ELECTRICAL ENERGY INTERRUPTION COST ASSESSMENT - A CASE STUDY FOR DOMESTIC CONSUMERS

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF ENGINEERING

in

HYDRO ELECTRIC SYSTEM ENGINEERING & MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the dissertation, **"Electrical Energy Interruption Cost Assessment–A Case Study for Domestic Consumers"** being submitted in partial fulfillment of the requirement for the award of degree of **Master of Engineering** in **Hydro Electric system Engineering and Management** at Water Resources Development Training Center , University of Roorkee, is an authentic record of my own work carried out period from July 16,1999 to March 2000 under the supervision of Prof. Devadutta Das, Director , WRDTC and Dr N.P.Padhy, Department of Electrical Engineering, University of Roorkee, Roorkee.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree or diploma.

Dated : 15-3-2000

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It is certified that the above statement made by the candidate is correct to the best of my knowledge.

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LIST OF SYMBOLS

C = Capacity in MW of generating units

Di = Duration in hours of load loss event i

di = Duration of outage in hours.

d_k = The duration in hours of the load curtailed due to an outage.

D_R = Departure rate

elc = Expected load curtailment

eens = Expected energy not supplied

edlc = Expected duration of load curtailment.

F(G) = Frequency of outage.

fi = Frequency (occurrence /yr) of load loss event i

IEAR = Interrupted energy assessment rate

Li = Load curtailed in kW of load loss event i.

L_f = Load forecast in kW .

LA = Actual Load in kW .

l_k = Load curtailed for an outage

M_+ and M_- = Mean absolute error

Nc = No. of load loss event

P(x) = Probability of capacity outage of X MW after unit is added.

P'(x) = Probability of capacity outage of X Mw before unit is added.

P(G)) = Generation outage probability.

P_k = Probability of the load at bus k exceeding the maximum load that can be supplied at that bus during an outage.

U	=	Forced outage rate (F.O.R) of unit being added
λ	=	Failure rate
μ	=	Repair rate
ΔL	=	Load forecast error in MW
λ_+ and λ_-	=	Transition rates to higher and lower available capacity levels respectively.
μ_L	=	Membership function for load forecast error.
μ_F	=	Membership function for load forecast.

ABSTRACT

In the proposed work the costs associated with an electrical energy supply interruption for residential customers loads are estimated using interruption data obtained from different residential income class surveyed. The expected energy not supplied for generation outage is also evaluated using frequency and duration technique. A fuzzy load model has been used for the interruption cost calculation to eliminate the error involved in the recorded loads. The results indicate the implications of electric service reliability to residential customers in India, and shows that reliability worth evaluation is both possible and practical in a devolving country. It may also help the utility engineer for future planning and decision making.

CONTENTS

CHAPTER-I

INTRODUCTION

Electric power is a vital element in any modern economy. The availability of reliable power supply at reasonable cost is crucial for economic growth and development of a country. Electric power utilities through out the world therefore endeavor to meet customer demands as economically as possible and at reasonable level of service reliability. Reliability is the key criterion in planning of the power system in developed countries, In developing countries reliability of supply is difficult to ensure due to widening gap between supply and demand on account of resource crunch. Therefore more rational approach is required to justify future power projects and to maintain acceptable reliability levels in developing countries.

The ability of the power system to meet its load requirements at any time is referred to as the 'reliability' of the system. System reliability can be grouped into two distinct aspects of system security and system adequacy. System security involves the ability of the system to respond to disturbances arising internally, whereas system adequacy relates to the existence of sufficient facilities with in the system to satisfy customer load demand.

The focus of any discussion concerning electric system reliability should begin with customer. The electric utility industry is moving towards an environment of competition and customer choice, where reliability is one of the key factors influencing customer loyalty. To remain competitive in this new environment, utilities must understand and meet the customers' expectations.

The main objective of this work is to evaluate the interruption cost due to electrical energy interruption of domestic loads. There is a growing interest in planning power system expansion and reliability study using an economic theory approach, which simultaneously optimizes system costs. From an economic theory prospective, any reliability criterion, must depend on the cost of providing extra reliability by changing one or more of system parameters versus the benefits accruing to society from the additional reliability. The utility or system cost will generally increase as consumers are provided with higher reliability. The consumer cost associated with supply interruptions will, however, decrease as the reliability increases. The total cost to society will therefore be the sum of the two costs. This total cost exhibits a minimum; hence, an optimum of reliability can be achieved.

Utility investments cost estimates are obtained through conventional cost estimation engineering techniques. On the other hand, Customers interruption cost estimates are subjective and depends veritably on his attitudes, economic status and his life style. Therefore interruption cost estimates for domestic loads can only be assessed through interviews and surveys covering all the sections of the society.

1.1 LITERATURE REVIEW

Interruption cost assessment has become a present day practice for power system operation and planning. Many research works have been carried out so far to evaluate interruption cost. Interruption cost data is currently considered as a key to relate the worth of service reliability with the cost of delivering that uninterrupted power.

E.M.Mackay and L.H.Berk [1978] presented the result of surveys made in 1976 by Ontario Hydro on consumers with demands in excess of 5 MW, in order to determine the effect of various proposed level of reliability. The results also include the customers' estimates of the cost of interruption of nine duration's, from less than one minute to one week. The estimates were reduced to a cost in $/kW of load interrupted, individual annual peak and noncoincident annual peak demands for groups were used to normalize the costs. Substantial variation in such costs, within and among residential groups, was observed. The effect of advance warning, frequency of occurrence on the interruption cost was also investigated.

G.Wacker and Roy Billinton [1983] presented the results of an investigation of the direct, short-term impacts and cost incurred by residential electrical consumers resulting from local random supply interruptions. The postal survey approach was adopted to determine the cost of electric service interruptions for residential consumers. The survey obtained user's cost valuation using three approaches. In two of these approaches the respondents were asked to indicate changes in the tariff that would ensure improved reliability. The third approach was an indirect worth evaluation based on the cost evaluation of the preparatory action that they would take to offset the adverse effects of recurring interruptions. The major contribution of this work was the compilation of residential cost of interruption information on function of both user and interruption characteristics. Another significant outcome was the improvement of interruption costing methodology.

G.Wacker and R.Billinton [1985] have discussed the results of a postal survey of Canadian farm operators, which was conducted to evaluate the direct and short-term costs and impact from local random electrical supply interruptions. The survey was designed to obtain the consumer's valuation of interruption cost. The major contribution of the work was compilation of cost of interruption data for farm-use. The responses from the respondents were not realistic as reported by the author's underestimation of costs.

Luige Salvaderi and R.Billinton [1985] compared two different approaches proposed for composite system reliability evaluation including a simulation i.e., Monte Carlo method. The main advantage of this method is the flexibility in accepting into variable, contingency cases. The disadvantage could be the computing time involved, the authors observed.

R.Billinton and J.Oteng Adjei [1987] used two different methods and a customer damage function to evaluate a factor designated as the interrupted energy assessment rate (IEAR) which can be used in conjunction with the calculated expected energy not supplied in the assessment of reliability worth. The first method was the frequency and duration approach. The IEAR values obtained can be used to assess the customer interruption costs for any particular sector and can be used to analyze the consequences associated with different load shedding policies. The second approach was the Monte Carlo simulation approach. The main advantage of Monte Carlo simulation is that it offered the opportunity to include, theoretically at least, any random variable and to include operation policies similar to the real ones.

R.Billinton and J.Oteng-Adjei [1988] illustrated how an optimum reserve margin, which maximizes net social benefits may be determined for a practical power system. The result shows that the estimated reserve margin is quite sensitive to change in system IEAR and uncertainties associated with demand forecasting. The basic conclusion was that the long range expansion plan of a power system may be optimized in terms of reliability by using an economic criterion for system planning in which the sum of both customer interruption and system cost is minimized.

L.Goel and R.Billinton [1991] presented a method for evaluating an interrupted energy assessment rate (IEAR) at each system customer load point considering the influence of outages in all parts of the electric power system. The IEAR values which was obtained can be used to relate the customer interruption costs with the worth of electric service reliability in an over electrical power system. The individual customer load point IEAR values and the customer sector IEAR values at each bulk system load point could be used in making decisions on preferred load curtailment strategies or in studies considering reliability based electric utility customer rates.

L.Goel and Roy Billinton [1994] presented three different methods for evaluating system customer load point reliability worth factors designated as interrupted energy assessment rates. The first method uses a contingency enumeration technique. This method involves a comprehensive analysis of all major component outages in an electric power system. The second method was the basic indices method which uses the average distribution level adequacy indices at each customer load point together with the sector customer cost characteristics. The third method was the system indices method which makes use of distribution system performance indices in conjunction with appropriate composite customer cost characteristics. Method 2 and 3 could be used to obtain approximate customer interruption costs in the absence of detailed study but the contingency enumeration method can be more accurate.

Michael J.Sullivan and Terry Vardell [1996] developed a method for measuring the interruption cost and customer satisfaction. That study shows that customer interruption costs vary systematically and predictably as a function of customer type and size and within commercial and industrial customer by processes, equipment and products being made and sold. The result of customer satisfaction survey indicates that reliability history has no direct effect on a customer's satisfaction with utility service. Because there are significant differences across utility circuits in the number of type customers served, this study suggests that it is inappropriate to apply system wide interruption cost estimates to transmission and distribution planning problems.

J.Gates and R.Billinton [1999] presented the study to determine the costs of electric service interruptions in the government, institution and office building sector (GIO). The results show that customer costs attributable to electricity supply interruptions in the GIO sector compare most closely to those found in the industrial sector.

1.2 PROPOSED METHODOLOGY

In this study, the methodology adopted for Indian condition is described below Customer interruption costs have been determined for different types of domestic consumers thorough a survey. The customer survey is the most popular and practical technique for interruption cost assessment

The most common index link thee generating capacity outage probability with customer interruption cost is the expected energy not supplied (EENS), EENS for each load loss events are evaluated using an analytical technique. After evaluating the EENS interruption energy assessment rate (IEAR) are determined.

1.3 OUTLINE OF THE REPORT:

The outline of the report has been prepared as follows:

Chapter-I	present the introduction of the project.
Chapter-II	contains the methods of analyzing the interruption cost for different types of domestic customers.
Chapter-III	presents the fuzzy load model.
Chapter-IV	presents the proposed model.
Chapter-V	presents results of the project.
Chapter-VI	is the conclusion drawn from the present work.

CHAPTER-II

INTERRUPTION COST ASSESSMENT

2.1 INTRODUCTION

Electric power supply shortage manifest either as brownout (frequency and voltage fluctuations) or blackout (complete interruptions of supply). These undesirable conditions impose certain economic costs on consumers, which can be generally termed as the costs of interruptions or outage cost. The effect of sudden supply interruption results in highest interruption costs. Interruption cost can be classified in to two categories. One is direct outage cost and another is indirect outage cost.

Outage costs are direct when they occur during or following an outage, but are considered indirect when they are incurred because an outage is expected. For example, during an outage, consumers will suffer direct outage cost, since normal productive activity is disrupted. Indirect outage costs are incurred because consumers may adapt their behavior patterns in ways that are less efficient or more costly, but less susceptible to outage disruptions. Generally direct outage costs are related more to the short-term effect of unexpected outages; indirect outage costs arise from longer-term considerations of outage expectation, including the effect of planned power cuts.

2.2 DIFFERENT METHODS FOR INTERRUPTION COST EVALUATION FOR RESIDENTIAL CONSUMERS

Evaluation of customer interruption costs for the residential consumers is a complex and often subjective task. A review of the literature reveals that interruption impacts can be evaluated using a variety of approaches. These methods can be grouped into three categories: analytical methods, case studies of actual black outs and customer surveys. The method considered to yield the most consistent results is the customer survey approach, which is based on the assumption that the customer is in the best position to estimate the losses resulting from a power interruption.

Customer survey costing methods can be grouped in to three main categories:

- Contingent valuation methods
- Direct costing methods
- Indirect costing methods.

Most customer surveys incorporate a combination of two or all three approaches. The choice is largely dependent upon the type of customer being surveyed.

Most of the customer surveys conducted in the past were in developed countries, such as Sweden, Finland, France, UK, USA and Canada. No customer surveys as conducting in the developing countries. One of the main objectives of the present work described in this thesis was to extend the evaluation technique to a developing country and to examine the problems associated with incorporating the approach in such a system.

There are two approaches for estimating the interruption cost. The first approach consist the lost output or forgone leisure in terms of monetary units as promote basis of the monetary output of the consumer. The second approach consist the cost of precautionary action initiated by the customer to reduce or and the effect of interruptions and the willingness to pay a higher tariff for improving reliability of power system and avoidance of interruptions.

2.2.1 VALUE OF FORGONE LEISURE

The outage cost from the value of forgone leisure can be calculated from the following expression

$$\Delta OC^{R}/\Delta T \approx w \quad \text{-------------------------} \quad (2.1)$$

$$MRS_{IV}\left(\frac{\Delta V}{\Delta \theta}\right) \approx w \quad \text{-------------------------} \quad (2.2)$$

ΔOC^{R} = Incremental monetary value of electricity dependent leisure.

$MRS_{I,V}$ = Incremental monetary value of electricity independent leisure.

ΔT = Time for electricity dependent leisure.

$\Delta\theta$ =Time for electricity independent leisure.

So with that expression, the incremental monetary values of both electricity-dependent and independent types of leisure per time unit are roughly equal to the wage or earning income rate.

The practical advantage of this method of estimating the outage costs of residential customers is the basis of forgone leisure, in its reliance on relatively easy-to-obtain income data. Often it may be possible to obtain a good correlation between family income data and kWh electricity consumption for a typical sample of residential consumers by using the utility companies and information from household budget surveys. In this way the income levels of electricity using households could be estimated.

Still this method of estimating residential consumer's outage costs may lead to incorrect estimates for four reasons namely.

- First it assumed that workers could vary their hours of work in the house to equate their wage with the marginal value of their leisure time.

Traditional work practices such as 48–hour week, union restrictions on hours worked, or insufficient employment alternatives might prevent this. If workers are unable to work as much as they wish, their wage will over estimate the value of lost of leisure. A related point is that the day time wage rate may not be good proxy for the value of leisure; the marginal wage rate corresponding to the leisure hours may be more appropriate and in some cases this may be the over time rate of pay.

- Second, the cost of non-wage earning members of the family is effectively ignored, by allowing only the wage earner to represent the household as an income-earning unit.
- Third, residential consumers may develop outage expectations, presumably because of the frequency of such occurrences in the past, so that possibility of interruptions in electricity supply will be considered when labor-leisure decisions are made. The cost of the outage will then be less than in instances where there is no such outage expectation.
- Finally, if the some leisure is enjoyed outside the household that is affected by the outage, then ideally, this case should be treated separately.

2.2.2 Cost Estimation Based On Prepatory Action And Willingness To Pay Approach

In this proposed method consumers are asked to predict which actions their household might take in preparation for the power failure. With the help of simple average or mean value, the cost of each categories can be determined in the form of Rs / Interruptions.

With the help of aggregate average cost normalized by annual energy consumption (not by unserved energy during interruptions) gives consumption normalized in Rs/MWh or Rs/kWh. The demand-normalized cost can be calculated using consumption-normalized cost in (Rs/kWh) and the sector load factor information obtained from the electrical authority.

