNATIVES= 5
PSILON= .05000

LPHA= 3.00000

O. OF ITERATIONS= 25
ROGRAM SELECTION= 3
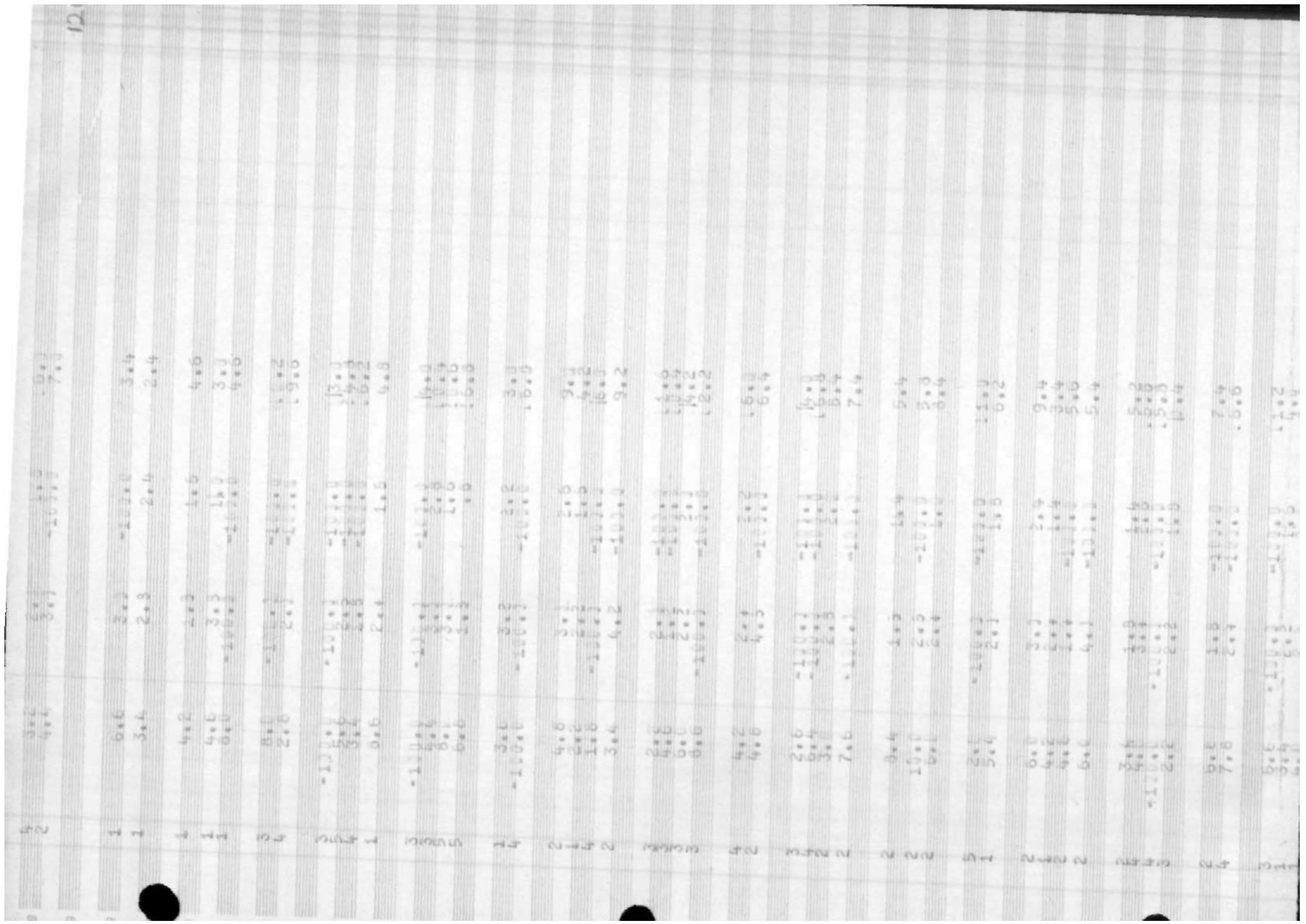
PARAMETER NO. 1
NITIAL VALUE= 15.00000
IN. ALLOWABLE VALUE= .02000
AXIMUM ALLOWABLE VALUE= 4.00000
ARAMETER INCREMENT= .22500

PARAMETER NO. 2

NITIAL VALUE= 1.9
IN. ALLOWABLE VALUE= .50000
AXIMUM ALLOWABLE VALUE= 11.00000
ARAMETER INCREMENT= .22500

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2...

2	4.4	2.8	2.6	7.4
1	3.0	2.2	2.0	5.2
2	2.8	.4	-100.0	9.2
3	5.6	2.3	.8	8.2
1	8.6	3.2	-100.0	2.2
5	3.6	1.2	-100.0	11.6
2	3.4	3.2	2.2	9.6
2	5.6	-100.0	-100.0	8.4
4	5.6	.3	-100.0	7.2
2	6.4	3.3	-100.0	6.2
2	2.2	1.4	.8	9.8
1	6.6	2.4	1.6	2.8
3	4.8	-100.0	-100.0	2.8
4	6.8	2.3	-100.0	10.6
1	4.6	2.3	2.4	3.4
1	3.4	2.2	1.8	4.4
1	7.6	1.2	.8	4.8
2	3.6	2.2	2.6	3.6
4	3.2	2.3	2.2	10.2
5	8.1	1.1	-100.0	11.2
3	9.1	4.2	-100.0	8.4
5	3.2	-100.0	-100.0	13.4
2	4.0	-100.0	-100.0	10.0
3	7.4	3.4	2.4	11.4



2	11.6	-2.[illegible]E+1	-1.[illegible]E+0	7.0
3	5.4	2.2	-12[illegible].2	13.2
4	11.1	3.2	-1[illegible].0	16.0
3	5.8	2.1	1.4	12.4
2	3.2	2.3	2.2	8.5
4	3.6	2.3	2.2	12.2
4	-103.1	-10[illegible].3	-10[illegible].3	17.0
3	4.2	3.3	-1[illegible].8	14.8
3	9.1	2.2	-10[illegible].0	12.4
3	3.4	2.3	[illegible].3	12.4
2	4.4	3.2	2.2	10.2
2	6.6	2.1	-1[illegible].0	9.2
1	8.4	2.3	2.2	2.0
5	3.4	2.3	2.2	13.0
4	3.8	2.3	1.4	15.6

BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT= -7116.53491

15- DELAY OF 15.1-20.0S

NO. OF ATTRIBUTES= 4
O. OF PARAMETERS= 2
O. OF SAMPLE POINTS= 61

O. OF ALTERNATIVES= 5
PSILON= .05000

LPHA= 3.00000
O. OF ITERATIONS= 50
ROGRAM SELECTION= 0
PARAMETER NO. 1
NITIAL VALUE= 15.03330

IN. ALLOWABLE VALUE= .00000
AXIMUM ALLOWABLE VALUE= 45.00000
ARAMETER INCREMENT= .01000

PARAMETER NO. 2
NITIAL VALUE= 1.8
IN. ALLOWABLE VALUE= .00000
AXIMUM ALLOWABLE VALUE= 11.00000
ARAMETER INCREMENT= .01000
SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2...