In this method, respondents are asked to comment on their capacity to bear the additional cost to avoid interruption. The method of calculating the Rs/Interruption, consumption normalized, demand normalized costs have been explained above.

2.3 PROBLEM FORMULATION

The objective of this work is to evaluate the interruption cost for residential consumers. Evaluation of electrical supply interruption costs is a complex and subjective work. Interruption costs represent the economic consequences of service curtailments to the customer when the demand for electricity temporarily exceeds the available supply capacity.

The estimation of an interruption energy assessment rate at HL1 (Hierarchical level I) involves basic mathematical models proposed are generation model, load model and cost model.

2.3.1 Generation Model

In the modeling of generation system, the units are characterized by their capacity, forced outage rates, failure rates and repair rates. The outage probabilities of generation, failure frequency are calculated by using frequency and duration technique. The data used for evaluating the adequacy indices for generation level (HL1) is presented in appendix -III.

2.3.2 Load Model

In this model hourly peak load for twenty-four hour period is given. The load data are represented by load duration curve. The forecasted loads will be fuzzified to remove the uncertainty in load forecasting. The actual data will be obtained by the combined fuzzified load forecast adding the error function to the forecasted load.

2.3.3 Cost Model

The cost model is represented by the composite customer damage function for the service area under study. The customer cost associated with a particular outage at a specific point in the system involves an amalgamation of the costs associated with the customers affected by the interruptions. A survey work is proposed for residential consumer to determine the interruption cost. Finally the composite customer damage function is determined which represent the cost model.

The actual load model can be combined with capacity model to yield the frequency and duration associated with each load loss event. The expected energy not supplied for each loss of load event is given by following equation.

Expected energy not supplied (EENS) = $L_i \times f_i \times D_i$ (Mwh) ------------ (2.31)

Where

L_i = Load curtailed in (MW or kW) of load loss event i.

f_i = Frequency (occurrence/yr.) of load loss event i.

D_i = Duration in hours of load loss event i.

$$\text{Total EENS} = \Sigma\ L_i \times f_i \times D_i\ \text{(Mwh)} \qquad \text{------------------------- (2.32)}$$

The total expected for all the load curtailment events of the system is given by

$$\text{Total expected cost} = C x \sum L_i \times f_i \times D_i \qquad \text{------------------------- (2.33)}$$

Where C is the interruption cost in Rs/kWh for duration D_i in hours of load loss event i.

$$\text{Estimated IEAR} = \frac{C x \sum L_i \times f_i \times D_i}{\sum L_i \times f_i \times D_i} \qquad \text{------------------------- (2.34)}$$

CHAPTER III

FUZZY LOAD MODEL

3.1 INTRODUCTION

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth and truth values between "completely true" and "completely false". Dr. Lotfi Zadeh introduced the above concept in the 1960's as a means to model the uncertainty of natural language. According to Zadeh the process of "fuzzification" is a methodology to generalize any specific theory from a crisp (discrete) to a continuous (fuzzy) form. Zadeh proposed a mathematical way of looking at vagueness that a computer would deal with. He called the new approach as fuzzy logic. Fuzzy logic lets computers assign numerical values that fall between 'ones' and 'zeros', and there being no clear dividing line between these values.

Fuzzy means uncertain or impression. Uncertainty is undesirable in science and technology and it should be avoided by all possible means. One of the reasons for the increasing popularity of fuzzy logic is that it offers a very simple, initiative way for engineers to describe a complex problem using the design methodology of fuzzy logic.

A fuzzy subset F of a set S can be defined as a set of ordered pairs, each with the first element from S, and the second element from the interval [0,1], with exactly one ordered pair present for each element of S. This defines a mapping between elements of the set S and values in the interval [0,1]. The value zero is used to represent complete non-membership, the value one is used to represent complete membership, and the values in between are used to represent intermediate degree of membership. The set S is referred to as the UNIVERSE OF DISCOURSE for the fuzzy subset F. Fuzzy logic is now applied to help computers simulate the vagueness and uncertainty of our thought processes and languages. finally is the DEFUZZIFICATION, which is used when it is useful to convert the fuzzy output set to a crisp number. In the present work centoried or center of area defuzzification method is used. In this method, the crisp value of the output variable is computed by finding the variable value of the center of gravity of the membership function for the fuzzy value.

3.2 PROPOSED FUZZY LOAD MODEL

The load model used in the thesis is the load duration curve, which presents hourly peak load, in a twenty four-hour period. Normally the forecasted loads are not exact due to environmental variations. So in the proposed model fuzzy membership function for both the forecasted loads and the error function have been designed precisely. Finally the sum of both the above functions leads to the exact load.

3.2.1 Membership Function For The Load Forecast Error

Thus the actual load, L_{actual} is the sum of the forecasted load, $L_{forecasted}$, and the forecast error, ΔL. This can be expressed by the following equation.

$$L_{actual} = L_{forecasted} + \Delta L \qquad \text{------------------------} \ (3.1)$$

The forecasted load $L_{forecasted}$ is crisp while both the forecast error and the actual load are characterized by the fuzzy set ΔL and L actual.

The membership function for the fuzzy set ΔL is represented by

$$\mu_L = \frac{L_f^2}{Lf^2 + 2.333\left(\frac{\Delta l.L.f}{M_+}\right)^2} \qquad \Delta l \geq 0 \qquad \text{-----------(3.2)}$$

$$= \frac{L_f^2}{1 + 2.333\left(\frac{\Delta l.L.f}{M_-}\right)^2} \qquad \Delta l < 0 \qquad \text{------------- (3.3)}$$

Where Δl = error in MW

$$= \frac{\Delta L}{L_{forecasted}} \qquad \text{-- (3.4)}$$

$$= \frac{L_{actual} - L_{forecasted}}{L_{forecasted}} \qquad \text{---------------------------------- (3.5)}$$

Load forecast errors can be either positive or negative. The loads forecasted error for twenty-four hour hours period is divided into five states. Such as -

VL = Very large

L = Large

M = Medium

VS = Very small

S = Small

M_+ and M_- give the mean absolute error for sample point. As for example M_+(VS) and M_- (VS) and give the mean absolute error (MAE) for those sample points with very small (VS) errors. The process can be repeated for very large, large, small and medium error also. The values of M_+ and M_- for five possible states are presented in Appendix- III

A computer program is developed to get the membership values for the load forecast error function presented in appendix - V.

3.2.2 Membership Function For Forecasted Load

A triangular membership function is defined for forecasted load L forecast.

$$\mu_F(x) = 0 \quad \text{if} \quad x < a_1 \qquad (3.6)$$

$$= (X-a_1)/(C-a_1) \quad \text{if } X \leq C$$

$$= (X-a_2)/(C-a_2) \quad \text{if } X \geq C$$

$$= 0 \quad \text{if } X > a_2$$

Where x is the forecasted load.

a_1 is the lower limit of the given class interval, C is the medium value and a_2 is the upper limit of the class interval under study. Thus membership values for load forecast membership function for each hour is determined. A computer program is also used to calculate these membership values shown in appendix - V.

3.2.3 Membership Function Of Actual Load

As already defined $L_{actual} = L_{forecast} + \Delta L$, to determine L_{actual}, the actual load, the membership functions for $L_{forecast}$ and forecast error is to be added. For each hour the membership values for both membership functions are added. For addition at first the minimum value for every possible sum is determined. Then from these minimum values the maximum is taken. Thus for each possible sum a maximum value is obtained. The series of these maximum values is obtained. The series of these maximum values for each hour duration is determined. Then these maximum membership values are defuzzified to get the crisp value for that duration. Thus for 24 hour period the process is continued to get the actual load for 24 hour period.

3.2.4 Defuzzification Of The Actual Load

Defuzzification is done by center of area defuzzificaation (COA) method. In COA the crisp value u* is taken to be the geometrical center of output fuzzy value $\mu_{out}(\mu)$ taken by adding the two membership functions L forecast and forecast error. The defuzziffied output is defined as

$$u^* = \frac{\sum_{i=1}^{N} \mu_i \, \mu_{out}(\mu_i)}{\sum_{i=1}^{N} \mu_{out}(\mu_i)} \qquad \text{---------------------------- (3.7)}$$

Where the summation (integration is carried over (desecrate) values of the universe of discourse μ_i sampled at N points. A computer program is used to carry out this calculation. The final output is the crisp value obtained from the defuzzified method mentioned above to get the actual loads for 24 hour period.

CHAPTER IV

PROPOSED MODEL

4.1 INTRODUCTION

Reliability worth can be evaluated in terms of expected customer interruption cost. This cost estimate can be obtained by multiplying the expected energy not supplied to customers due to power interruptions by a suitable factor. This factor designated as interrupted energy assessment rate (IEAR) is expressed in Rs/kWh. The expected energy not supplied is a basic generating system adequacy assessment index calculated using frequency and duration approach. This method in conjunction with the appropriate customer function can be used to estimate IEAR. The basic models required in this approach are as follows.

4.2 GENERATION MODEL

The exact state generating capacity model for use in frequency and duration methods is defined by the following basic parameters for each of the possible capacity outage states: probability and effective departure rates to higher and lower capacity outage states. Parameters, which that can be readily calculated from these basic parameters are capacity outage, state frequency and duration.

The data used for generation model are presented in appendix III. The generating capacity outage probability table is presented in chapter V. A recursive algorithm for unit addition is adopted to construct this outage probability table. In the present system it is assumed that transmission lines are reliable to carry the generated energy to the customer load point. A computer program has been developed for capacity model building, which is shown in appendix V.

4.2.1 Generation Unit Unavailability

The basic generating unit parameter used in static capacity evaluation is the probability of finding unit on forced outage rate at some distant time in the future.

This probability is defined as unit unavailability. And in power system application its known as the unit forced outage rate (FOR).

$$\text{Where FOR} = \frac{\text{Time on forced outage}}{\text{Time exposed to forced outage}} \quad \text{------------------ (4.1)}$$

Time exposed to forced outage = Time on forced outage + Operating time

$$\text{Unavailability (FOR)} = \frac{\Sigma[\text{Down time}]}{\Sigma\,[\text{Down time}] + \Sigma\,[\text{Up time}]} \quad \text{---------- (4.2)}$$

$$\text{FOR(U)} = \frac{\lambda}{\lambda + \mu} \quad \text{------------------------------------- (4.3)}$$

Where

λ = Expected failure rate

μ = Expected repair rate

From using the equation, the unit FOR is calculated which is used to determine the probability of capacity outage state.

4.2.2 Probability Of Capacity Outage State

The recursive expression for a state of " exactly X MW on forced outage" after a unit of C MW and force outage rate U is added is given by the following equations.

$$PX = p^{/}(X)(1-U) + p^{/}(X-C)U \quad \text{-------------------- (4.4)}$$

where,

$P(X)$ = probability of capacity outage of X MW after unit is added,

$P'(X)$ = probability of capacity outage of X MW before unit is added,

U = Forced outage rate (FOR) of unit being added.

C = Capacity of unit being added.

In the above expression $P'(X-C)$ is zero if X is less than C since a state of negative capacity outage is obviously impossible. The recursive expression of equation (1) is initiated by setting $P(O)=1-U_1$, $P(C1)=U_1$, and all other state probabilities equal to zero where the first unit added to the capacity model has capacity C_1 and forced outage rate U_1. Equation (1) takes into account the two mutually exclusive ways that a capacity outage of X MW may arise after a unit is added:

1) System in capacity outage state X before unit added and the added unit up, and

2) System in capacity outage state X-C before unit added and the added unit down.

4.2.3 Effective Departure Rate From Capacity Outage

$\lambda_+(X)$ be the effective departure rate from an exact capacity outage state X to states having less capacity out (i.e. to higher available capacity states). Similarly $\lambda_-(X)$ be the effective departure rate from exact capacity outage state X to states having more capacity out. The departure rates $\lambda_+(X)$ and $\lambda_-(X)$ may be computed by adding one generating unit at a time in a manner similar to that used in calculating P (X).

$$\lambda_+(X) = \frac{P'(X)(1-U)\lambda'_+(X) + P'(X-C)U(\lambda'_+(X-C)+\mu)}{P(X)} \qquad \text{------- (4.5)}$$

$$\lambda_{-}(X) = \frac{P'(X)(1-U)\lambda'_{-}(X) + P'(X-C)U(\lambda'_{-}(X-C))}{P(X)} \quad \text{------- (4.6)}$$

$\lambda_{+}(X)$, $\lambda_{-}(X)$ = Upward and downward capacity departure rates respectively.

λ = Average forced outage occurrence rate of unit being added.

μ = Average forced outage restoral rate of unit being added,

In equations (4.4), (4.5) and (4.6), if X is less than C

$P'(X-C) = 0$

$\lambda_{+}'(X-C) = 0$

$\lambda_{-}'(X-C) = 0$

The procedure is initiated with the addition of the first unit C_1.

In this case,

$\lambda_{+}(0) = 0$

$\lambda_{-}(0) = \lambda_1$

$\lambda_{+}(C_1) = \mu_1$

$\lambda_{-}(C_1) = 0$

$\lambda_{+}(X) = \lambda_{-}(X) = 0$ For X not equal to 0 and C_1.

4.2.4 Frequency And Duration Of Exact Capacity Outage State

Once the quantities P(X), $\lambda_{+}(X)$, and $\lambda_{-}(X)$ have been found using equations (4.4), (4.5) and (4.6), the frequency f(x) and duration D(X) of the exact capacity outage state X are easily found:

$$f(X) = P(X)[\lambda_{+}(X) + \lambda_{-}(X)] \quad \text{--------} \quad (4.7)$$

$$D(x) = 1/[\lambda_{+}(X) + \lambda_{-}(X)] \quad \text{----------} \quad (4.8)$$

4.3 FUZZY LOAD MODEL

The load model used in this thesis is the load duration curve, which presents hourly peak load, in a twenty four-hour period. The forecasted loads are fuzzified. The forecasted loads are not actual. There may exist some error. In the proposed model the actual loads for twenty-four hours period is calculated. The detailed method for preparing of fuzzy load model is presented in chapter III.

4.4 COST MODEL

This is represented by the sector costs of interruption with their distribution of energy and peak demand of the service area. The customer survey approach, however, seems to be most popular and practical technique, which is based on the assumption that customer is in the best position to estimate the losses resulting from a power interruption. A survey of hundred residential customers in Meerut in the state of Uttar Pradesh was conducted in the month of December 1999 to determine the effect of outages on these residential consumers and to collect data to estimate the resulting interruption cost.

4.4.1 Residential Survey Methodlogy For Devloping Countries

Mail, telephone or through personal interviews are the media's for conducting customer surveys. It was found that most surveys conducted in India is through personal interactions(interviews). Mail surveys was not considered viable due to extremely poor response rates experienced by other research organization. Customer surveys by telephone are not feasible because of the detailed customer information requirements, and the lack of awareness of the concept and practice in the country. It was therefore decided to conduct surveys through in-person interviews.

The specific methodology and questionnaire used in the survey under went an extensive developmental process. This involved an iterative approach consisting of the identification of factor to be included, design and development of the questionnaire, and small scale testing of the questionnaire using interviews with sample users.

4.4.2 Factors Investigate In The Survey

A comprehensive list of factors hypothesized to affect the cost of interruptions was prepared. While it would have been desirable to investigate all the factors, the length of questionnaire is limited by degree of effort that respondents are willing to engage in. The following factors which were concerned to influence the reaction of the customers to power interruptions were selected for inclusion in the final questionnaire.

Interruption duration

Frequency of occurrence of interruptions

Different customer's class based net income category

Preparatory actions

Willingness to pay

Monthly electricity bill

Satisfaction level of users regarding electric service and interruptions

The questionnaire is shown in appendix IV.

4.4.3 Data Analysis

The first stage of interruption cost assessment is data compilation analysis. Data was compiled according to the respondent answer. Firstly histogram was prepared for every respondent's answers after mean or average values were calculated to prepare the data of interruption cost calculation, the results are shown in appendix II.

4.4.4 Different Approaches Adopted For Finding Out Survey Result

Therefore, more of the results obtained from the survey are presented in a general qualitative way, with the quantitative cost estimates derived from the cost questions for each of the customer class presented in more detail. For this analysis all values are determined are based on net income pattern of five different consumer classes, which is lower, lower- medium, medium, upper-medium and upper. The number of customers interviewed was limited and survey area was also very small but the approaches, which are describing for finding out the survey result, will be very useful for developing countries.

4.4.5 Satisfaction Level Regarding Electric Service And Interruption

Customers were asked to give opinions regarding the quality of service provided by the UPSEB. This was based on five-point scale, which varies from far-from satisfactory, unsatisfactory, satisfactory, good, very good. Histogram was prepared which is shown in appendix II for compilation of result for every category that clearly indicates the quality of service provided by the UPSEB. The price of electricity with respect to the given quality, importance of electrical energy, and number of power failures at their homes were also calculated in the same fashion.

4.4.6 Cost Estimation From A Preparatory Action Approach

In this method, consumers were asked to answer the type precaution measure that they prefer to take under failure. This was categorized into three parts such as preparatory action in the night, summer and winter seasons. To determine these cost, some possible preparatory actions were provided to help respondent to predict their choices for every preparatory actions and their corresponding costs in Indian Rupees (Rs) were employed. With the help of simple average or mean value, the cost of each categories can be determined in the form of Rs / Interruptions. With the help of aggregate average cost normalized by annual energy consumption (not by unserved energy during interruptions) gives consumption normalized in Rs/MWh or Rs/kWh. The demand-normalized cost can be calculated using consumption-normalized cost in (Rs/kWh) and the sector load factor information obtained from the electrical authority. These costs were used to estimate the cost that respondent were willing to undertake to reduce or eliminate the adverse effects of stated interruptions.

4.4.7 Cost Estimation From Willingness-To-Pay Approach

In this method respondents asked suppose that failure occur without warning any time during day time or evening, how mush they would extra to pay to avoid this interruption. This was categories in to five parts that was willing ness to pay for leisure hour, peak summer period, peak winter period, house keeping and preparation of food. But it was found that In India majority of consumer was not willing to pay extra if outage occur in during period of house keeping and preparation of food. Seasonwise cost calculation also gives a idea that interruption during which seasons are most undesirable. With the help of simple average or mean value, the cost of each categories can be determined in the form of Rs / Interruptions. The other listing are the aggregate average cost normalized by annual energy consumption (not by unserved energy during interruptions) gives consumption normalized in Rs/MWh or Rs/kWh. The demand-normalized cost can be calculated using consumption-normalized cost in (Rs/kWh) and the sector load factor information obtained from the electrical authority. The cost calculations for different category from willingness to pay approach are shown in appendix I.

CHAPTER – V

RESULTS AND DISCUSSION

An analytical technique, (frequency and duration) is used to calculate frequency, duration and expected energy not supplied for a load loss events. The results are presented in tabular forms for different types of load loss events.

The generation capacity outage probability is presented in Table 5.1. The fuzzified residential loads for 24 hours are presented in Table 5.2. The expected energy not supplied for load loss events are presented in tables from Table No. 5.3 to 5.22. The interruption cost assessment has been evaluated on the basis of willingness to pay approach and preparatory action approach as shown in Table 5.23 and calculation shown in appendix – I. Thereafter a typical tariff evaluation was carried out on willingness to pay approach showing practical applicability for implementation in actual practice are shown in Table 5.24.

DISCUSSION

Customer interruption cost can be used to analyze the necessity of system planning and applicability of tariff application in power distribution system. The expected cost associated with each generation outage can be obtained by multiplying the expected energy not supplied for that outage of generation, by the interruption cost function for that service area. This will enable the utility to reduce the energy not supplied by rectifying the generation system so that loss in terms of money and difficulty being faced by the consumer can be minimized to improve the reliability.

Table 5.1

Capacity outage probability table

State	Capacity out Kw	Probability	λ_+(occ/day)	λ_-(occ/day)
1	0.000000	0.922368	0.000000	0.040000
2	75.000000	0.056472	0.490000	0.030000
3	100.000000	0.018825	0.490000	0.030000
4	150.000000	0.001153	0.979800	0.019996
5	175.000000	0.001152	0.980000	0.020000
6	250.000000	0.000024	1.470000	0.010000

Table 5.2

Actual load obtained from fuzzy load model

SL. No.	No. of occurrences	Load kW
1	365	3.659506
2	1095	3.640402
3	365	6.303118
4	365	11.168653
5	365	25.504576
6	365	114.674271
7	365	25.548767
8	730	6.447150
9	365	6.430020
10	365	16.170616
11	365	9.391030
12	730	7.214380
13	365	9.391030
14	365	16.216452
15	365	231.367340
16	365	230.983673
17	365	231.357376
18	365	30.560648
19	365	20.877607
20	365	10.982298

Table 5.3

Evaluation of expected energy not supplied for different hourly load

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 3.659506 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	3.659000	0.047439	0.769268	0.210240

Table 5.4

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 3.6402 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	3.640400	0.047198	0.765358	0.210240

Table 5.5

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 6.303116 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	6.300000	0.081680	1.324512	0.210240

Table 5.6

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 11.168653 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	11.160000	0.144689	2.346279	0.210240

Table 5.7

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 25.504576 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	25.500000	0.330608	5.361121	0.210240

Table 5.8

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 114.674271 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	1.000000	24.243097	14.669998	6.111888	148.171097	10.100281
0.001152	0.420480	75.000000	1.000000	24.000000	39.669998	16.680441	400.330597	10.091520
0.000024	0.012965	0.000000	1.000000	16.215967	114.669998	1.486697	24.108223	0.210240

Table 5.9

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 25.548767 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	Elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	25.540001	0.331126	5.369530	0.210240

Table 5.10

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 6.447150 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	Eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	6.447000	0.083585	1.355417	0.210240

Table 5.11

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 6.430020 KW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	6.430000	0.083365	1.351843	0.210240

Table 5.12

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 16.170616 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	16.170000	0.209644	3.399581	0.210240

Table 5.13

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 9.391030 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	9.390000	0.121741	1.974154	0.210240

Table 5.14

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 7.214380 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	7.214000	0.093530	1.516672	0.210240

Table 5.15

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 9.391030 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	9.391000	0.121754	1.974364	0.210240

Table 5.16

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 16.216452 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	16.216000	0.210240	3.409252	0.210240

Table 5.17

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 231.367340 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	1.000000	46.153847	56.367004	604.163269	27884.460938	494.694733
0.018825	3.572985	150.000000	1.000000	46.153847	81.367004	290.723083	13417.988281	164.906998
0.001153	0.416625	100.000000	1.000000	24.243097	131.367004	54.730778	1326.843506	10.100281
0.001152	0.420480	75.000000	1.000000	24.000000	156.367004	65.749199	1577.980835	10.091520
0.000024	0.012965	0.000000	1.000000	16.215967	231.367004	2.999673	48.642605	0.210240

Table 5.18

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 230.98367 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	1.000000	46.153847	55.983002	600.047424	27694.496094	494.694733
0.018825	3.572985	150.000000	1.000000	46.153847	80.983002	289.351044	13354.664062	164.906998
0.001153	0.416625	100.000000	1.000000	24.243097	130.983002	54.570793	1322.964966	10.100281
0.001152	0.420480	75.000000	1.000000	24.000000	155.983002	65.587738	1574.105591	10.091520
0.000024	0.012965	0.000000	1.000000	16.215967	230.983002	2.994695	48.561871	0.210240

Table 5.19

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 231.357376 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	1.000000	46.153847	56.356995	604.056030	27879.507812	494.694733
0.018825	3.572985	150.000000	1.000000	46.153847	81.356995	290.687317	13416.337891	164.906998
0.001153	0.416625	100.000000	1.000000	24.243097	131.356995	54.726608	1326.742432	10.100281
0.001152	0.420480	75.000000	1.000000	24.000000	156.356995	65.744987	1577.879761	10.091520
0.000024	0.012965	0.000000	1.000000	16.215967	231.356995	2.999543	48.640499	0.210240

Table 5.20

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 30.560648 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	30.559999	0.396210	6.424935	0.210240

Table 5.21

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 20.877607 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	20.877001	0.270670	4.389181	0.210240

Table 5.22

EXPECTED ENERGY NOT SUPPLIED FOR LOAD = 10.982298 kW								
P(G)	F(G)	C(I)	PK	Dk(Hrs)	Lk(Kw)	elc	eens	edlc
0.922368	13.466573	250.000000	0.000000	600.000000	0.000000	0.000000	0.000000	0.000000
0.056472	10.718386	175.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.018825	3.572985	150.000000	0.000000	46.153847	0.000000	0.000000	0.000000	0.000000
0.001153	0.416625	100.000000	0.000000	24.243097	0.000000	0.000000	0.000000	0.000000
0.001152	0.420480	75.000000	0.000000	24.000000	0.000000	0.000000	0.000000	0.000000
0.000024	0.012965	0.000000	1.000000	16.215967	10.982000	0.142382	2.308856	0.210240

Table 5.23 : Cost Estimates from Preparatory and Willingness to Pay Approach

			Mean value Rs/ interruption			Mean value Rs/interruption		
Income class	No.of consumer surveyed	Interruption characteristics	Preparatory action approach			Willing ness to pay approach		
			Failure in night	Failure in summer	Failure in winter	For leisure/ night	For summer	For winter
Lower	47	1 hour	11.32	8.67	11.37	4.3	1.74	1.59
		2hour	22.64	17.34	22.74	8.61	3.48	3.18
		4hour	45.28	34.68	45.48	17.22	6.96	6.36
Middle	14	1 hour	11.21	17.42	13.38	9.15	4.5	3.96
		2hour	22.42	34.84	26.76	18.3	9	7.92
		4hour	44.84	69.58	53.52	36.6	18	15.84
Upper middle	12	1 hour	38.16	26.85	28.43	21.28	11.8	9.23
		2hour	76.32	53.7	56.86	42.56	23.6	18.46
		4hour	152.64	107.4	113.72	85.12	47.2	36.92
Upper	14	1 hour	39.85	35.41	41.07	58.05	32.12	28.72
		2hour	79.7	70.82	82.14	116.1	64.24	57.44
		4hour	159.4	141.64	164.28	232.2	128.48	114.88

Table 5.24 : Tariff Assessment Analysis

Income class	Average unit consumed per month	Average interruption cost from willingness to pay approach	Peak demand (kW)	Rs./kWh	Tariff applicable for each class
Lower	127	3.71	.875	4.24	3+2/2 = 3.12
Middle	196	6.57	1.3	5.05	5.05+2/2 = 3.52
Upper middle	458	15.87	3.04	5.22	5.22+2/2 = 3.61
Upper	1360	44.68	9.07	4.91	4.91+2/2 = 3.45

The above-evaluated tariff is purely on the basis of willingness to pay approach, hence can be practically accepted by the consumers and can be implemented in practice.

CHAPTER – VI

CONCLUSION

The proposed model can help the utility as well as customer to reduce their financial losses and negative effect in their social life, due to electrical energy supply interruption. The expected cost associated with the expected energy not supplied can be evaluated from the interruption cost data. The planner may have an opportunity to restructure the network by taking the help of study conducted for evaluation interruption cost & tariff. It has been observed from the study conducted for evaluation of tariff that the lower income class is ready to pay @ 3.12/kWH for improved reliability in supply in place of current tariff rate Rs. 1.80 which is being charged by U.P.S.E.B. It means that the additional revenue which will be received can be utilized for improvement of reliability by installing the additional generating units.

Customer interruption costs have been used to analyze the impact of over/under capacity planning. The inherent uncertain nature of long term capacity planning creates a situation in which there is the potential for mismatch in supply and demand. An important component is the assessment of the customer costs associated with that condition.

This study presents a summary of a investigation of the interruption costs perceived by residential customers in the Indian Power Scenario. The work presents the power interruption costs for residential customers of a developing country, and advances the customer survey approach to power system reliability worth evaluation and tariff.

The results indicate the implications of electric service reliability to residential customers in India, and shows that reliability worth evaluation is both possible and practical in a developing country. The approach is illustrated by application to the Indian Power System. The concepts, however, can be used by utility planners in similar developing countries to evaluate electric service reliability worth.

APPENDIX- I

DATA ANALYSIS

The first stage of interruption cost assessment is data compilation analysis. Data was compiled according to the respondent answer. Firstly histogram was prepared for every respondent answers after mean or average values were calculated.

MONTHLY ELECTRICITY BILL

For calculating monthly electricity bill for every category taking uniformly tariff rate 2.0 Rs/kWh.

1) Average monthly electricity bill in terms of money for lower class (Reference histogram no 1 appendix II)

$$= \frac{125X15+175X8+225X6+275X5+325X1+375X4+425\ X3+\ 475X2+575+625+725}{47}$$

$$= \quad Rs254.78$$

So monthly electricity bill in terms of kWh/month

$$= \frac{254.78}{2.0} \approx 127 \text{ kWh per month}$$

2) Average monthly electricity bill in terms of money for middle class (Reference histogram no 2 appendix II)

$$= \frac{125X2 + 175 + 225X2 + 275X2 + 325 + 425X2 + 675 + 725X2 + 775}{14}$$

= Rs 392.85

So monthly electricity bill in terms of kWh/month

$$= \frac{392.85}{2.0} \approx 196 \text{ kWh/month}$$

3) Average monthly electricity bill in terms of money for upper middle class (Reference histogram no 3 appendix II)

$$= \frac{250 + 550 + 650 + 750 + 850 + 950X2 + 1150\square 4 + 1450}{12}$$

$$= \text{Rs } 916.60$$

So monthly electricity bill in terms of kWh/month

$$= \frac{916.60}{2.0} \approx 458 \text{ kWh/month}$$

4) Average monthly electricity bill in terms of money for upper class (Reference histogram no 4 appendix II)

$$= \frac{250 + 1250X5 + 2850 + 3250X2 + 3750X2 + 4250 + 4750 + 5750}{14}$$

$$= \text{Rs } 2721.42$$

So monthly electricity bill in terms of kWh/month

$$= \frac{2721.42}{2.0} \approx 1360 \text{ kWh/month}$$

OUTAGE PER MONTH

1) Average outage per month according to poor class (Reference histogram no 5 appendix II)

$$= \frac{50X1 + 113X7 + 138X10 + 163X2 + 188X13 + 238X11 + 288X3}{47}$$

$\approx$ 180 hour/month

$\approx$ 6 hour daily

2) Average outage per month according to medium class (Reference histogram no 6 appendix II)

$$= \frac{50X6 + 113X2 + 138 + 188X2 + 238 + 288X3}{14}$$

$\approx$ 132 hour/month

$\approx$ 4hour40 minutes daily

3) Average outage per month according to upper medium class (Reference histogram no 7 appendix II)

$$= \frac{50 + 113X2 + 138X1 + 163X4 + 188X2 + 263 + 288}{12}$$

$\approx$ 166 hour/month

$\approx$ 5hour40minutes daily

4) Average outage per month according to upper class (Reference histogram no 8 appendix II)

$$= \frac{50X2 + 113X4 + 138X2 + 188X5 + 163}{14}$$

$\approx$ 138 hour/month

≈ 4hour45minutes daily

LEISURE HOUR

In the questionnaire respondents were asked electricity essential for leisure and for cross check this question another question was asked which is in appendix. Average values are obtained which will useful for find out interruption cost assessment. One calculation for lower class is showing below.