2	4.6	2.2	1.6	5.4
3	3.2	2.2	1.0	12.6
1	10.2	-100.0	-100.0	4.3
3	2.4	2.4	2.2	11.4
3	3.4	2.3	-100.0	10.3
2	4.0	2.2	1.2	6.4
3	2.4	2.2	1.6	14.6
3	6.4	2.2	-100.0	14.0
2	6.6	4.4	1.2	7.2
3	7.0	1.5	-100.0	10.4
5	4.2	3.2	2.4	23.4
3	6.2	-100.2	-100.0	11.2
2	10.6	1.2	.6	7.2
2	6.6	2.8	.8	6.4
2	4.4	3.2	1.2	8.6
5	4.8	3.2	-100.0	22.0
5	-100.0	-100.0	-100.0	26.0
3	6.6	1.3	1.8	12.0
3	7.0	3.2	1.0	14.6
4	8.6	-100.2	-100.0	16.3
1	2.8	2.3	2.0	3.6
4	10.0	1.2	-100.0	15.2

```
 2          3.2          2.7        -100.0          7.6
 3          6.2          2.1          1.5          10.4

 5       -100.0       -100.1       -100.0          11.8
 6          4.8          3.9       -100.0          12.4
 1          3.6          2.5          2.0           4.3
 3          3.2          2.3          1.4          14.8
 3          6.1          3.5       -100.0          13.8

 4       -100.0       -100.1       -100.0          10.8
 3       -100.0       -100.0       -100.0          11.6
 2          4.2          4.1          2.2           6.2

 2          2.4          2.2          1.8           9.0
 3          2.8          2.5          1.6          11.0

 4          1.6          1.2       -100.0          17.6
 3          7.0          1.4       -100.0          10.4
 5          3.6          1.8          1.4          12.4
 2          4.2          3.5          2.4           6.4

 2          9.0       -100.1       -100.0           9.4
 2          7.4          2.5       -100.0           5.2
 3          2.8          2.5          2.2          12.0
 1          6.0          1.4       -100.0           3.4

 3          3.8          3.3          2.8          12.0
 2          2.8          2.8          2.6           8.2

 1          3.0          2.1          1.8           5.6
 2          2.8          2.2          2.0           6.8
 1          3.0          2.3          1.8           4.2
 1          7.2          2.1          1.6           7.2
 1          5.6          2.3          1.4           8.2

 2          5.0          3.3          1.8           6.8
 2          3.4          3.1          2.0           8.4
 3         10.0       -100.1       -100.0          11.4

 2          3.0          2.3          2.2           6.8
 2          3.2          1.8          1.6           7.0

 2          8.6       -100.1       -100.0           5.4
 1          1.8          1.8          1.2           2.4
 1          3.6          3.2          2.2           3.2
 1          4.4          2.8          2.4           3.4

 1          5.4          2.5       -100.0           2.4
 3          6.6          5.4       -100.0          12.4
 4          3.8          2.1          1.4          18.6
BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT=          -6171.31469
ITERATION  1


LOG LIKELIHOOD=     -5920.91564
PAR. NO.          PAR.VALUE
 1                   18.31391

 2                   1.74628

END PHASE I
LOG LIKELIHOOD AT START OF PHASE II=          -12145.99921

OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 600 FROM LINE  74
ESTIMATED PARAMETER COVARIANCE MATRIX

AR. NOS.          COVARIANCE(APPROX.)          COVARIANCE(EXACT)
```

NO. OF ATTRIBUTES= 6

O. OF PARAMETERS= 2

O. OF SAMPLE POINTS= 104

O. OF ALTERNATIVES= 7

PSILON= .05000

LPHA= 3.
O. OF ITERATIONS= 50
ROGRAM SELECTION= 0

PARAMETER NO. 1
NITIAL VALUE= 9.00000
IN. ALLOWABLE VALUE= .80000

AXIMUM ALLOWABLE VALUE= 40.00000
ARAMETER INCREMENT= .21000

PARAMETER NO. 2
NITIAL VALUE= 1.7
IN. ALLOWABLE VALUE= .25000

AXIMUM ALLOWABLE VALUE= 10.00000
ARAMETER INCREMENT= .01000

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2,...

3	6.6	2.1	1.4	1.2	2.2	6.2
2	4.4	2.2	1.6	1.4	2.6	5.2

3	2.0	3.2	2.7	1.2	1.6	13.0
4	3.8	1.3	4.0	2.3	1.0	10.8
5	2.4	3.2	1.2	1.9	6.0	12.6
3	3.1	1.4	2.0	2.2	.8	7.4
3	6.0	1.4	3.4	2.3	1.4	9.0
2	7.2	4.4	3.0	-100.0	-100.0	6.8
2	2.4	7.2	2.8	1.8	2.2	5.6
3	6.1	6.4	4.6	2.2	-100.0	6.4
2	2.4	3.4	2.2	2.2	2.8	4.6
2	4.2	1.4	3.0	1.6	2.8	3.4
4	1.4	2.5	2.4	4.4	1.2	10.2
7	1.6	8.2	3.4	2.6	-100.0	28.6
5	.8	16.8	-100.0	-100.0	-100.0	18.5
3	8.6	5.5	1.8	-100.0	-100.0	8.2
7	2.8	2.2	3.6	2.2	-100.0	18.2
2	1.6	6.2	5.6	2.3	1.4	5.8
6	2.8	4.2	2.0	3.2	2.2	16.4
4	2.8	2.2	1.6	2.4	2.2	10.8
5	2.0	2.2	2.6	2.8	1.8	13.8
4	2.6	3.2	2.4	4.0	3.0	12.0
3	2.0	3.8	7.8	2.4	-100.0	7.8
2	1.4	1.5	1.2	3.4	2.4	6.0
4	1.2	6.2	3.2	2.2	1.8	17.2
7	2.1	1.2	3.4	2.6	2.0	21.0
7	2.4	3.2	3.8	2.0	2.6	18.2
3	6.2	1.4	2.8	1.6	1.4	7.2
6	3.4	1.8	2.1	2.2	-100.0	17.2
7	7.4	3.2	2.6	2.4	2.2	24.2
2	2.2	3.4	3.2	2.6	2.4	5.2
5	3.0	2.8	3.2	2.2	-100.0	12.4
2	6.6	1.6	1.6	4.2	1.8	4.4
4	6.2	3.8	2.5	2.2	2.4	16.8
2	6.6	1.8	1.6	1.2	2.4	3.0
5	2.2	1.8	3.0	3.0	1.8	15.0
7	3.2	2.2	5.2	1.8	-100.0	23.6
4	1.8	2.2	4.4	2.3	2.2	11.4
5	3.6	3.8	1.2	2.8	3.6	13.0
7	4.4	3.2	2.6	1.8	2.0	26.0
6	1.8	1.4	7.8	2.0	2.8	16.0
5	6.2	2.4	1.2	2.0	1.4	12.6
7	6.0	3.8	2.8	2.8	1.2	19.0
4	3.4	4.8	2.2	4.4	3.2	9.4
7	2.6	4.2	2.2	2.2	2.2	31.0
7	2.8	2.4	1.6	1.8	2.0	19.8
3	4.0	2.2	1.6	2.0	2.4	8.4
4	2.8	2.4	2.8	1.3	1.6	10.4
2	4.0	1.3	2.6	2.4	2.0	4.6
2	1.6	1.8	7.8	3.2	1.6	3.6
7	.6	.8	5.8	2.2	-100.0	23.0
3	2.2	2.4	1.8	2.0	2.8	6.2
4	1.8	2.5	2.8	6.4	1.6	13.8
2	10.0	1.2	1.4	1.3	-100.0	4.4
5	3.2	1.5	3.3	2.4	3.2	13.2
4	2.2	4.3	2.6	2.0	5.8	9.4