Lower

1) According to what hour electricity essential for the enjoyment of your leisure.

(Reference histogram no 9 appendix II)

$$= \frac{60X1+120X11+180X3+240X7+300X6+360X8+420X3+480X5+540X1+600X2}{47}$$

≈ 290 minutes per day

≈ 4hour50minutes per day

2) According to how do you spend average your evening/night time leisure hour.

a) Watching TV time (Reference histogram no 13 appendix II)

$$= \frac{60X29 + 120X12 + 180X5 + 240}{47}$$

≈ 90minutes/day

≈ 1hour30minutes/day

b) Reading time (Reference histogram no 17 appendix II)

$$= \frac{0X10 + 60X15 + 120X21 + 1X180}{47}$$

≈ 76minutes/day

≈ 1hour36minutes/day

c) Listening music time (Reference histogram no21appendix II)

$$= \frac{0X25 + 30X15 + 60X3 + 120X1 + 180X3}{47}$$

≈ 28minutes/day

d) Going out time (Reference histogram no 25appendix II)

$$= \frac{0X26 + 30X8 + 60X6 + 120X2 + 180X1 + 240X1 + 300X3}{47}$$

≈ 45minutes/day

Dinner time = 30 minutes daily

Total leisure hour =270 minutes/day

So that correct value of leisure hour will mean value of 1& 2.

$$= \frac{290 + 270}{2.0} = \text{4hour 40minutes per day}$$

From the same fashion mean value for leisure hour of other class values was calculated result are showing below

Middle 4hour per day

Upper middle 4hour20minutes per day

Upper 4hour40minutes per day

So that total mean value of all categories for interruption cost calculation will 4hour30minutes per day.

OUTAGE OCCOUR IN LEISURE (CRITICAL) HOUR

One calculation for one category are presented below

Lower (Reference histogram no29 appendix II)

$$= \frac{10X1+20X5+30X2+40X12+50X7+60X11+70X2+80X1+0X6}{47}$$

$$= 40\%$$

From the same manner average value of outage occur in leisure hour for other class was calculated result are showing below

Middle 40%

Upper middle 45%

Upper 35%

TABLE 1: CONSUMER SURVEY DATA PREPARATION FOR INTERRUPTION COST ASSESSMENT

Income class	No. of consumer surveyed	Average monthly electricity bill	Average interruption hour	Average critical or leisure hour	Interruption occur in critical period (%)
Lower	47	127	6.00	4.40	40
Medium	14	196	4.40	4.00	40
Upper medium	12	458	5.40	4.30	45
Upper	14	1360	4.45	4.40	35

Selected peaking period (from load duration curve): 7-8 A.M. & 6-9 P.M.

Average daily interruption hour of all categories

$$= \frac{6.00 + 4.40 + 5.40 + 4.45}{4}$$

= 5hour 20miutes daily

≈ 5 hour daily

Average daily critical or leisure hour of all categories

$$= \frac{4\text{hr } 40\text{min.} + 4\text{hr } 00\text{min.} + 4\text{hr } 30\text{min} + 4\text{hr } 40\text{min.}}{4}$$

= 4hour 30miutes daily (approx.)

Average interruption occur in critical period of all categories

$$= \frac{40 + 40 + 45 + 35}{4}$$

≈ 40% daily

INTERRUPTION COST ASSESSMENT FOR LOWER CLASS

1. SATISFACTION LEVEL REGARDING ELECTRIC SERVICE AND INTERRUPTION

a) Satisfaction level of the users

Customers were asked to give opinions regarding the quality of service provided by the UPSEB. This was based on five-point scale, which is far from satisfactory, unsatisfactory, satisfactory, good, very good. Histogram was prepared which is shown in appendix II for compilation of data for lower category that will clearly indicate the quality of service providing by the UPSEB.

$$\text{Far from satisfactory} = \frac{21 X 100}{47} = 44.6\ \%$$

$$\text{Unsatisfactory} = \frac{22 X 100}{47} = 46.80\ \%$$

$$\text{Satisfactory} = \frac{4 X 100}{47} = 8.51\ \%$$

b) Frequency of power outage

Customers were asked to give opinions regarding the frequency of power outage in his service area. This was based on five-point scale, which is shown in questionnaire appendix IV. Histogram was prepared, which is shown in appendix II for compilation of data for lower category.

$$\text{Very frequently} = \frac{19 X 100}{47} = 40.42\ \%$$

$$\text{Frequently} = \frac{21 \times 100}{47} = 44.6\ \%$$

$$\text{Average} = \frac{7 \times 100}{47} = 14.8\ \%$$

c) Price of electrical service with respect to given quality

Customers were asked to give opinions regarding price of electrical service with respect to given quality provided by the UPSEB. This question was based on yes or no alternative. 80% customer says the price of electricity is not expensive with respect to given quality provided by the UPSEB. Only 20% customer says price of electricity is too high with respect to given quality.

2. COST ESTIMATES FROM A PREPARATORY ACTION APPROACH (P.A.C)

To determine these cost some possible preparatory action were provided to help respondent to predict their choices and make was assumption that every preparatory action, which were maid by the consumers having hourly costs in Indian Rupees (Rs).

a) Failure in night (Reference histogram no41 appendix II)

Burn a candle = 3.0Rs per hour

Start the generator = 50Rs per hour

Emergency gas/light = 9.0Rs per hour

Inverter = 20Rs per hour

Kerosene light = 5.0Rs per hour

$$\text{P.A.C} = \frac{29X3+13X9+5X50+9X20}{56} = \text{Rs } 11.32 \text{ per hour}$$

b) Failure in summer (Reference histogram no45 appendix II)

Use hand fan	= 1.50Rs per hour
Start the generator	= 50Rs per hour
Use ice box	= 3.0Rs per hour
Inverter	= 20Rs per hour

$$P.A.C = \frac{6X0+6X50+7X20+32X1.5+8X3}{59} = Rs\ 8.67\ per\ hour$$

c) Failure in winter (Reference histogram no49appendixII)

Burning fuel	= 5.0Rs per hour
Start the generator	= 50Rs per hour
Kerosene stove	= 6.0Rs per hour
LPG	= 9.0Rs per hour

$$P.A.C = \frac{7X0+6X50+8X6+20X9+11X5+1X20}{53} = Rs\ 11.37\ per\ hour$$

3. COST ESTIMATES FROM WILLINGNESS TO PAY APPROACH

Unit can be consumed in peak hour in interruption duration = 3.38 unit.

Unit can be consumed in rest of interruption duration = 0.13 unit

Therefore total unit can be consumed in interruption duration = 3.51 unit

a) For Leisure hour (Reference histogram no53appendixII)

Extra willing to pay

$$= \frac{9X0+8X5+15X15+6X25+1X35+3X55+2X65+3X175}{47}$$

$= \quad 27.8\%$

$\approx \quad$ Rs 2.55

Interruption cost

= 2.55 x 3.38

= Rs 8.61 per interruption

= Rs 4.30 per hour

b) For summer hour (Reference histogram no57appendixII)

Extra willing to pay

$$= \frac{10X0+7X5+13X15+7X25+1X35+3X55+3X65+3X175}{47}$$

$= \quad 24\%$

$\approx \quad$ Rs 2.48

Interruption cost

= 2.48 x 3.51

= Rs 8.70 per interruption

= Rs 1.74 per hour

c) **For winter hour** (Reference histogram no61appendixII)

Extra willing to pay

$$= \frac{23X0 + 8X5 + 6X15 + 4X25 + 3X35 + 2X\ 65 + 1X175}{31}$$

$= \quad 13.63\%$

$\approx \quad$ Rs 2.27

Interruption cost

= 2.27 x 3.51

= Rs 7.96 per interruption

= Rs 1.59 per hour

$$\text{Average Interruption cost} = \frac{4.30 + 1.74 + 1.59}{3}$$

= Rs 2.54 per hour

INTERRUPTION COST ASSESSMENT FOR MIDDLE CLASS

1. SATISFACTION LEVEL REGARDING ELECTRIC SERVICE AND INTERRUPTION

a) Satisfaction level of the users

Customers were asked to give opinions regarding the quality of service provided by the UPSEB. This was based on five-point scale, which is far from satisfactory, unsatisfactory, satisfactory, good, very good. Histogram was prepared which is shown in appendix II for compilation of data for middle class that will clearly indicate the quality of service providing by the UPSEB.

$$\text{Far from satisfactory} = \frac{5 \text{ X } 100}{14} = 35.7\ \%$$

$$\text{Unsatisfactory} = \frac{7\text{X } 100}{14} = 50.0\ \%$$

$$\text{Satisfactory} = \frac{2 \text{ X } 100}{14} = 14.2\ \%$$

b) Frequency of power outage

Customers were asked to give opinions regarding the frequency of power outage in his service area. This was based on five-point scale, which is shown in questionnaire appendix IV. Histogram was prepared which is shown in appendix II for compilation of data for middle category.

$$\text{Frequently} = \frac{5\text{X}100}{14} = 35.71\ \%$$

$$\text{Average} = \frac{9 \times 100}{14} = 64.28\ \%$$

c) Price of electrical service with respect to given quality

Customers were asked to give opinions regarding price of electrical service with respect to given quality provided by the UPSEB. This question was based on yes or no alternative. 85% customer says the price of electricity is not expensive with respect to given quality provided by the UPSEB. Only 15% customer says price of electricity is too high with respect to given quality.

2. COST ESTIMATES FROM A PREPARATORY ACTION APPROACH (P.A.C)

To determine these cost some possible preparatory action were provided to help respondent to predict their choices and make was assumption that every preparatory action, which were maid by the consumers having hourly costs in Indian Rupees (Rs).

a) Failure in night (Reference histogram no42appendixII)

Burn a candle	= 3.0Rs per hour
Start the generator	= 50Rs per hour
Emergency gas/light	= 9.0Rs per hour
Inverter	= 20Rs per hour
Kerosene light	= 5.0Rs per hour

$$\text{P.A.C} = \frac{2X5 + 7X9 + 2X2 + 4X20}{14} = \text{Rs } 11.21 \text{ per hour}$$

b) Failure in summer (Reference histogram no46appendixII)

Use hand fan	= 1.50Rs per hour
Start the generator	= 50Rs per hour
Use ice box	= 3.0Rs per hour
Inverter	= 20Rs per hour

$$P.A.C = \frac{5X50 + 3X20 + 8X1.5 + 3X3}{19} = \text{Rs } 17.42 \text{ per hour}$$

c) Failure in winter (Reference histogram no50appendixII)

Burning fuel	= 5.0Rs per hour
Start the generator	= 50Rs per hour
Kerosene stove	= 6.0Rs per hour
LPG	= 9.0Rs per hour

$$P.A.C = \frac{0X1 + 2X50 + 3X5 + 4X6 + 3X9}{18} = \text{Rs } 13.38 \text{ per hour}$$

3. COST ESTIMATES FROM WILLINGNESS TO PAY APPROACH

Unit can be consumed in peak hour in interruption duration = 5.2 unit

Unit can be consumed in rest of interruption duration = 0.21 unit

Therefore total unit can be consumed in interruption duration = 5.41 unit

a) **For Leisure hour** (Reference histogram no54appendixII)

Extra willing to pay

$$= \frac{3X5 + 2X25 + 1X35 + 1X65 + 3X125 + 3X175}{14}$$

= 76.07%

≈ Rs 3.52

Interruption cost

= 3.52 x 5.2

= Rs 18.30 per interruption

= Rs 9.15 per hour

b) **For summer hour** (Reference histogram no58appendixII)

Extra willing to pay

$$= \frac{5X1 + 15X2 + 25X1 + 35 + 95 + 175X5 + 225X2}{14}$$

= 108.2%

≈ Rs 4.16

Interruption cost = 5.416 x 4.16

= Rs 22.53 per interruption

= Rs 5.63 per hour

c) **For winter hour** (Reference histogram no62appendixII)

Extra willing to pay

$$= \frac{6X175 + 55X1 + 35X1 + 25X1 + 5X2}{14}$$

= 83.92%

≈ Rs 3.66

Interruption cost

= 5.416 x 3.66

= Rs 19.82 per interruption

= Rs 4.95 per hour

$$\text{Average Interruption cost} = \frac{9.15 + 5.63 + 4.95}{3}$$

= Rs 6.57 per hour

INTERRUPTION COST ASSESSMENT FOR UPPER MIDDLE CLASS

1. SATISFACTION LEVEL REGARDING ELECTRIC SERVICE AND INTERRUPTION

a) Satisfaction level of the users

Customers were asked to give opinions regarding the quality of service provided by the UPSEB. This was based on five-point scale, which is far from satisfactory, unsatisfactory, satisfactory, good, very good. Histogram was prepared which is shown in appendix II for compilation of data for upper middle class that will clearly indicate the quality of service providing by the UPSEB.

$$\text{Far from satisfactory} = \frac{5 \text{ X } 100}{12} = 41.66\ \%$$

$$\text{Unsatisfactory} = \frac{7\text{X}100}{12} = 58.3\ \%$$

b) Frequency of power outage

Customers were asked to give opinions regarding the frequency of power outage in his service area. This was based on five-point scale, which is shown in questionnaire appendix IV. Histogram was prepared which is shown in appendix II for compilation of data for medium category.

$$\text{Very frequently} = \frac{7\text{X}100}{12} = 58.33\%$$

$$\text{Frequently} = \frac{3\text{X}100}{12} = 25.00\ \%$$

$$\text{Average} = \frac{2 \times 100}{12} = 16.66\ \%$$

c) Price of electrical service with respect to given quality

Customers were asked to give opinions regarding price of electrical service with respect to given quality provided by the UPSEB. This question was based on yes or no alternative. 85% customer says the price of electricity is not expensive with respect to given quality provided by the UPSEB. Only 15% customer says price of electricity is too high with respect to given quality.

2. COST ESTIMATES FROM A PREPARATORY ACTION APPROACH (P.A.C)

To determine these cost some possible preparatory action were provided to help respondent to predict their choices and make was assumption that every preparatory action, which were maid by the consumers having hourly costs in Indian Rupees (Rs).

a) Failure in night (Reference histogram no43 appendix II)

Burn a candle	= 3.0Rs per hour
Start the generator	= 50Rs per hour
Emergency gas/light	= 9.0Rs per hour
Inverter	= 20Rs per hour
Kerosene light	= 5.0Rs per hour

$$\text{P.A.C} = \frac{2X9 + 8X50 + 2X20}{12} = \text{Rs } 38.16 \text{ per hour}$$

b) Failure in summer (Reference histogram no47 appendix II)

Use hand fan = 1.50Rs per hour

Start the generator = 50Rs per hour

Use ice box = 3.0Rs per hour

Inverter = 20Rs per hour

$$P.A.C = \frac{0X1 + 8X50 + 2X20 + 3X1.5 + 4X3}{17} = Rs\ 26.85 \text{ per hour}$$

c) Failure in winter (Reference histogram no51appendix II)

Burning fuel = 5.0Rs per hour

Start the generator = 50Rs per hour

Kerosene stove = 6.0Rs per hour

LPG = 9.0Rs per hour

$$P.A.C = \frac{1X0 + 8X50 + 4X5 + 1X6 + 1X9 + 1X20}{16} = Rs\ 28.43 \text{ per hour}$$

3. COST ESTIMATES FROM WILLINGNESS TO PAY APPROACH

Unit can be consumed in peak hour in interruption duration = 12.16 unit

Unit can be consumed in rest of interruption duration = 0.50 unit

Therefore total unit can be consumed in interruption duration = 13.16 unit

a) For Leisure hour (Reference histogram no55appendix II)

Extra willing to pay

$$= \frac{5X3 + 35X1 + 65X2 + 95X2 + 125X3 + 175X1}{12}$$

= 76.6%

≈ Rs 3.53

Interruption cost

= 3.53 x 12.16

= Rs 42.56 per interruption

= Rs 21.28 per hour

b) For summer hour (Reference histogram no59appendix II)

Extra willing to pay

$$= \frac{5X1 + 15X2 + 55X1 + 65X1 + 175X5 + 225X2}{12}$$

= 125.0%

≈ Rs 4.50

Interruption cost

= 4.50X13.16

= Rs 59.22 per interruption

= Rs 14.80 per hour

c) For winter hour (Reference histogram no63appendix II)

Extra willing to pay

$$= \frac{0X3 + 5X1 + 55X1 + 65X2 + 95X2 + 175X3}{12}$$

= 75.41%

≈ Rs 3.50

Interruption cost

= 3.50X13.16

= Rs 46.16 per interruption

= Rs 11.54 per hour

$$\text{Average Interruption cost} = \frac{21.28+14.80+11.54}{3}$$

= Rs 15.87 per hour

INTERRUPTION COST ASSESSMENT FOR UPPER CLASS

1. SATISFACTION LEVEL REGARDING ELECTRIC SERVICE AND INTERRUPTION

a) Satisfaction level of the users

Customers were asked to give opinions regarding the quality of service provided by the UPSEB. This was based on five-point scale, which is far from satisfactory, unsatisfactory, satisfactory, good, very good. Histogram was prepared which is shown in appendix II for compilation of data for upper class that will clearly indicate the quality of service providing by the UPSEB.

$$\text{Far from satisfactory} = \frac{5 \text{ X } 100}{14} = 35.7\ \%$$

$$\text{Unsatisfactory} = \frac{9\text{X } 100}{14} = 64.2\ \%$$

b) Frequency of power outage

Customers were asked to give opinions regarding the frequency of power outage in his service area. This was based on five-point scale, which is shown in questionnaire appendix IV. Histogram was prepared, which is shown in appendix II for compilation of data for medium category.

$$\text{Very frequently} = \frac{5\text{X}100}{14} = 35.71\%$$

$$\text{Frequently} = \frac{7\text{X}100}{14} = 50.0\ \%$$

$$\text{Average} = \frac{2 \text{ X } 100}{14} = 14.2\ \%$$

c) Price of electrical service with respect to given quality

Customers were asked to give opinions regarding price of electrical service with respect to given quality provided by the UPSEB. This question was based on yes or no alternative.95 %customer says the price of electricity is not expensive with respect to given quality provided by the UPSEB. Only 5% customer says price of electricity is too high with respect to given quality.

2. COST ESTIMATES FROM A PREPARATORY ACTION APPROACH (P.A.C)

To determine these cost some possible preparatory action were provided to help respondent to predict their choices and make was assumption that every preparatory action, which were maid by the consumers having hourly costs in Indian Rupees (Rs).

a) Failure in night (Reference histogram no 44appendixII)

Burn a candle	= 3.0Rs per hour
Start the generator	= 50Rs per hour
Emergency gas/light	= 9.0Rs per hour
Inverter	= 20Rs per hour
Kerosene light	= 5.0Rs per hour

$$\text{P.A.C} = \frac{2X9 + 10X50 + 2X20}{14} = \text{Rs } 39.85 \text{ per hour}$$

b) Failure in summer (Reference histogram no48appendix II)

Use hand fan	= 1.50Rs per hour
Start the generator	= 50Rs per hour
Use ice box	= 3.0Rs per hour
Inverter	= 20Rs per hour

$$P.A.C = \frac{11X50 + 20X2 + 4X1.5 + 2X3}{17} = Rs\ 35.41\ \text{per hour}$$

c) Failure in winter (Reference histogram no52appendix II)

Burning fuel	= 5.0Rs per hour
Start the generator	= 50Rs per hour
Kerosene stove	= 6.0Rs per hour
LPG	= 9.0Rs per hour

$$P.A.C = \frac{11X50 + 2X5 + 1X6 + 1X9}{14} = Rs\ 41.7\ \text{per hour}$$

3. COST ESTIMATES FROM WILLINGNESS TO PAY APPROACH

Unit can be consumed in peak hour in interruption duration = 36.28 unit

Unit can be consumed in rest of interruption duration = 1.51 unit

Therefore total unit can be consumed in interruption duration = 37.8 unit

a) For Leisure hour (Reference histogram no56 appendix II)

Extra willing to pay

$$= \frac{5X3 + 1X35 + 55X1 + 65X3 + 95X4 + 175X2}{14}$$

= 60.0%

≈ Rs 3.20

Interruption cost

= 3.20 x 36.28

= Rs 116.9 per interruption

= Rs 58.05 per hour

b) For summer hour (Reference histogram no60appendix II)

Extra willing to pay

$$= \frac{15X1 + 25X2 + 65X3 + 95X2 + 175X5 + 250X1}{14}$$

= 112.5%

≈ Rs 4.25

Interruption cost

= 4.25X 37.8

= Rs 160.60 per interruption

= Rs 40.15 per hour

c) For winter hour (Reference histogram no 64 appendix II)

Extra willing to pay

$$= \frac{0X1 + 5X3 + 15X1 + 55X2 + 65X2 + 75X2 + 95X1 + 175X2}{14}$$

= 61.78%

≈ Rs 3.23

Interruption cost

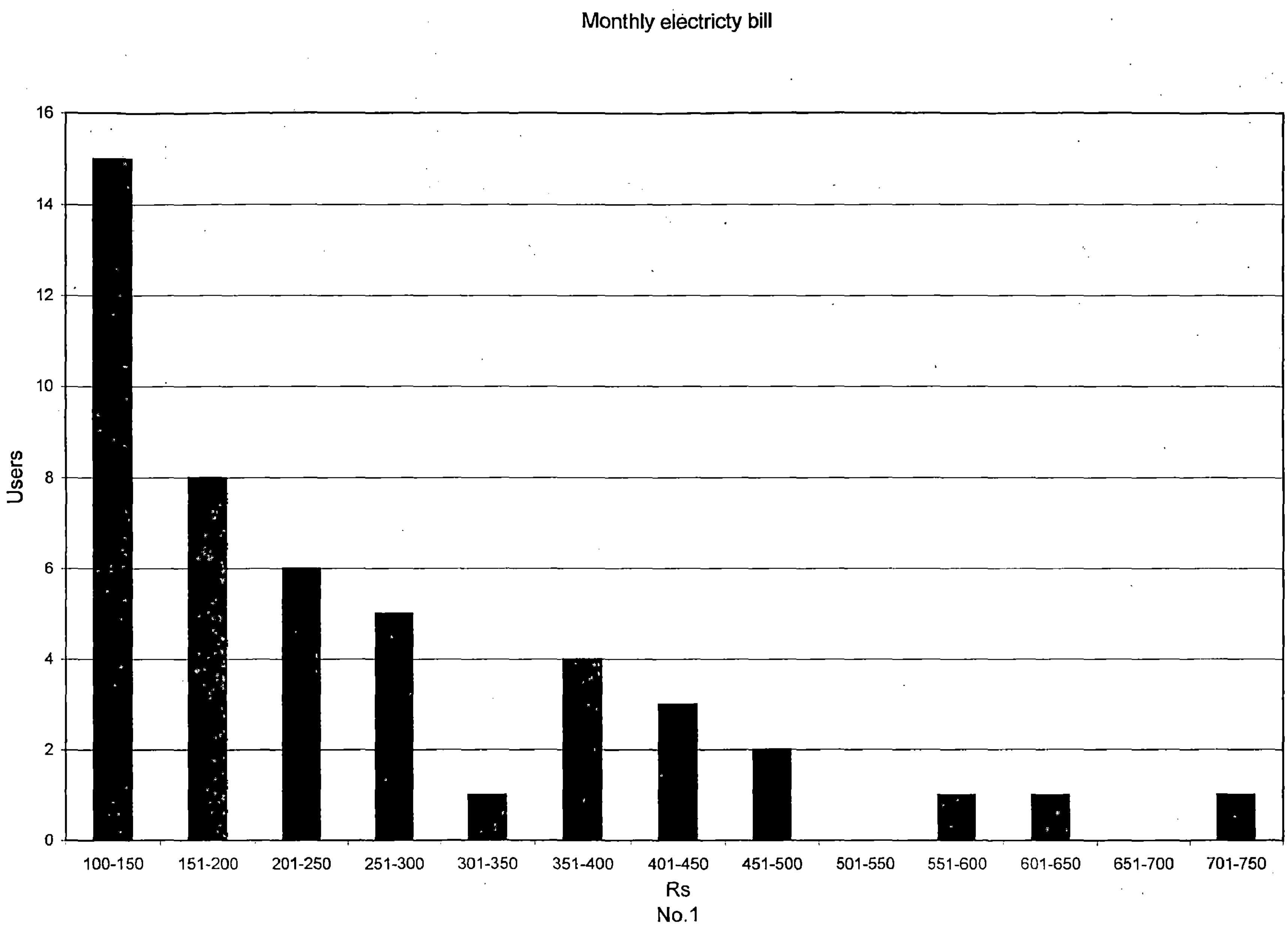
= 3.23X37.8

= Rs 143.64 per interruption

= Rs 35.91 per hour

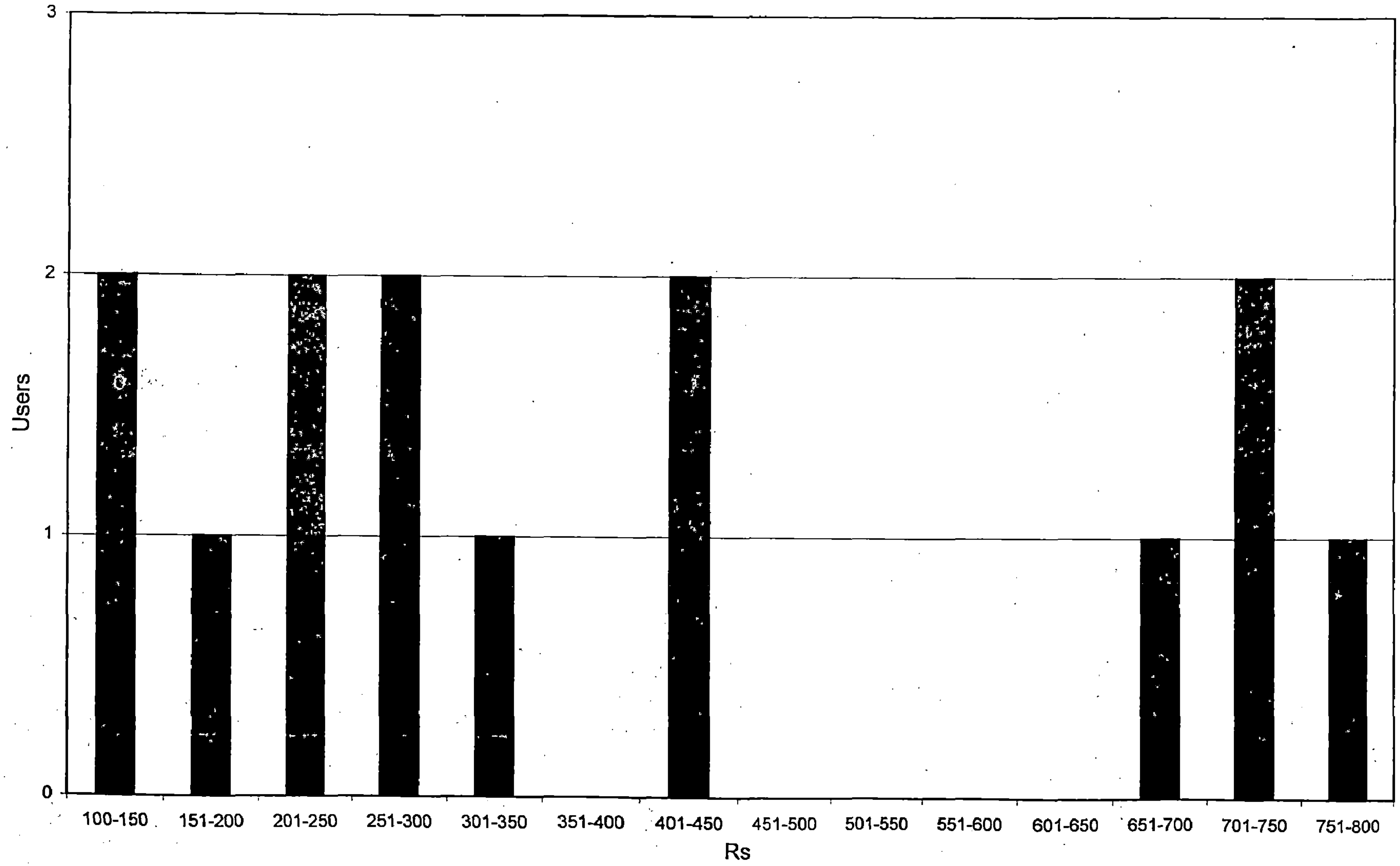
$$\text{Average Interruption cost} = \frac{58+40.15+35.91}{3}$$