3	2.8	2.4	2.2	2.3	2.2	5.8
2	2.0	3.0	4.4	3.3	2.4	3.6
4	6.6	1.8	1.8	1.8	2.6	12.0
1	2.2	1.8	1.8	1.3	2.2	2.0
3	5.2	1.2	3.0	5.6	1.4	6.8
2	3.2	3.5	3.3	3.2	2.4	4.8
3	5.6	3.2	5.4	3.6	1.6	7.4
4	2.2	1.4	3.6	2.2	1.8	16.8
2	4.4	3.2	2.4	3.6	1.2	4.2
5	1.8	8.2	2.2	-110.0	-100.0	14.2
2	4.2	5.0	1.8	1.6	1.2	5.8
4	1.8	6.2	1.0	2.0	2.4	18.4
2	7.4	2.6	3.0	1.8	2.6	8.2
3	3.0	2.2	2.2	2.4	2.2	7.6
2	2.0	3.4	4.6	3.2	2.4	8.2
4	4.8	1.3	-1[illegible]	-1[illegible]	-100.0	15.4
3	2.4	3.5	2.0	4.2	2.6	6.4
3	5.0	2.2	4.2	4.8	-100.0	6.6
2	6.2	3.4	3.0	2.8	3.2	3.6
3	2.8	2.8	2.6	2.4	-100.0	6.2
7	1.4	6.2	3.4	2.0	2.2	25.0
5	3.6	5.4	1.8	2.6	2.2	12.2
3	2.4	2.8	3.0	1.2	1.8	6.6
5	5.2	2.4	3.2	2.2	1.6	12.2
2	5.4	6.8	1.8	-110.2	-100.0	6.0
5	6.6	2.8	1.8	2.8	1.6	7.4
2	1.6	5.2	5.6	2.6	3.4	4.8
4	4.2	1.8	1.2	1.6	3.6	9.4
2	5.2	1.4	1.2	2.2	2.4	5.2
1	1.8	4.2	2.6	4.4	2.2	2.2
3	2.6	2.2	4.8	3.4	2.2	8.2
2	1.6	2.4	1.8	3.0	3.6	13.8
2	2.0	4.2	2.2	1.8	2.4	5.4
3	2.2	4.2	1.8	3.2	2.8	6.8
7	2.6	6.2	3.8	-110.2	-100.2	28.4
2	3.8	3.6	2.4	1.2	1.2	4.4
5	3.0	2.2	1.2	2.2	2.2	12.8
3	4.6	1.4	3.4	4.6	2.2	8.6
2	4.4	1.8	1.6	1.6	1.8	3.4
5	1.6	2.4	3.2	4.2	1.4	14.4
4	6.6	5.4	-100.0	-110.0	-100.0	11.4
2	1.4	1.8	2.2	2.2	1.4	5.6
3	4.0	1.6	2.2	2.2	1.8	6.2
2	4.0	2.4	5.0	-110.0	-100.0	3.2
3	8.8	3.2	3.2	-110.2	-100.0	6.6
2	5.6	3.2	2.2	2.4	2.2	4.2

GIN OUTPUT

G LIKELIHOOD AT STARTING POINT= -749.85129

```
ITERATION  1

LOG LIKELIHOOD=      -611.89385

PAR. NO.              PAR.VALUE
      1                 9.85527
      2                 1.74216

END PHASE I
LOG LIKELIHOOD AT START OF PHASE II=          -7791.19564

OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 610 FROM LINE  74
```

DELAY OF 25.1 - 30.05

NO. OF 'TT RIBUTES= 6

O. OF PARAMETERS= 2

O. OF SAMPLE POINTS= 65

O. OF ALTERNATIVES= 7

PSILON= .05000

LPHA= 3.00000

O. OF ITERATIONS= 50
ROGRAM SELECTION= 0

PARAMETER NO. 1
NITIAL VALUE= 9.00000
IN. ALLOWABLE VALUE= .00001

AXIMUM ALLOWABLE VALUE= [illegible]
ARAMETER INCREMENT= .02000

PARAMETER NO. 2

NITIAL VALUE= 2.00000
IN. ALLOWABLE VALUE= .20001

AXIMUM ALLOWABLE VALUE= 17.00000
ARAMETER INCREMENT= .01000

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2...

1	2.8	5.6	3.6	4.2	4.6	2.2
2	2.4	3.4	2.0	3.0	2.0	4.8
1	2.6	3.4	1.8	7.6	2.2	2.4
7	1.0	.8	5.8	5.4	4.4	24.2
5	6.4	8.3	1.0	2.8	2.0	14.8
4	4.8	3.6	2.4	2.5	2.6	11.6
2	3.8	2.4	1.8	1.6	2.4	4.2
2	6.6	2.2	2.2	3.4	1.8	5.2
3	2.2	18.8	4.2	18.8	-100.2	12.8
5	3.0	1.8	2.0	5.8	6.2	12.2
5	6.4	5.6	2.8	4.7	-100.0	12.4
4	4.2	2.0	1.2	1.6	4.4	11.6
6	11.2	1.4	1.8	2.8	1.4	17.4
7	2.6	3.2	3.8	1.6	6.2	20.2
5	1.8	6.4	2.4	2.6	2.2	12.2
3	1.4	1.0	5.2	5.8	3.8	7.0
6	2.4	2.4	2.2			

6	3.0	2.3	5.0	2.4	6.8	16.4
3	7.6	14.2	2.0	-100.0	-100.0	8.8
6	2.0	2.2	5.0	3.8	2.2	16.8
2	.8	1.5	3.8	9.4	1.6	3.8
5	4.2	3.8	2.6	2.2	2.6	8.4
7	3.6	2.5	3.2	3.2	2.8	19.2
2	2.6	3.8	2.6	1.8	-100.6	25.8
7	5.8	4.6	4.2	4.8	5.8	19.8
1	10.8	4.8	3.6	-120.0	-100.0	3.0
2	4.6	6.4	10.8	1.2	1.4	4.6
3	2.4	2.8	2.0	4.6	1.8	7.4
2	2.4	2.2	5.4	2.4	1.6	3.4
3	2.0	3.8	3.8	2.0	3.2	8.2
3	2.6	1.4	4.8	2.4	5.8	6.4
2	5.4	5.4	1.6	8.0	-100.0	5.8
4	7.2	3.2	2.0	2.2	2.4	11.2
2	3.6	2.2	2.4	2.0	3.4	4.8
3	2.8	8.0	4.8	4.0	3.8	7.0
3	2.4	1.8	5.0	3.8	3.4	6.6
2	4.8	3.5	3.4	1.2	1.6	5.8
1	4.2	3.5	2.8	5.3	2.8	1.4
2	3.6	11.2	1.8	1.2	1.4	3.2
2	6.6	3.6	5.4	3.2	-100.0	5.4
3	2.1	2.2	2.4	1.3	2.2	8.8
2	2.8	2.3	2.4	4.3	1.6	4.8
4	3.8	3.3	3.8	3.3	3.6	8.4
2	4.8	9.2	3.8	2.3	2.6	8.4
3	3.6	2.3	2.2	2.3	4.2	10.2
4	7.8	2.8	2.4	2.3	2.2	10.2
2	2.4	4.8	3.2	2.2	2.4	5.6
2	3.4	4.8	3.6	4.6	1.8	5.2
5	3.6	4.5	3.6	1.4	1.2	14.0
3	1.6	3.3	5.2	2.8	2.2	9.0
2	7.6	7.4	3.6	-100.0	-100.0	5.4
3	3.6	3.1	3.8	3.2	3.4	8.4
5	4.8	2.3	3.6	2.4	6.8	13.2
5	2.2	1.6	3.0	3.4	5.2	14.8
4	4.2	2.2	4.2	2.3	2.2	10.4
2	12.1	2.5	1.6	1.8	1.6	4.0
2	2.4	2.2	2.0	1.3	3.2	5.2
4	3.4	2.4	3.4	1.3	2.2	11.2
3	9.4	4.8	2.0	2.4	-100.0	6.6
2	2.1	3.2	2.2	7.2	3.2	5.0
4	1.6	2.2	2.3	2.0	3.0	10.0
3	3.4	2.3	2.8	3.3	3.0	7.4
2	2.8	2.2	3.8	5.4	2.6	3.6

BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT= -107.98647

ENT PHASE

IQ AT START OF PH

1.02651

NO. OF ATTRIBUTES= 6

O. OF PARAMETERS= 2

O. OF SIMPLE POINTS= 75
O. OF ALTERNATIVES= 7

PSILON= .05000

LPHA= 3.00000

O. OF ITERATIONS= 50
ROGRAM SELECTION= 1

PARAMETER NO. 1

NITIAL VALUE= 15.00000
IN. ALLOWABLE VALUE= .80000
AXIMUM ALLOWABLE VALUE= 50.00000

ARAMETER INCREMENT= .01000

PARAMETER NO. 2
NITIAL VALUE= 1.60000
IN. ALLOWABLE VALUE= .20000
AXIMUM ALLOWABLE VALUE= 12.00000

ARAMETER INCREMENT= .01500

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2,...