= Rs 44.68 per hour



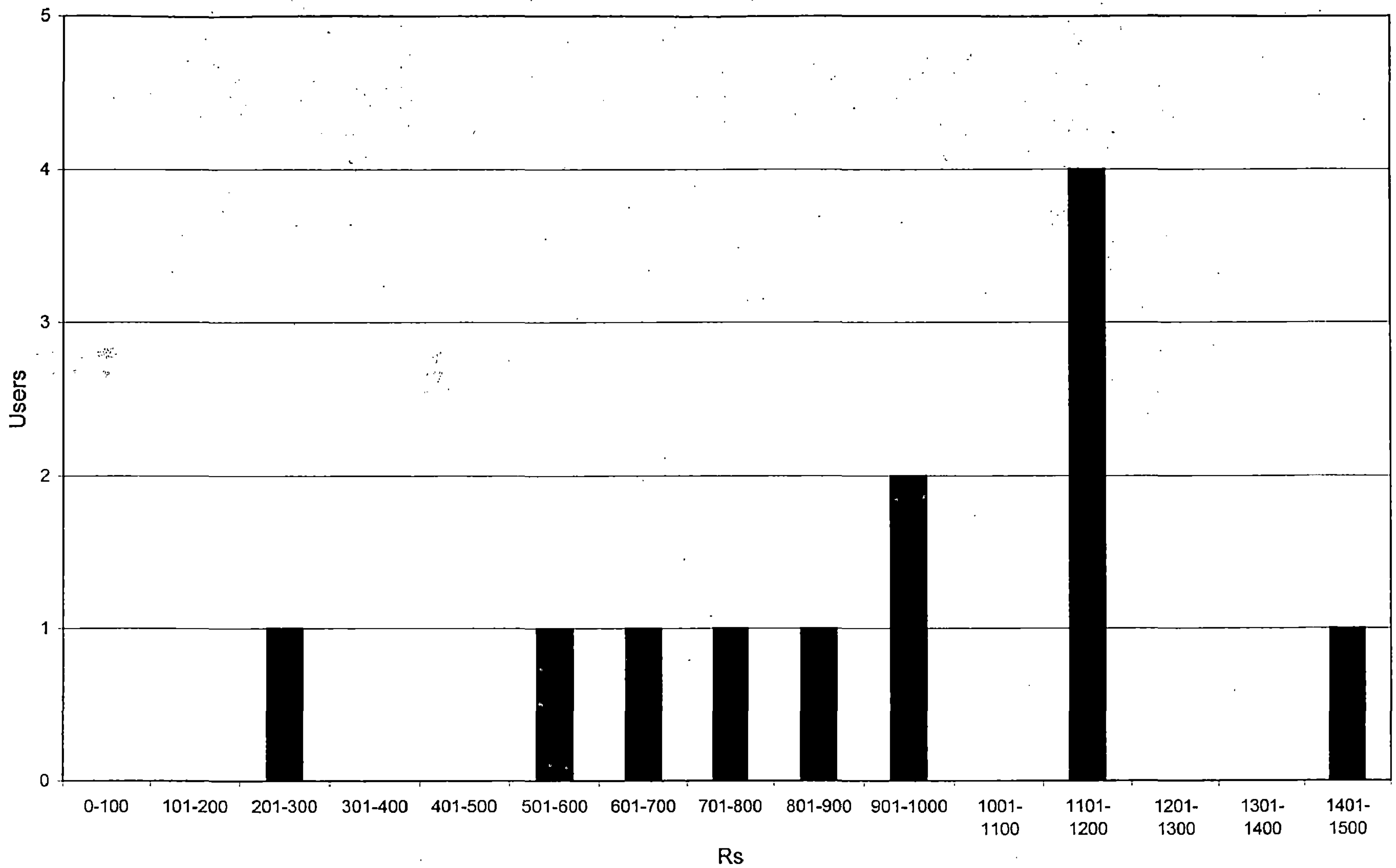
Monthly electricty bill
Users
16
14
12
10
8
6
4
2
0
100-150
151-200
201-250
251-300
301-350
351-400
401-450
451-500
501-550
551-600
601-650
651-700
701-750
Rs
No.1