3	3.4	4.4	7.2	3.0	4.0	8.2
1	3.6	2.6	2.8	3.6	3.0	2.4
3	2.8	5.2	2.0	2.4	9.0	7.0
4	4.0	2.4	1.2	1.8	10.0	9.6
2	8.2	4.6	3.8	2.4	2.2	3.4
2	3.8	2.8	2.0	2.6	1.8	3.2
2	4.8	6.8	2.4	2.2	3.4	6.0
2	7.2	4.2	5.2	4.8	2.4	4.8

```
      7        2.0        2.2        2.0        2.0        2.0       32.6
      2        7.4        1.5        8.0        2.0        2.2        5.6
      7        2.8        3.0        2.8        2.2        4.0       18.6


      2        1.2       18.5        4.6        4.4        3.0        4.4
      5        4.6        7.8        3.4        2.4        2.2       14.4

      2        2.2        2.2        4.4        5.6        2.4        5.2
      3        3.2        5.2        5.4        2.8        2.2        8.0

      7        2.8        2.2        2.4        5.2        3.8       29.2
      6        2.2        4.0        7.4        5.6        2.4       16.0
      5        7.2        3.6        2.4        2.2        2.8       13.8
      6        2.8        2.4        3.2        2.6        2.4       17.6

      4        4.8        2.4        3.6        2.8        3.6       10.2
      4        2.6        4.2        2.4        4.0        5.6       18.0
      4        5.4        3.0        2.4        6.0        2.4        9.6

      3        2.8        5.6        3.2        4.8        6.8        7.2
      2        4.8        2.8        3.0        3.8        3.0        6.0

      2        2.6        3.0        2.8        2.8        3.4        3.6
 BEGIN OUTPUT


 LOG LIKELIHOOD AT STARTING POINT=          -237.40632

 END PHASE I


 LOG LIKELIHOOD AT START OF PHASE II=          -1061.36905

 ITERATION  1
 OG LIKELIHOOD=     -932.61746
 AR.NO           PAR.VALUE
    2              2.96458

 OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 600 FROM LINE  74
```

DELAY OF 35.1 - 40.0S

```
NO. OF ATTRIBUTES=     6

O. OF PARAMETERS=      2
O. OF SAMPLE POINTS=    48

O. OF ALTERNATIVES=     7
PSILON=     .05000




LPHA=    3.00000

O. OF ITERATIONS=     5
ROGRAM SELECTION=     0

PARAMETER NO.  1
NITIAL VALUE=   15.00000
IN. ALLOWABLE VALUE=      .50000

AXIMUM ALLOWABLE VALUE=   21.00000
ARAMETER INCREMENT=       .01000

PARAMETER NO.  2

NITIAL VALUE=    1.80000
IN. ALLOWABLE VALUE=      .20000

AXIMUM ALLOWABLE VALUE=   10.00000
ARAMETER INCREMENT=       .01000

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2,...

     2        3.0        2.1        3.0        2.0        6.0        3.4
     5        6.4        5.5        2.6        5.0        7.4        4.8
     3        2.6        2.4        5.0        2.8        6.6        8.8
     2        3.8        3.8        3.4        3.2        3.2        6.0

     2        2.8        7.4        4.0        2.4        3.0        5.0
     5        2.8        6.2        2.4        2.8        3.0       12.4

     2        4.2        7.2        3.2        3.0        4.6        5.0
     2        3.6        2.6        3.6        4.4        6.0        4.6
     4        4.0        3.4        2.6        4.0        3.8       10.2
     2        3.6        4.8        4.2        3.8        5.8        5.4

     2        3.0        4.2        4.8        2.8        2.4        4.2

     2        2.4        9.8        4.8        4.2        2.8        3.6
     2        2.6        3.2        3.0        4.8        2.8        4.0

     3        8.8        1.6        1.8        2.8        4.8        8.0
     3        4.2        3.8        4.8        7.4        3.0        7.6

     6        5.4        4.2        2.6        4.2        4.6       16.8
     2        3.6        6.2        3.0        6.6        6.4        3.4
     3        2.2        3.2        4.0        3.6        2.8        8.8
     2        4.4        6.6        2.8        3.8        3.2        3.8

     6        3.4        5.2        2.8        5.0        6.8       14.8
     2        6.0        3.2        3.6        2.4        9.0        4.4
```

2	5.2	6.3	3.4	6.4	3.2	6.8
7	3.4	8.4	2.4	3.8	2.6	22.8
4	5.0	2.8	3.0	3.8	2.6	9.2
3	4.2	4.3	3.8	4.0	4.2	6.4
2	3.8	3.0	3.8	4.3	2.6	4.8
3	2.6	3.8	5.2	7.2	1.8	8.8
3	2.4	4.2	4.4	2.4	5.4	7.8
3	3.1	5.3	4.2	2.0	2.1	6.2
6	8.6	4.4	2.0	4.3	3.8	15.8
3	3.6	4.2	1.6	2.4	2.2	8.0
3	3.4	2.1	3.2	2.6	4.6	9.0
2	5.0	3.2	3.3	3.2	2.6	4.0
2	10.2	2.4	2.6	2.0	4.8	4.8
5	3.8	2.8	2.6	8.8	2.8	12.4
2	2.2	2.3	2.2	3.4	3.6	3.8
2	4.2	2.3	4.2	2.8	3.6	3.8
3	3.6	9.3	2.8	3.0	5.2	7.0
4	4.4	3.0	2.4	2.8	4.6	11.2
2	4.6	3.0	3.4	5.4	3.8	5.8
3	6.1	2.1	1.8	3.4	4.4	7.6
3	2.8	3.8	2.6	-110.0	-100.0	7.4
4	7.4	2.2	3.6	3.2	2.6	9.2
4	4.1	5.2	2.6	6.4	-100.0	9.2
7	3.1	1.4	3.0	9.4	2.6	23.2
5	6.2	1.3	2.3	8.9	2.6	13.2
4	4.0	6.2	3.6	4.2	4.0	9.8

BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT= -1105.52826

END PHASE I

LOG LIKELIHOOD AT START OF PHASE II= -2799.38176

ITERATION 1
OG LIKELIHOOD= -1827.30574
AR.NO PAR.VALUE
1 8.29561

2 1.71943

OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 620 FROM LINE 74

O. OF PARAMETERS= 2
O. OF SAMPLE POINTS= 42

O. OF ALTERNATIVES= 8 DELAY OF 40.1-60.0S
PSILON= .05000

LPHA= 3.00000

O. OF ITERATIONS= 5
ROGRAM SELECTION= 3

PARAMETER NO. 1
NITIAL VALUE= 20.01000
IN. ALLOWABLE VALUE= .00000

AXIMUM ALLOWABLE VALUE= 60.00000
ARAMETER INCREMENT= .10000

PARAMETER NO. 2
NITIAL VALUE= 1.50000

IN. ALLOWABLE VALUE= .20000
AXIMUM ALLOWABLE VALUE= 15.00000
ARAMETER INCREMENT= .01000

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2...

1	9.0	3.0	3.6	3.6	2.8	4.8	2.4
2	7.6	4.5	5.8	6.2	4.4	4.4	4.6
7	3.6	5.5	4.0	6.2	4.2	4.4	14.4
2	7.8	8.2	6.2	2.2	1.6	5.6	4.6
7	9.4	4.3	4.4	7.4	4.2	4.4	14.6
5	12.4	4.2	8.2	3.6	5.2	8.6	11.2
6	6.8	2.0	3.0	6.4	2.8	2.4	12.4
3	6.0	1.5	3.8	6.0	4.2	5.4	6.4
3	8.0	2.8	3.8	3.0	11.2	3.2	6.2
2	10.2	6.2	3.0	4.2	6.8	3.2	4.2
3	3.8	4.3	3.4	3.6	3.8	11.8	6.6
8	10.4	1.4	5.0	3.6	3.8	2.4	17.8
5	3.0	3.2	5.4	2.8	3.8	3.2	18.4
8	8.1	2.3	15.4	3.2	3.4	-100.0	20.4
7	2.4	3.1	3.6	2.2	2.4	3.1	15.4
3	15.4	11.4	4.2	1.8	2.4	-100.0	7.8
4	8.8	4.5	5.8	3.6	4.8	8.6	9.2
8	6.4	8.1	4.4	6.4	3.8	14.0	23.4
7	3.8	3.4	4.4	5.0	3.4	4.4	15.2
2	3.8	7.2	7.4	4.6	3.6	4.4	3.4
5	6.8	5.2	3.6	7.6	4.4	3.4	11.6
2	2.6	7.2	4.8	2.8	2.4	2.8	4.2
2	4.0	2.8	4.4	5.6	6.8	6.6	4.8
1	7.6	8.4	3.2	3.4	4.6	-100.0	3.8

2	4.8	3.5	5.3	4.6	3.8	3.8	5.
6	6.2	12.2	5.4	4.3	4.0	2.6	13.
4	7.6	3.5	3.3	2.9	3.2	3.2	8.
6	4.8	11.4	3.0	3.6	3.8	3.0	16.
4	4.4	3.2	3.3	2.2	3.4	6.0	9.
2	8.6	4.2	5.2	3.4	3.0	2.8	5.
4	11.0	5.5	4.3	6.0	3.4	4.4	3.
8	3.4	3.7	3.6	3.0	2.2	2.2	33.
3	11.4	5.2	4.8	2.6	2.6	3.4	7.
2	7.8	6.4	7.6	4.4	2.8	2.8	5.
1	3.6	2.2	3.2	6.2	3.6	13.6	2.
8	6.2	2.4	5.6	2.3	3.0	4.2	22.
5	5.0	3.8	4.4	2.3	2.4	4.4	11.
3	4.6	3.4	3.2	3.6	4.0	3.4	6.
4	5.4	2.6	4.6	6.4	7.4	8.0	8.
4	5.6	3.1	3.6	2.4	3.2	4.0	8.
1	2.8	6.3	3.0	3.3	3.6	3.8	3.

BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT= -2083.83351

END PHASE I

LOG LIKELIHOOD AT START OF PHASE II= -4551.15571

ITERATION= 1
LOG LIKELIHOOD= -3284.53225
PAR.NO PAR.VALUE
1 8.75124
2 1.26012

OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 690 FROM LINE 74

ESTIMATED PARAMETER COVARIANCE MATRIX

DELAY OF GREATER THAN 60S

NO. OF ATTRIBUTES= 7

O. OF PARAMETERS= 2

O. OF SAMPLE POINTS= 15

O. OF ALTERNATIVES= 6

PSILON= .05000

LPHA= 3.

O. OF ITERATIONS= 5

ROGRAM SELECTION= 0

PARAMETER NO. 1

PARAMETER NO. 2

SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2,...

2	3.2	3.3	12.4	6.6	7.2	8.0	4.2
3	5.2	4.2	4.6	3.3	2.8	3.8	5.4
6	6.4	6.3	2.8	4.0	3.6	14.0	43.4
4	4.4	4.3	2.2	4.4	4.8	6.0	9.5

3	3.4	3.1	3.6	7.2	3.4	5.1	7.2
2	12.6	4.3	3.5	4.3	4.4	6.2	3.3
3	10.1	4.4	4.8	4.2	6.2	4.2	5.4
1	10.0	6.2	3.4	3.8	5.2	3.6	2.4
6	5.4	6.1	3.5	8.4	6.4	5.1	12.2
5	4.0	3.5	4.8	6.4	4.4	5.4	10.4
2	7.4	3.8	3.8	6.4	5.6	3.6	4.4
7	4.8	6.2	7.0	8.8	6.3	3.6	15.8
2	3.8	3.4	2.6	3.0	5.1	4.6	5.2
1	4.6	4.3	4.2	4.9	5.8	4.2	2.4
3	4.8	4.4	7.6	6.5	8.6	4.2	7.1

BEGIN OUTPUT

LOG LIKELIHOOD AT STARTING POINT= -449.77282

```
 ITERATION  1

 LOG LIKELIHOOD=      -104.66623

 PAR. NO.            PAR.VALUE

       1                2.32653
       2                1.64551

 END PHASE 1

 LOG LIKELIHOOD AT START OF PHASE II=          -104.66623

 OPTIMUM REACHED.....END EXECUTION BY TRANSFER TO LINE 611 FROM LINE  74
```