Monthly electricty bill



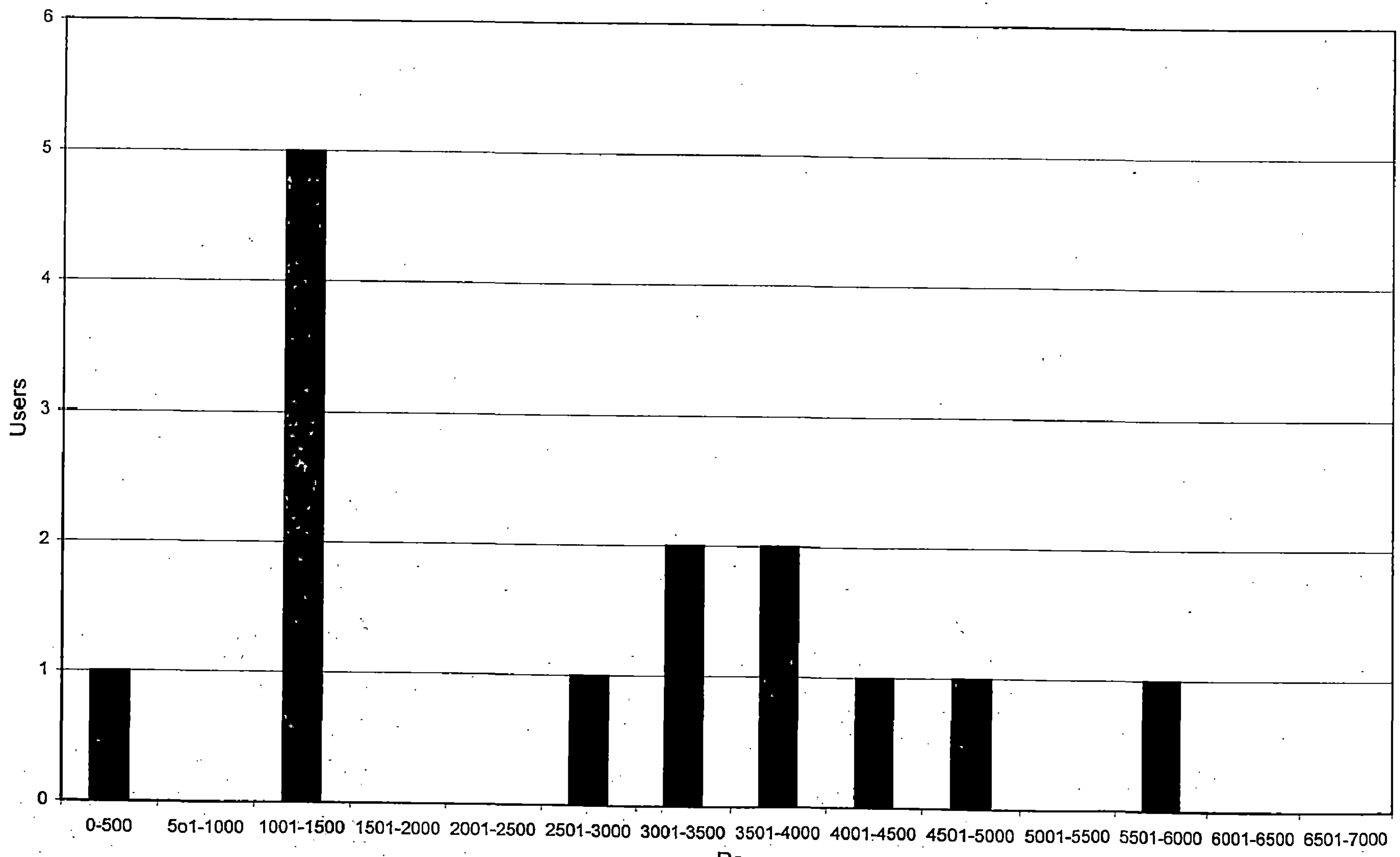
No. 2

Monthly electricty bill

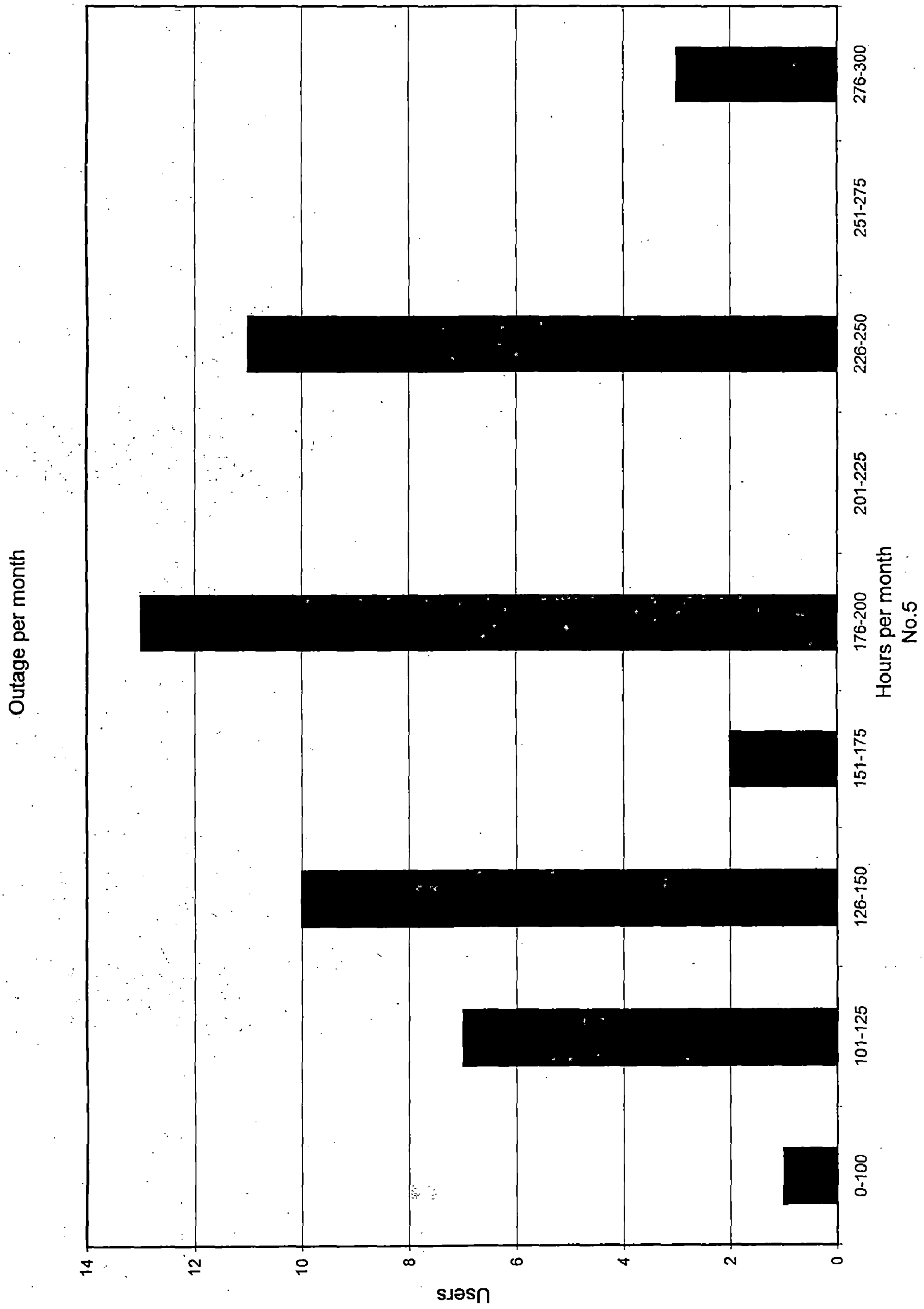


No. 3

Monthly electricty bill

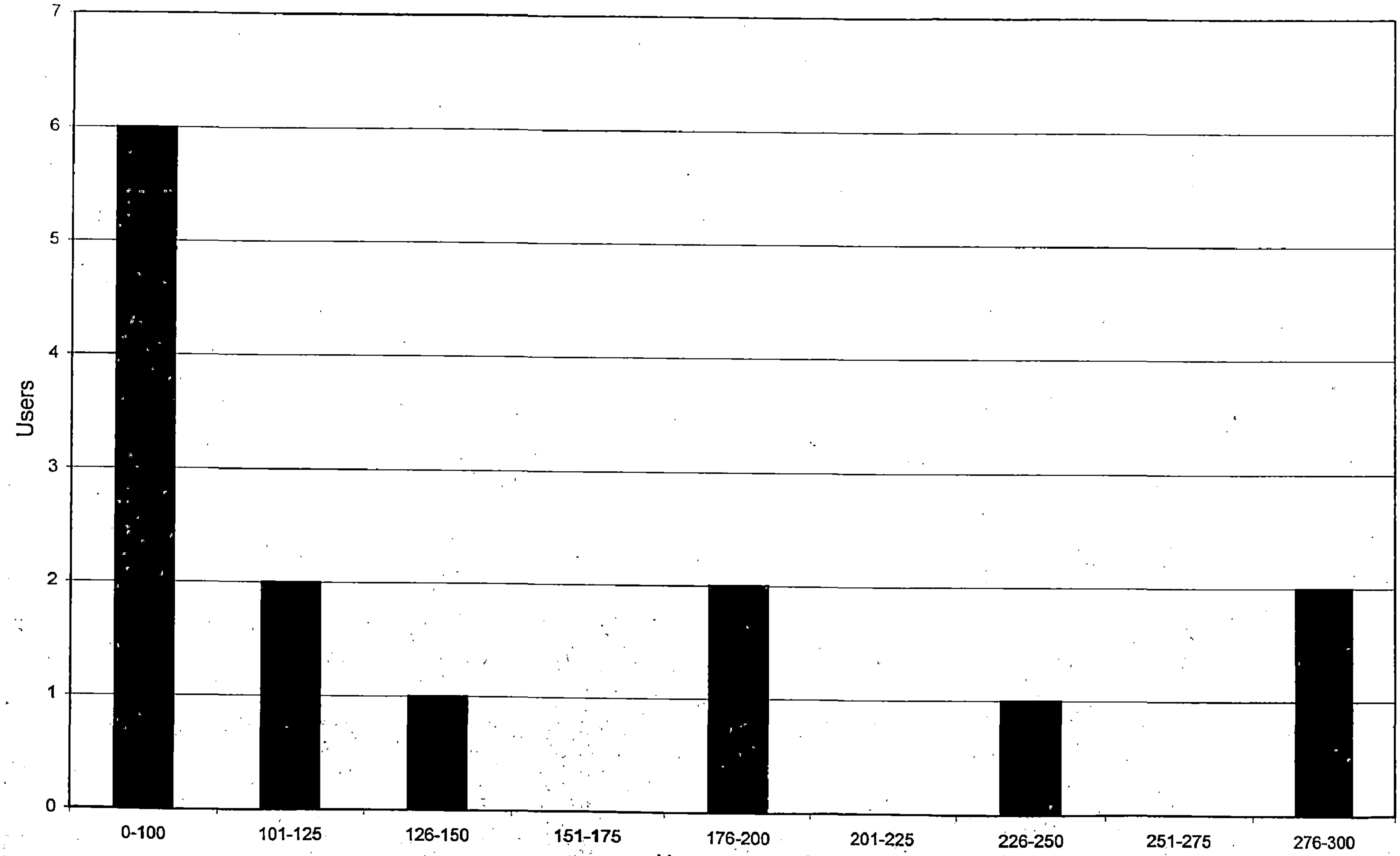


No. 4

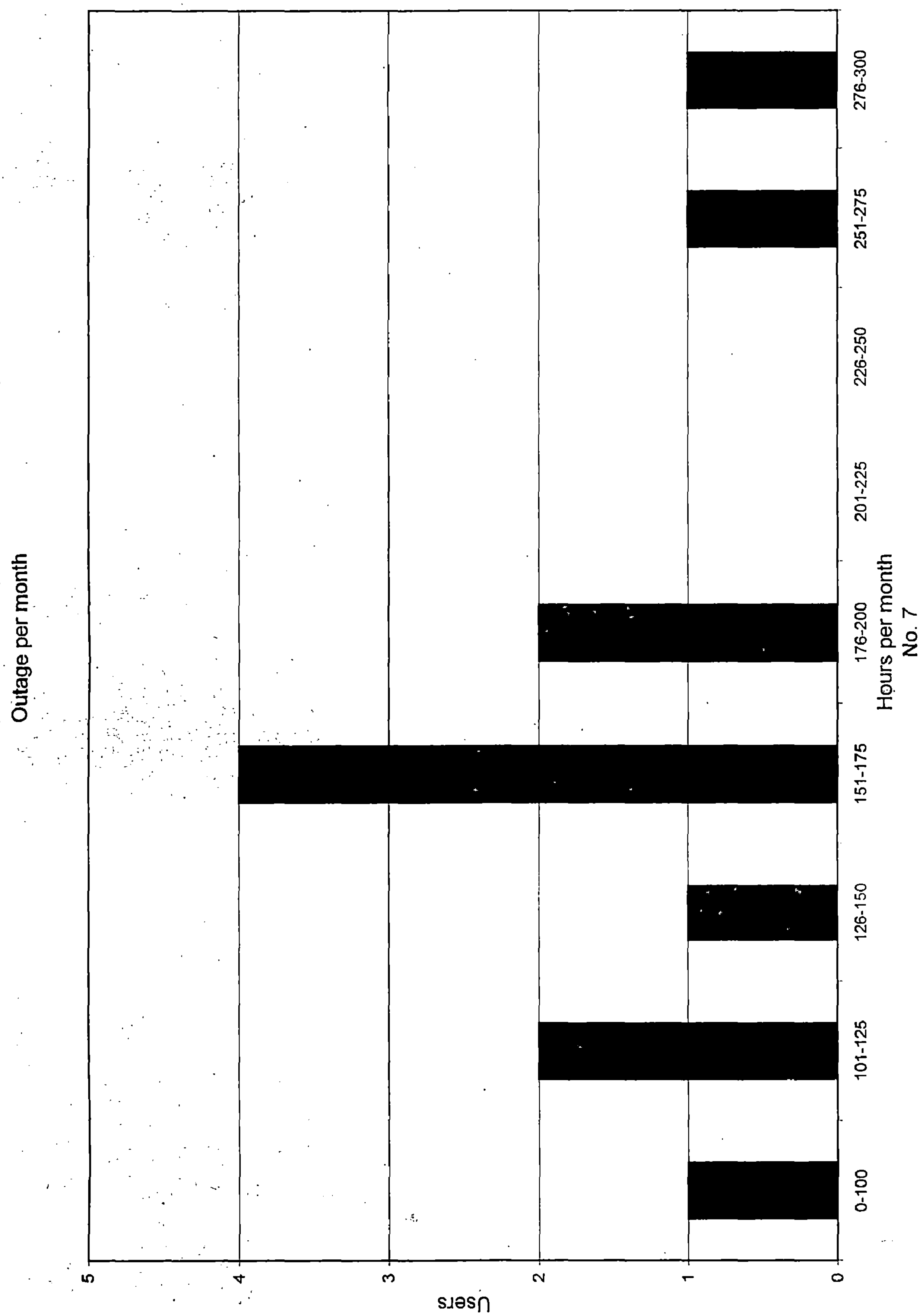


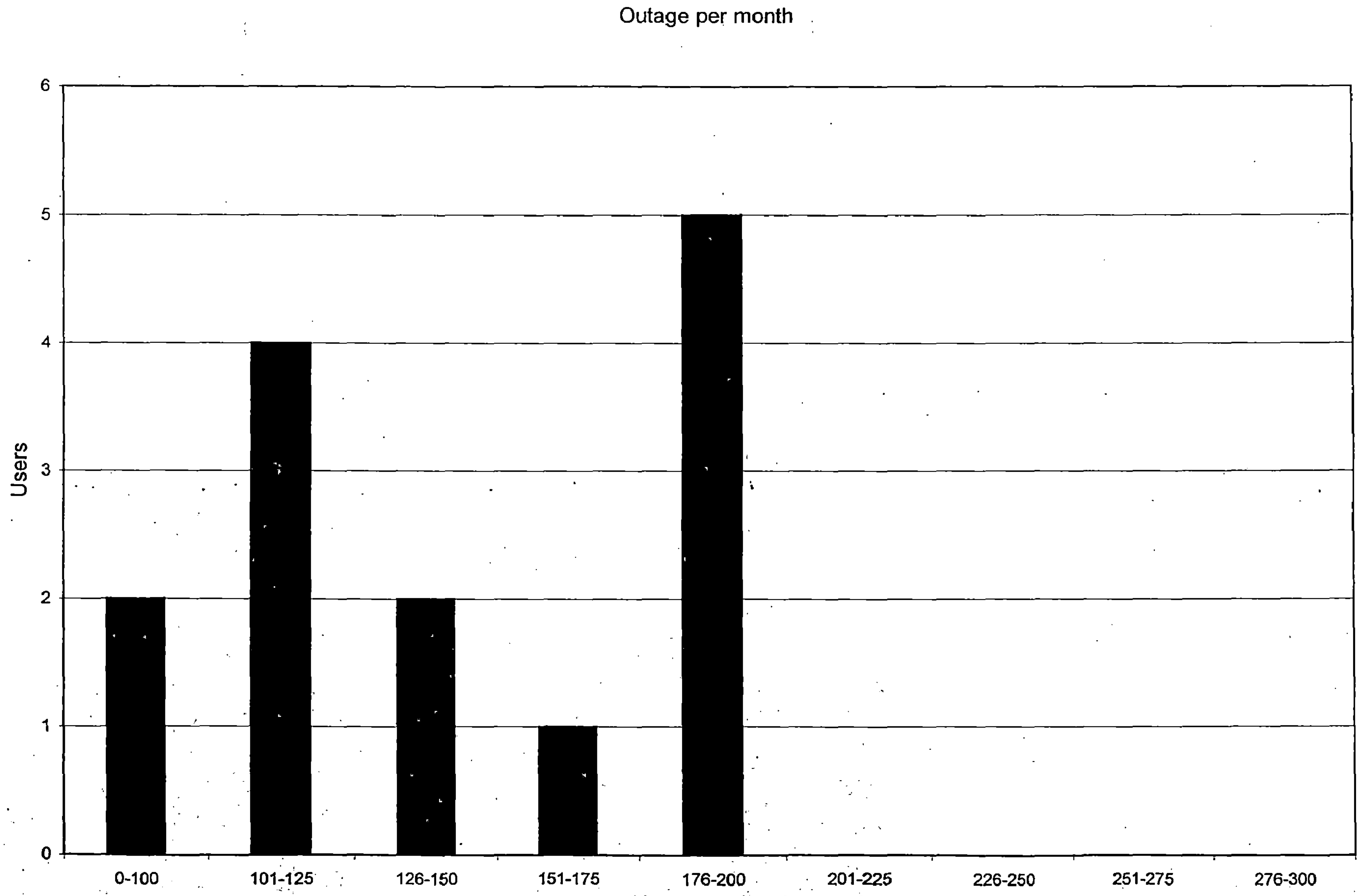
Outage per month
Users
0
2
4
6
8
10
12
14
0-100
101-125
126-150
151-175
176-200
201-225
226-250
251-275
276-300
Hours per month
No.5

Outage per month

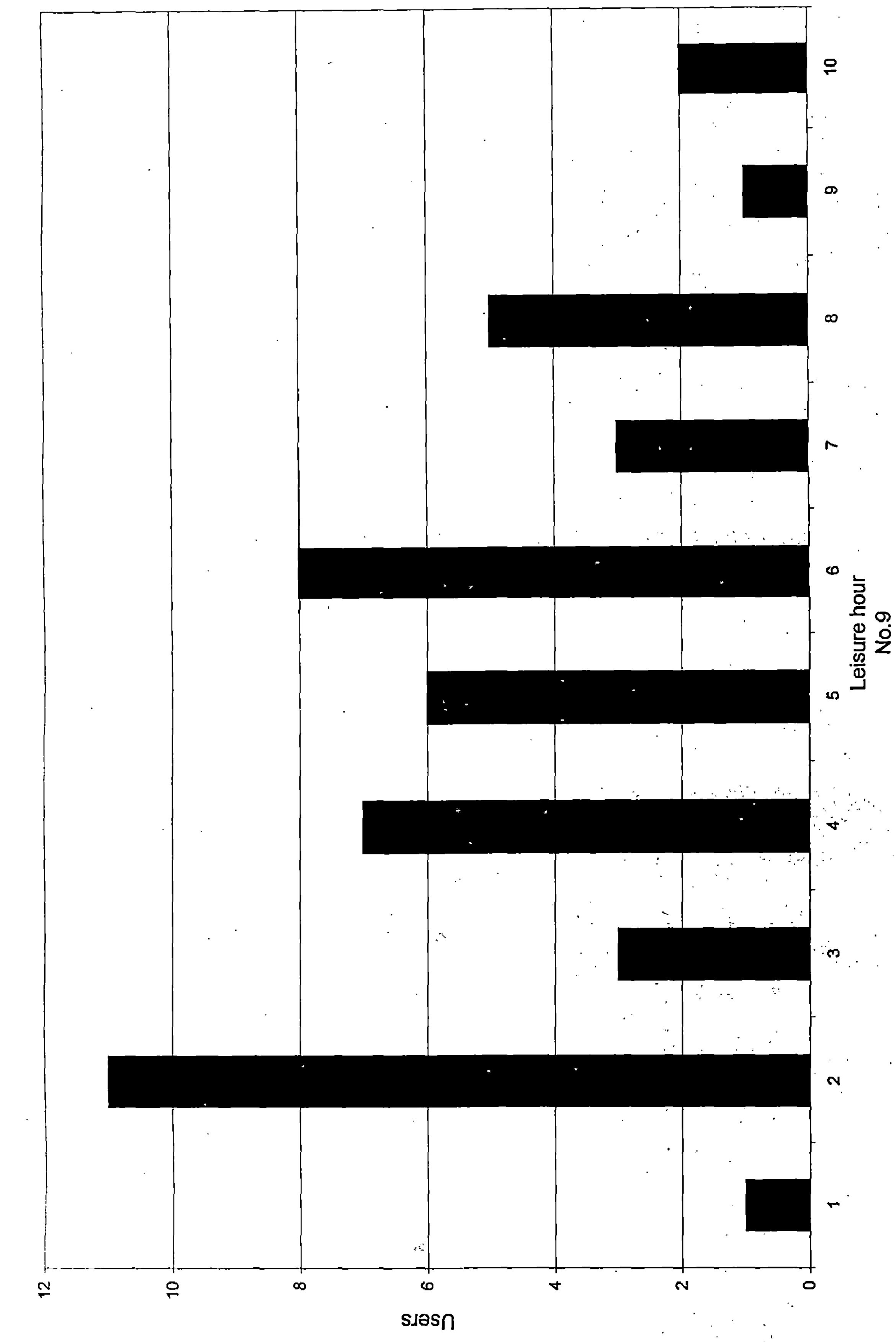


No.6

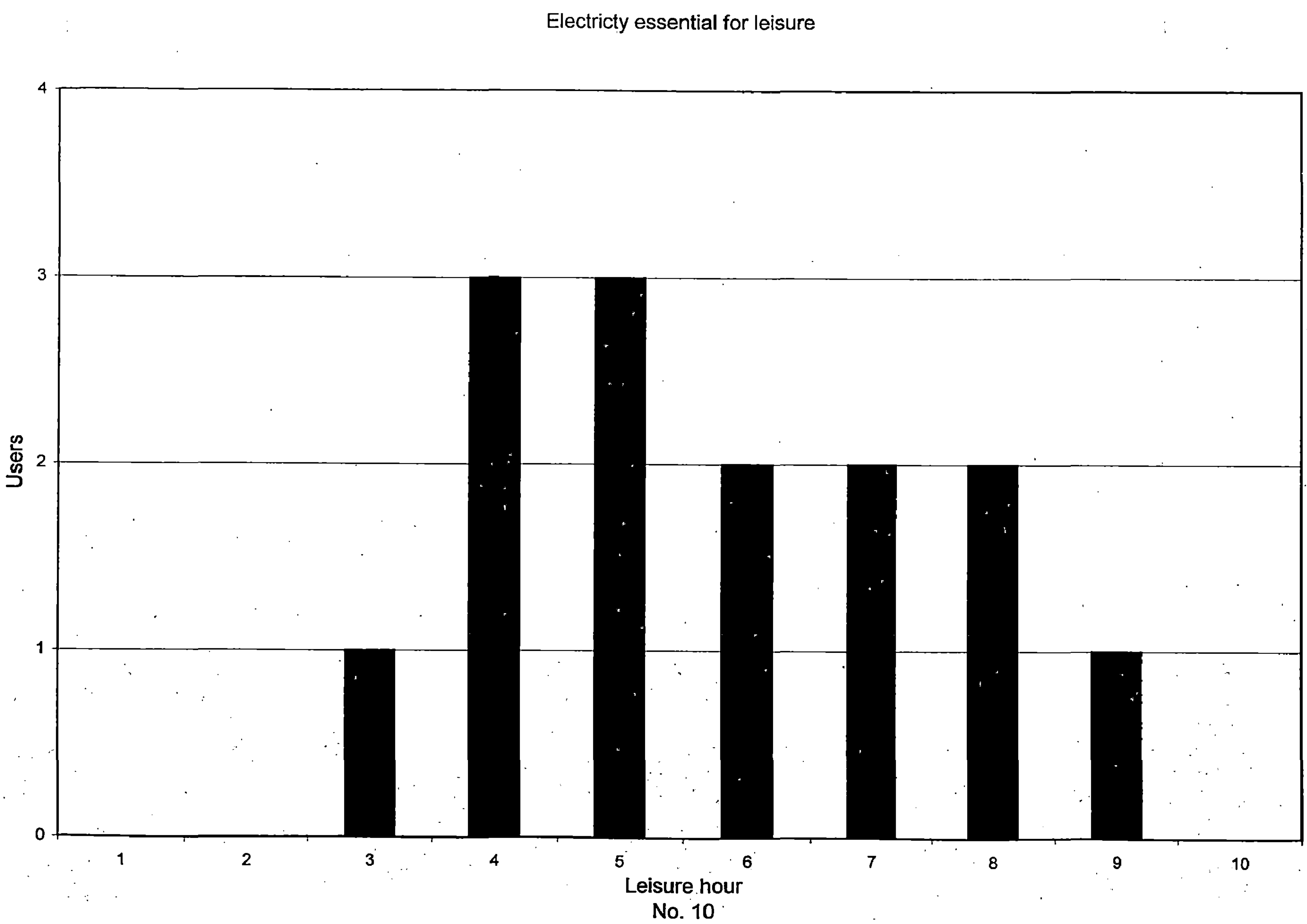

Outage per month
Users
0
1
2
3
4
5
0-100
101-125
126-150
151-175
176-200
201-225
226-250
251-275
276-300
Hours per month
No. 7