Appendix C

Listing of "Chomp" Computer Program.

```
      PROGRAM CHOMP(INPUT,OUTPUT)


C     MAIN PROGRAM
 1000 FORMAT(I10,7F10.5/8F10.5/5F10.5)
 1010 FORMAT(I10,7F10.5)
```

```
1020   FORMAT(I10,7F10.5/8F10.5)

3000   FORMAT(4F10.5)

4000   FORMAT(4I10,2F10.5,I10,2I3)

5000 IF(SAMPLE.GT.NSAM)PRINT,25,SAMPLE,NSAM,25,'EXECUTION BY TRANSFER TO LINE

9500 FORMAT(*0*,*END EXECUTION BY TRANSFER TO LINE*,I4,1X,*FROM LINE*,I

900    FORMAT(*1*,*ITERATION*,I3)

905    FORMAT(*0*,*LOG LIKELIHOOD=*,F15.5)

910    FORMAT(*0*,*PAR. NO.*,1OX,*PAR.VALUE*)

920    FORMAT(* *,I6,F22.5)

930 FORMAT(*SAMPLE*,I6,*OBSERVATIONS*,5X,*NUMBER OF VARIABLES=*,I2,/*CRITERION=*,F8.6
    2,/*ALPHA=*,F10.5,/*NO. OF ITERATIONS=*,I5,/*PROGRAM SELECTION=*,I5
    3)

950 FORMAT(/*VARIABLE*,I2,*INCLUDED*,5X,*NUMBER OF OBSERVATIONS=*,I6,5X,*VARIABLE
    2ER INCREMENT=*,F10.5)

960    FORMAT(*1*,*SAMPLE DATA=CHOICE,ATTRIBUTE 1,ATTRIBUTE 2,...*)
```

```
 970   FORMAT(* *,I5,12F13.5 / 8F11.5)
 975   FORMAT(*0*,*BEGIN OUTPUT*)
 980   FORMAT(*1*,*END PHASE I*)


 985 1HM,MGDVARIANCESPRECISION,PARAMETER COVARIANCE MATRIX*,/ *PAR. NOS.*,1
 986 1HM,MGDVARIANCESPRECISION,PARAMETER COVARIANCE MATRIX*,/ *PAR. NOS.*,1


 990   FORMAT(* *,I3,*,*,I2,F25.5,E25.5)
 991   FORMAT(* *,I3,*,*,I2,F25.5)

 996   FORMAT(*0*,*LOG LIKELIHOOD AT START OF PHASE=*,I2,F21.5)
       DIMENSION XINC(20),PAR(20),XMINPAR(20),XMXPAR(20),XLIK(20)

       DIMENSION D(20),PAR1(20),PAR2(20),PAR3(20),GJ(20),PARL(20)
       DIMENSION PARR(20),OPAR(20),OD(20),ICH(1000),T(20,1000),XHESS(20,2
      10)
       DIMENSION DER2(20,20)

       WE INITIALIZE EVERYTING AND XLIKE AT STARTING POINT


       K1=10
       K2=1
       K3=10

       READ 4000,NATTR,NPAR,NSAMP,IALT,EPSIL,ALPHA,NITERA,IO,IHESS
       IF(ID.EQ.2) CALL PRED(IALT)


       IF(ID.EQ.2)STOP
       ICOUNT=NITERA
       ICFP=0
       DO 2 K=1,NPAR

       D(K)=0
       DO 2 I=1,NPAR
       XHESS(I,K)=0
       IF(I.EQ.K) XHESS(I,K)=-1.

       CONTINUE
       DO 5 K=1,NSAMP

       IF(NATTR.NE.(7.OR.15))READ 1000,ICH(K),(T(J,K),J=1,NATTR)
```

```
      IF(NATTR.EQ.15) READ 1020,ICH(K),(T(J,K),J=L,NATTR)
2     CONTINUE


4

      DO 6 I=1,NPAR
      READ 3000,PAR(I),XMNPAR(I),XMXPAR(I),XINC(I)

      CONTINUE
      PRINT 7030,NATTR,NPAR,NSAMP,IALT,EPSIL,ALPHA,NITERA,ID
10

      DO 7035 I=1,NPAR
12    PRINT 7050,I,PAR(I),XMNPAR(I),XMXPAR(I),XINC(I)
  35  CONTINUE
14    PRINT 7060

16    DO 7065 K=1,NSAMP
      PRINT 7070,ICH(K),(T(J,K),J=1,NATTR)
18 365 CONTINUE

20    L=NSAMP/2
      DO 3 K=1,L,2
22

      TS=ICH(K)
24    ICH(K)=ICH(NSAMP-K)
      ICH(NSAMP-K)=ICS
26    DO 4 J=1,NATTR

28    TS=T(J,K)
      T(J,NSAMP-K)=TS
30    CONTINUE

      CONTINUE
34    L1=NSAMP/2

      L2=NSAMP/4
36    DO 12 K=1,L2,4
      ICS=ICH(K)
38    ICH(K)=ICH(L1-K)

40    ICH(L1-K)=ICS
      DO 13 J=1,NATTR
42    TS=T(J,K)

44    T(J,K)=T(J,L1-K)
      T(J,L1-K)=TS
46

  3   CONTINUE
48 2  CONTINUE
      DO 14 K=2,L2,4
50    ICS=ICH(K)

52    ICH(K)=ICH(L1+2-K)
      ICH(L1+2-K)=ICS
54    DO 15 J=1,NATTR

56    TS=T(J,K)
      T(J,K)=T(J,L1+2-K)


      T(J,L1+2-K)=TS
60  5 CONTINUE
  4   CONTINUE
62    PRINT 7075

64    NSTO=NSAMP
      NSAMP=AMAX0(NPAR*K2,NSAMP/K3)
```

```
      IF(NSAMP.GT.NSTO)NSAMP=NSTO

      NITERI=NITERA
      NITERA=K1



      IPRINT=0


      WE NOW COMPUTE THE GRADIENT D(1) AND THE COSINES CO(1) AT
      POINT PAR(I)

      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR,NPAR,XLIKE,NATTR)

      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR,XLIKE)
      IF(NITERI.NE.0) PRINT 7095,XLIKE

      IF(NITERI.EQ.0)PRINT 7096,XLIKE
      SSQ=0.
      DO 30 I=1,NPAR
      O(I)=D(I)

      I1=I-1

      IF(I1)20,20,10
      CONTINUE

      PAR(I1)=PAR(I1)-XINC(I1)
      PAR(I)=PAR(I)+XINC(I)

      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR,NPAR,XLIK(I),NATTR)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR,XLIK(I))
      D(I)=(XLIK(I)-XLIKE)/XINC(I)
      SSQ=SSQ+D(I)**D(I)

      PAR(NPAR)=PAR(NPAR)-XINC(NPAR)
      SQSSQ=SQRT(SSQ)
      DO 40 I=1,NPAR

      CO(I)=D(I)/SQSSQ
      IF(IDFP)9,9,8

      GO TO 49
      CALL DFP(XHESS,OD,O,OPAR,PAR,DD,NPAR)
      IDFP=1
      DO 51 I=1,NPAR

      OPAR(I)=PAR(I)
      WE INITIALIZE THE FIBBONACCI SEARCH BY BRACKETING
      FOR TWO GIVEN INCREMENTS XHO AND XHI WE COMPUTE PAR1,PAR2,PAR3

      ENSURING FEASIBILITY


      I45=1
      FIRST=0.
      IDIC=-1.
      XHOMAX=1.1E+30

      XHIMAX=1.1E+30
      XHO=EPSIL
      XHI=EPSIL*ALPHA

      CONTINUE
      DO 52 I=1,NPAR

      PAR1(I)=PAR(I)
```

```
      PAR2(I)=PAR1(I)+XHO*CD(I)
      IF(PAR2(I)-XMNPAR(I))45,45,42
   42 IF(XMXPAR(I)-PAR2(I))46,46,43


   43 PAR3(I)=PAR2(I)+XHI*CD(I)
      IF(PAR3(I)-XMNPAR(I))47,47,44

   44 IF(XMXPAR(I)-PAR3(I))48,48,50
   48 XHOMAX= AMIN1 (XHOMAX,(XMNPAR(I)-PAR1(I))/CD(I))

      GO TO 42
   46 XHOMAX= AMIN1 (XHOMAX,(XMXPAR(I)-PAR1(I))/CD(I))
      GO TO 43
   47 XHIMAX= AMIN1 (XHIMAX,(XMNPAR(I)-PAR2(I))/CD(I))
      GO TO 44

   50 XHIMAX=AMIN1(XHIMAX,(XMXPAR(I)-PAR2(I))/CD(I))
      GO TO 50
   45 CONTINUE

      IF(XHOMAX.GE.1.0E+30)GO TO 55
      INDIC=0

      XHO=(XHOMAX-.001)/(1.+ALPHA)
      XHI=XHO*ALPHA
      XHOMAX=1.0E+30
      IF(XHI)49,49,41

   49 CONTINUE

      IF(XHIMAX.GE.1.0E+30)GO TO 59
      INDIC=1

      XHI=XHIMAX-.001
      XHIMAX=1.0E+30
      IF(XHI)700,700,41

C     WE NOW CHECK IF THOSE THREE POINTS ARE SUITABLE FOR STARTING
C     THE FIBBONACCI SEARCH

   55 CONTINUE
      IF(INDIC)60,81,90
   60 CONTINUE

      IF(FIRST)70,70,71
   71 XLIK1=XLIKE

      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR2,NPAR,XLIK2,NATTR)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR2,XLIK2)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR3,NPAR,XLIK3,NATTR)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR3,XLIK3)

      IF(XLIK2-XLIK1)600,600,61
   61 CONTINUE
      IF(XLIK2-XLIK3)65,73,73

   70 XL=0
      XR=XHI+XHO

      XLTKL=XLIK1
      XLTKR=XLIK3
      NIT=2
      ZOLD=1

   80 NIT=NIT+1
      ZNUM=ZOLD+ZNEW
```

```
      ZOLD=ZNEW

      ZNEW=ZSUM
      IF((XR/EPSIL)-ZSUM)63,63,62



3     CONTINUE
      DO 64 I=1,NPAR

      PARL(I)=PAR1(I)
4     PARR(I)=PAR3(I)
      GO TO 501

5     CONTINUE
8     IF(I55)72,72,800

2     CONTINUE
      DO 65 I=1,NPAR
5     PAR(I)=PAR2(I)
      XHO=XHO+ALPHA

      XJOMAX=1.0E+30
      XHZUEX=1.0E+30
      IDIC=-1
      FIRST=2.

      I55=0
      XLIK1=XLIK2

      XLIK2=XLIK3
      GO TO 41
0     IWG=80
      GO TO 505

0     CONTINUE
      I55=1
      GO TO 60

91    IWG=490
      IWH=53

      GO TO 505

33    CALL FIBBO(XL,XR,XLIKL,XLIKR,NIT,NPAR,PARL,PARR,CO,XX,XXLIKX,NSAMP
     1,IALT,T,ICH,ID)

31    DO 711 I=1,NPAR
      PAR(I)=PAR1(I)+XX*CO(I)
      IPRINT=IPRINT+1
      PRINT 7060,IPRINT

      PRINT 7065,XXLIKX
      PRINT 7010

      DO 7115 I=1,NPAR
015   PRINT 7020,I,PAR(I)
      IF(NITERA.EQ.IPRINT)GO TO 777
02    XLIKE=XXLIKX

      GO TO 7

05    PRINT 5060,IWG,IWH
77    IF(NITERI.NE. )GO TO 778

      IF(IHESS.NE.0) CALL HESS(NPAR,XINC,PAR,NSAMP,IALT,T,ICH,NATTR,DEP2
     1,ID,XXLIKX)

      IF(IHESS.EQ.0) PRINT 7005
```

```
      IF(IHESS.NE.0) PRINT 7706
      DO 801 I=1,NPAR
      DO 802 J=1,I


      XHESS(I,J)=-XHESS(I,J)
      IF(IHESS.NE.0) PRINT 7091,I,J,XHESS(I,J),DER2(I,J)

      IF(IHESS.EQ.1) PRINT 7091,I,J,XHESS(I,J)
802   CONTINUE

801   CONTINUE
      STOP
778   NITERA=IPRINT + NITERI
      NITERI= 0

      NSAMP=NSTO
      PRINT 7080
      IEFP=0

      GO TO 11
610   IF(NITERI.EQ.0) GO TO 611

      NITERA=IPRINT+NITERI
      NITERI=0
      NSAMP=NSTO
      PRINT 7080

      GO TO 11
611   IG=600
601   IG=600
      IH=74

      GO TO 565
600   IG = 700

      IH=56
      GO TO 565
600   IF(NITERI.EQ.0) GO TO 634
      NITERA=IPRINT+NITERI

      NITERI=0
      NSAMP=NSTO
      PRINT 7080

      IEFP=0
      GO TO 11

634   IG=800
      IH=68
      PRINT 5050,IG,IH
      GO TO 777

      END
      SUBROUTINE FIBRO(XL,XR,XLIKL,XLIKR,NIT,NPAR,PARL,PARR,CD,XX,X
     1XLIKX,NSAMP,IALI,T,ICH,ID)
      THIS SUBROUTINE PERFORMS A ONE DIMENSIONAL FIBRONACCI SEARCH

      BY CALLING YLIKE NIT TIMES


      WE CALCULATE NIT + 4 FIBONACCI NUMBERS
      DIMENSION PARL(20),PARR(20),CD(20),T(1000),PARX1(20),PARX2(20)
      DIMENSION PARXX(20)
      DIMENSION T(25,1000),ICH(1399)

      F(1)=1
      F(2)=1
```

```
      NIT22=NIT+4

      DO 10 I=3,NIT22
      II=I-1



      F(I)=F(II)+F(I2)

      FIBBONACCI NUMBERS HAVE BEEN COMPUTED
      WE START BY COMPUTING X1,X2, AND THEIR LIKELIHOOD XLIKEX1 AND
      XLIKEX2

      K=1
      NIT1=NIT-1

      NIT2=NIT+1
      X1=XL+F(NIT1)*(XR-XL)/F(NIT2)
      X2=XL+F(NIT)*(XR-XL)/F(NIT2)
      DO 20 J=1,NPAR

      PARX1(J)=PARL(J)+(X1-XL)*CD(J)
      PARX2(J)=PARL(J)+(X2-XL)*CD(J)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PARX1,NPAR,XLIKX1,NATTR)

      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PARX1,XLIKX1)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PARX2,NPAR,XLIKX2,NATTR)

      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PARX2,XLIKX2)
      WE ARE DONE AND NOW MAKE SURE THAT THEIR VALUES ARE REASONABLE
      AND SIMULTANEOUSLY PERFORM THE INTERNAL REDUCTIONS



      DO 100 K=2,NIT1
      IF(XLIKX2.GT.XLIKX1)GO TO 40
      SINCE XLIKX1 IS LARGER WE REJECT THE RIGHT HAND SIDE

      X2=X2
      X2=X1

      NITK2=NIT-K+2
      NITK1=NIT-K+1
      NITK=NIT-K
      X1=XL+F(NITK)*(XR-XL)/F(NITK2)

      X1KR=XLIKX2
      XLIKX2=XLIKX1
      DO 30 I=1,NPAR

      PARR(I)=PARX2(I)
      PARX2(I)=PARX1(I)

      PARX1(I)=PARL(I)+(X1-XL)*CD(I)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PARX1,NPAR,XLIKX1,NATTR)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PARX1,XLIKX1)
      GO TO 100
      END OF THE CASE FOR LARGER XLIKX1

      WE NOW DO THE CASE FOR LARGER XLIKX2 AND REJECT THE LEFT
      HAND SIDE


   40 X1=X1
      X2=X2

      XLIKL=XLIKX1
```

```
      NITK2=NIT+K+2
      NITK1=NIT+K+1


      NITK=NIT+K
      XL=XL+F(NITK1)*(XR-XL)/F(NITK2)

      DO 50 I=1,NPAR
      PARL(I)=PARX1(I)

      PARX1(I)=PARX2(I)
   0  PARX2(I)=PARL(I)+(X2-XL)*GD(I)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PARX2,NPAR,XLIKX2,NATTP)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PARX2,XLIKX2)

  00  C ENTRANCE FOR THE CASE FOR LARGER XLIKX2
      X1=X2
      XLIKX1=XLIKX2

      DO 110 I=1,NPAR
  10  PARX1(I)=PARL(I)


      RETURN
      END
      SUBROUTINE DFP(XHESS,DD,D,DPAR,PAR,GD,NPAR)
     DIMENSION GXHESS(20,20),XHESS(20,20),DD(20),D(20),DPAR(20),PAR(20)

     1,XGAM(20),XPP(20),XGAMM(20,20),XNUM1(20,20),XHGAM(20),XNUM2(20,20)
     2,XPROD(20,20),GD(20)
      DEN1=0.


      DEN2=0.
      DO 10 I=1,NPAR


      XGAM(I)=D(I)-DD(I)
      XPP(I)=PAR(I)-DPAR(I)
   3  DEN1=DEN1+XPP(I)*XGAM(I)
      *** GAMMA, P AND DEN1 HAVE BEEN COMPUTED***
      DO 25 I=1,NPAR

      XHGAM(I)=0
      DO 13 J=1,NPAR
      GXHESS(I,J)=XHESS(I,J)
   3  XHGAM(I)=XHGAM(I)+GXHESS(I,J)*XGAM(J)

   5  CONTINUE
      DO 17 K=1,NPAR

   7  DEN2=DEN2+XHGAM(K)*XGAM(K)
      *** THE OLD HESSIAN HAS BEEN CREATED AND DEN2 COMPUTED ***
      DO 20 I=1,NPAR
      DO 19 J=1,NPAR

      XNUM1(I,J)=XPP(I)*XPP(J)
   9  XGAMM(I,J)=XGAM(I)*XGAM(J)
   9  CONTINUE

      *** XNUM1 HAS BEEN COMPUTED ***
      DO 27 I=1,NPAR

      DO 26 J=1,NPAR
      XPROD(I,J)=0
      DO 25 K=1,NPAR
   5  XPROD(I,J)=XPROD(I,J)+XGAMM(I,K)*GXHESS(K,J)
   6  CONTINUE

   7  CONTINUE
      DO 32 I=1,NPAR
      DO 32 J=1,NPAR
```

```
      DO 31 K=1,NPAR
1     XNUM2(I,J)=XNUM2(I,J)+OXHESS(I,K)*XPROD(K,J)



2     CONTINUE
3     CONTINUE

      *** XNUM2 HAS BEEN CALCULATED ***
      DO 50 I=1,NPAR
      O(I)=O(I)
      OPAR(I)=PAR(I)

      DO 45 J=1,NPAR
5     XHESS(I,J)=OXHESS(I,J)+XNUM1(I,J)/DEN1-XNUM2(I,J)/DEN2

0     CONTINUE
      ***THE NEW HESSIAN HAS BEEN OBTAINED
      SSQ=0
      DO 60 I=1,NPAR

      DO 55 J=1,NPAR
5     CO(I)=CO(I)-O(J)*XHESS(J,I)
0     SSQ=SSQ+CO(I)*CO(I)

      SQSSQ=SQRT(SSQ)
      DO 70 I=1,NPAR

0     CO(I)=CO(I)/SQSSQ
      *** THE NEW SEARCH DIRECTION HAS BEEN COMPUTED
      RETURN
      END

      SUBROUTINE YLIKE(NSAMP,IALT,T,ICH,PAR,NPAR,XLIKE,NATTR)
      DIMENSION T(20,1000),ICH(1000),PAR(20),E(20),V(20,20)
      XLIKE=0.

      DO 100 K=1,NSAMP
      CALL SPEC(T,PAR,K,E,V)

      ICIF=IALT-ICH(K)
      IF(ICIF)26,26,25
5     CONTINUE
      CALL ROTA(ICH,K,IALT,E,V)

6     CONTINUE
      CALL CLARK(IALT,E,V,P)
      IF(P)51,51,71
1     XLIKE=XLIKE+P

      GO TO 100
1     XLIKE=XLIKE-10.**4)

      GO TO 100
1     XLIKE=XLIKE+ALOG(P)
00    CONTINUE
      RETURN

      END
      SUBROUTINE CLARK(N,E,V,P)
      DIMENSION E(20),V(20,20),RO(20,20),C(20),VC(20,20)

      TWO=2.
      ITWO=2

      C=.39894228
```

```
      )
      ))
2
      )
      )
      )
```

```
      PAR=-XNUM/SQRT(XNUM)

      IF(PAR-8.64361)80,80,81
80    CALL MERFC(PAR,P)


      GO TO 82
81    P=.5+.5-.38938534*PAR**2*PAR/2.-ALOG(PAR)
82    CONTINUE

      RETURN
      END
      SUBROUTINE MERFC(Z,ERF)
      Q=Z

      IF(Q.LT.0.)Q=-Q
      P=.2316419

      B1=.31938153
      B2=-.356563782
      B3=1.78177937
      B4=-1.821255978

      B5=1.330274429

      PI=.39894228
      T=1./(1.+P*Q)

      ERF=((((((B5*T+B4)*T+B3)*T+B2)*T+B1)*T)*PI*EXP(-Q*Q/2.)
      IF(Z.LT.0.)ERF=1.-ERF

      RETURN
      END
      SUBROUTINE ROTA(ICH,K,IALT,E,V)
      DIMENSION E(20),V(20,20),ICH(1000)
      DO 10 J=1,IALT
      ES=E(J)
      E(J)=E(IALT)
      E(IALT)=ES
      DO 10 I=1,IALT

      VS=V(I,J)
      V(I,J)=V(I,IALT)

      V(I,IALT)=VS
10    CONTINUE
      DO 20 I=1,IALT
      VS=V(J,I)

      V(J,I)=V(IALT,I)
      V(IALT,I)=VS
20    CONTINUE
      RETURN

      END
      SUBROUTINE LOGIT(NSAMP,IALT,T,ICH,PAR,XLIKE)

      DIMENSION T(20,1000),ICH(1000),PAR(20),E(20),V(20,20)
      XLIKE=0
      DO 150 K=1,NSAMP
      CALL SPEC(T,PAR,K,E,V)

      XMAX=E(1)
      DO 140 I=1,IALT
      XMAX=AMAX1(E(I),XMAX)

      IF(XMAX.EQ.E(I))J=I
40    CONTINUE

      ICH(K)
```

```
      DO 160 I=1,IALT
60    SUM=SUM+EXP(E(I)-E(J))
      P=-ALOG(SUM)+E(L)-E(J)



      XLIKE=XLIKE+P
50    CONTINUE

      RETURN
      END

      SUBROUTINE HESS(NPAR,XINC,PAR,NSAMP,IALT,T,ICH,NATTR,DER2,ID,XXLI
     1KX)
      DIMENSION XINC(20),PAR(20),T(20,100),ICH(100),DER2(20,20)
      DIMENSION A(20,40)
      DO 61 I=1,NPAR

      PSTO=PAR(I)
      PAR(I)=PAR(I)+XINC(I)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR,NPAR,XLIK2,NATTR)

      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR,XLIK2)
      PAR(I)=PAR(I)-2.*XINC(I)

      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR,NPAR,XLIK3,NATTR)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR,XLIK3)
      PAR(I)=PSTO
      DER2(I,I)=(XLIK2-2.*XXLIKX+XLIK3)/(XINC(I)*XINC(I))

3     CONTINUE
      DO 81 I=2,NPAR
      K=I-1

      DO 82 J=1,K
      PSTO1=PAR(I)

      PSTO2=PAR(J)
      PAR(I)=PAR(I)+XINC(I)
      PAR(J)=PAR(J)+XINC(J)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR,XLIK1,NATTR)

      PAR(I)=PAR(I)-2.*XINC(I)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR,NPAR,XLIK2,NATTR)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR,XLIK2)
      PAR(I)=PAR(I)+2.*XINC(I)

      PAR(J)=PAR(I)-2.*XINC(J)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR,NPAR,XLIK3,NATTR)

      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR,XLIK3)
      PAR(I)=PAR(I)-2.*XINC(I)
      IF(ID.EQ.0) CALL YLIKE(NSAMP,IALT,T,ICH,PAR,NPAR,XLIK4,NATTR)
      IF(ID.NE.0) CALL LOGIT(NSAMP,IALT,T,ICH,PAR,XLIK4)

      PAR(I)=PSTO1

      PAR(J)=PSTO2
      DER2(I,J)=(XLIK1-XLIK2-XLIK3+XLIK4)/(4.*XINC(I)*XINC(J))

      DER2(J,I)=DER2(I,J)
2     CONTINUE

1     CONTINUE
      WE NOW INVERT THE NEGATIVE OF THE HESSIAN MATRIX
      DO 83 I=1,NPAR
      A(I,J)=DER2(I,J)

      A(I,J+NPAR)=0
      IF(I.EQ.J) A(I,J+NPAR)=1.
4     CONTINUE
```

```
3     CONTINUE

      K=2*NPAR
      DO 85 I=1,NPAR




      E=A(I,I)

      DO 86 J=1,K
6     A(I,J)=A(I,J)/E
      DO 87 L=1,NPAR

      IF(L.EQ.I) GO TO 87
      F=-A(L,I)

      DO 88 M=1,K
8     A(L,M)=A(L,M)+F*A(I,M)
7     CONTINUE
5     CONTINUE
      DO 89 I=1,NPAR

      DO 91 J=1,NPAR
      DER2(I,J)=A(I,J+NPAR)
1     CONTINUE

9     CONTINUE
      RETURN

      END
      SUBROUTINE PRED(IALT)
      DIMENSION E(20),V(20,20),EC(20),VC(20,20)
      FORMAT(8F10.5/8F10.5/4F10.5)
      FORMAT(* *,I6,F22.5)
      FORMAT(* *,I6,*,*,I2,F19.5)
      FORMAT(*1*,*ALTERNATIVE*,11X,*MEAN*)

      FORMAT(*0*,*PROBABILITY OF CHOICE*,I2,1X,*IS*,F10.8)
      FORMAT(*0*,*ALTERNATIVES*,9X,*COVARIANCE*)

      READ 1,(E(I),I=1,IALT)
      DO 70 I=1,IALT
0     READ 1,(V(I,J),J=1,IALT)
      PRINT 4
      DO 80 I=1,IALT

0     PRINT 2,I,E(I)
      PRINT 5
      DO 90 I=1,IALT
      DO 100 J=1,IALT

      PRINT 3,I,J,V(I,J)
00    CONTINUE

3     CONTINUE
      DO 10 I=1,IALT
0     EC(I)=E(I)
      DO 20 I=1,IALT

      DO 30 J=1,IALT
      VC(I,J)=V(I,J)
0     CONTINUE

0     CONTINUE
      DO 40 J=1,IALT
```

```
      E(IALT)=ES
      DO 15 I=2,IALT

      VS=V(I,J)
      V(I,J)=V(I,IALT)

      V(1,IALT)=VS
      DO 25 I=1,IALT

      VS=V(J,I)
      V(J,I)=V(IALT,I)
      V(IALT,I)=VS
      CONTINUE

      CALL CLARK(IALT,E,V,P)
      PRINT 5,J,P
      DO 71 K=1,IALT

      E(K)=EC(K)
      DO 72 K=1,IALT

      DO 72 L=1,IALT
      V(K,L)=VC(K,L)
      CONTINUE
      RETURN

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