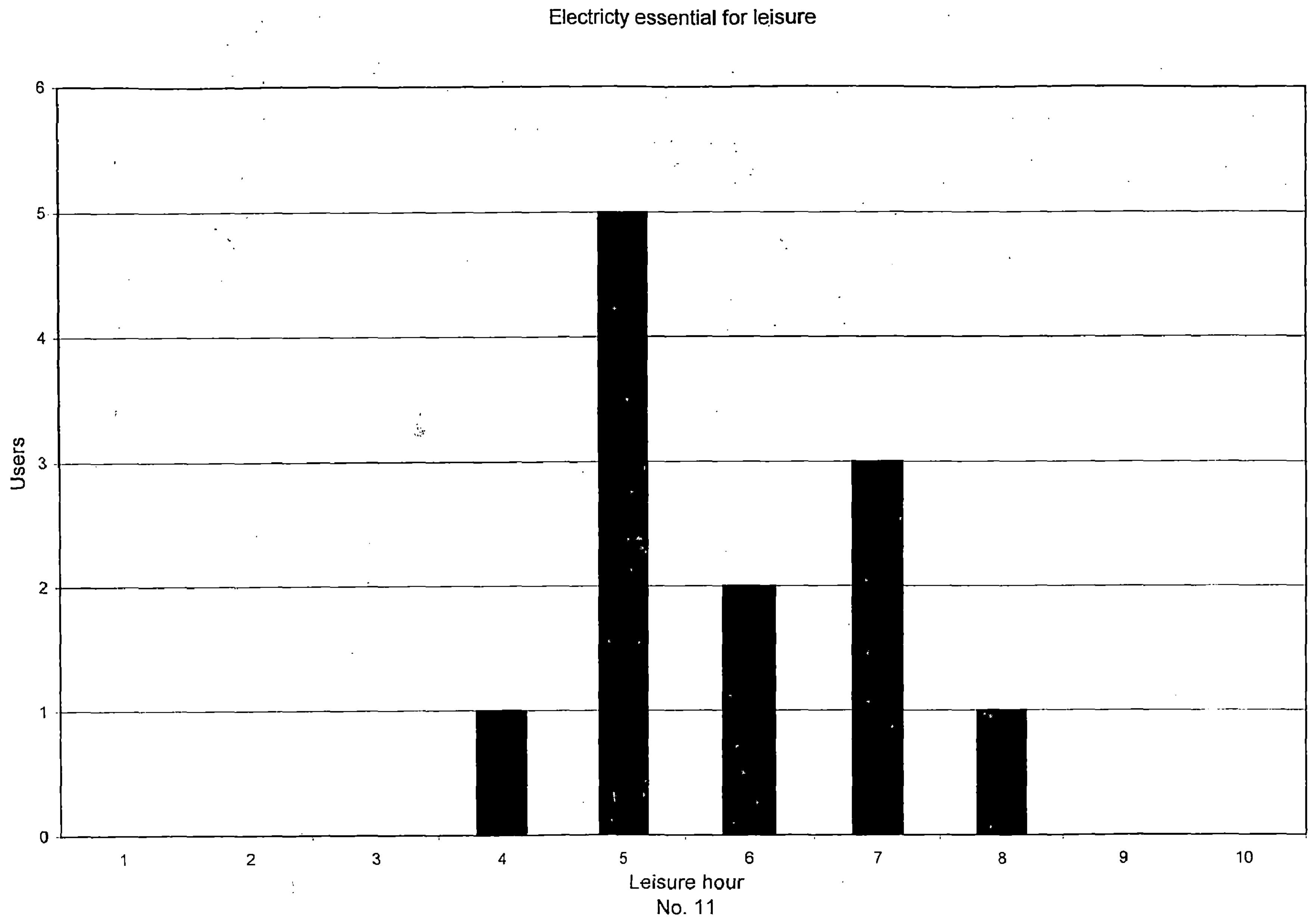

Outage per month
Users
6
5
4
3
2
1
0
0-100
101-125
126-150
151-175
176-200
201-225
226-250
251-275
276-300
Hours per month

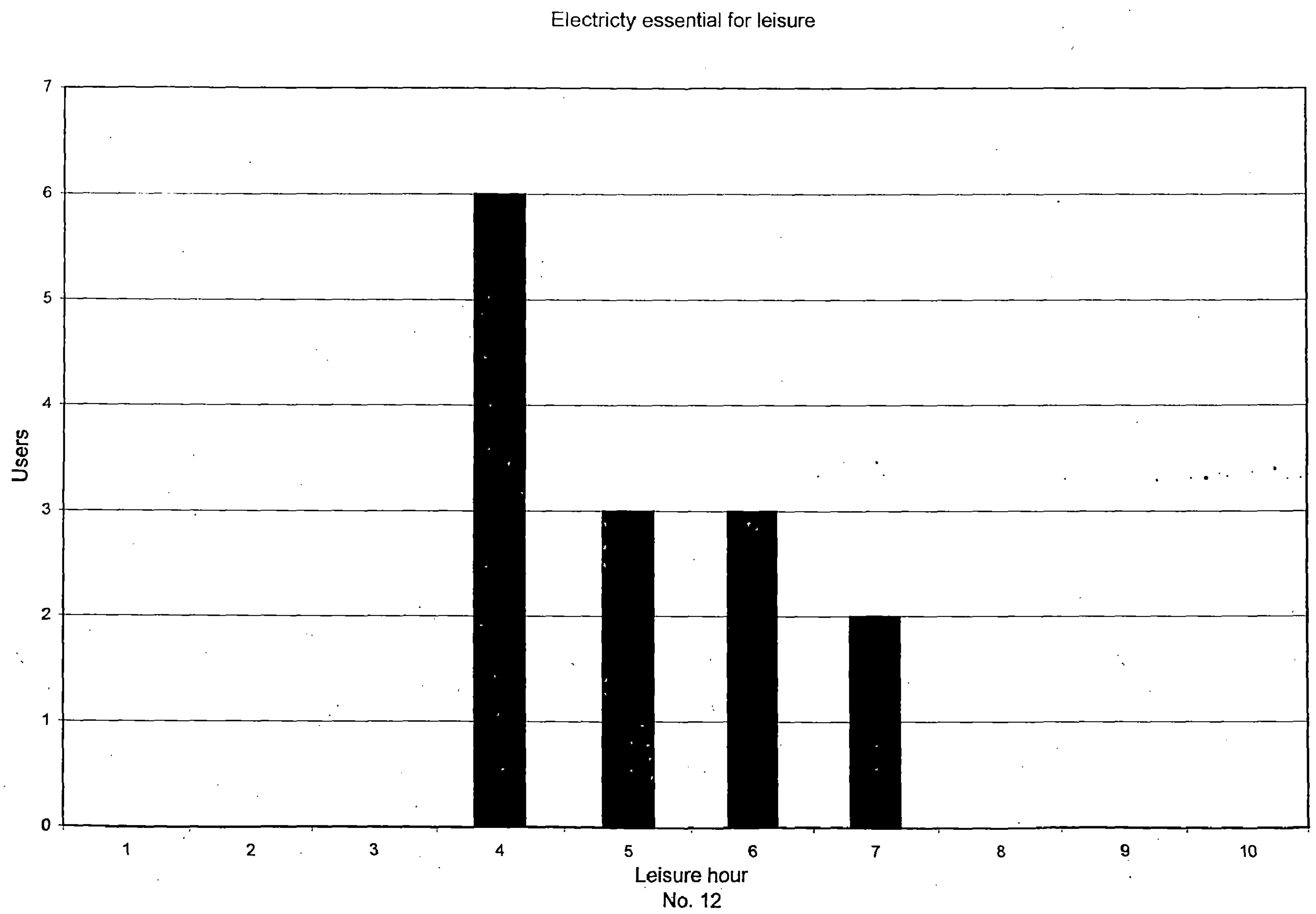
No. 8

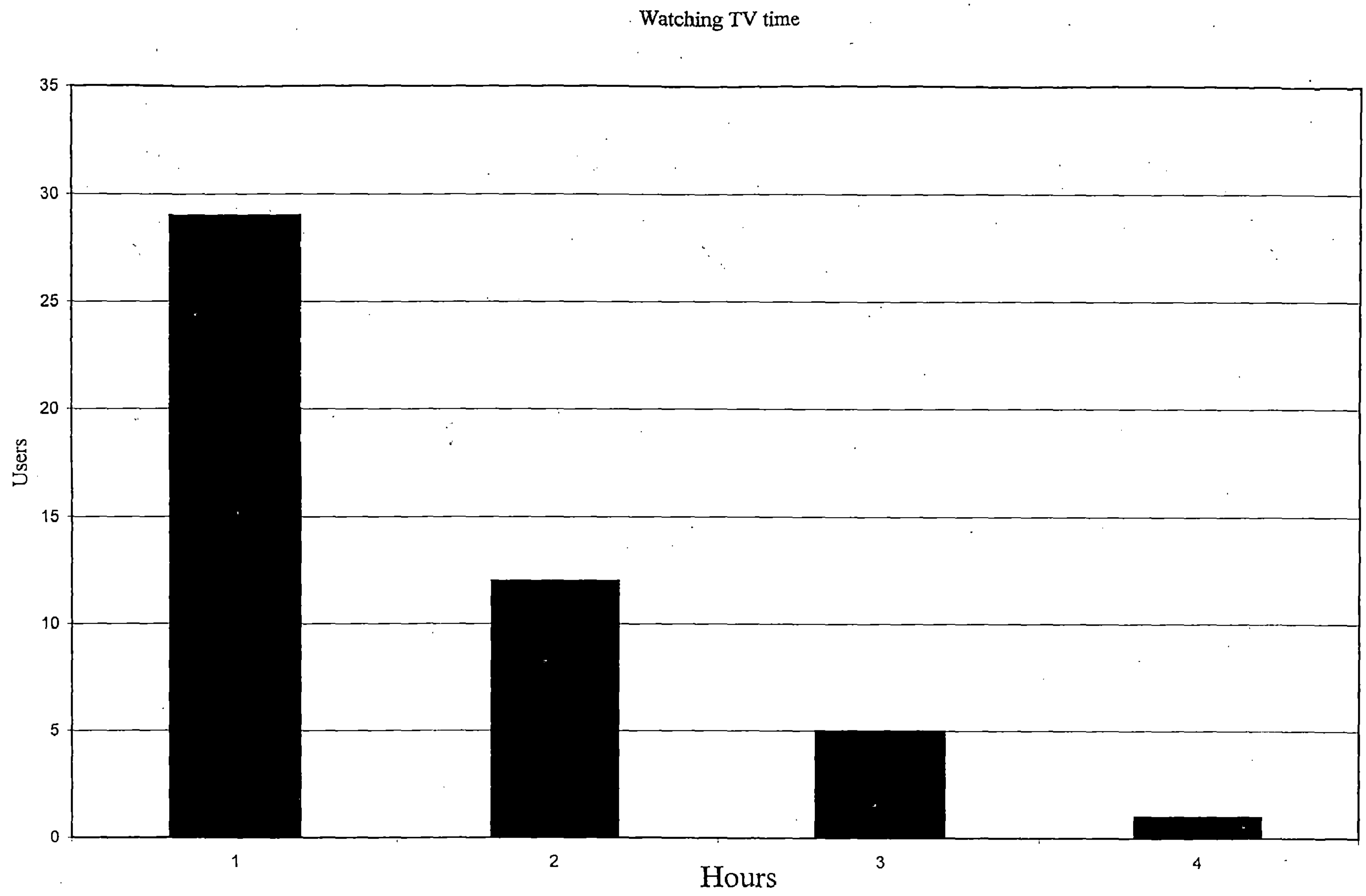


Electricty essential for leisure

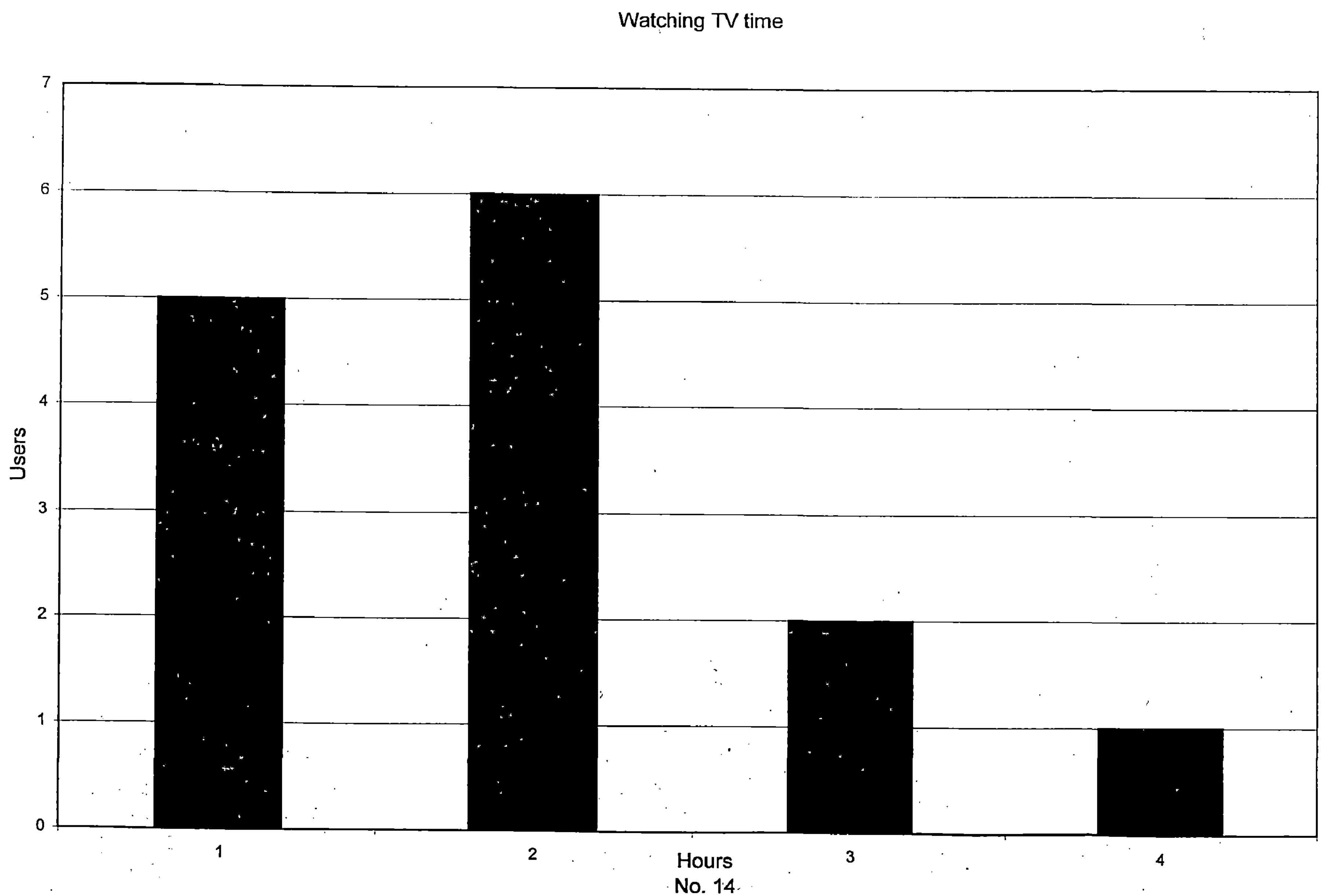

Electricty essential for leisure
Users
0
1
2
3
4
1
2
3
4
5
6
7
8
9
10
Leisure hour
No. 10

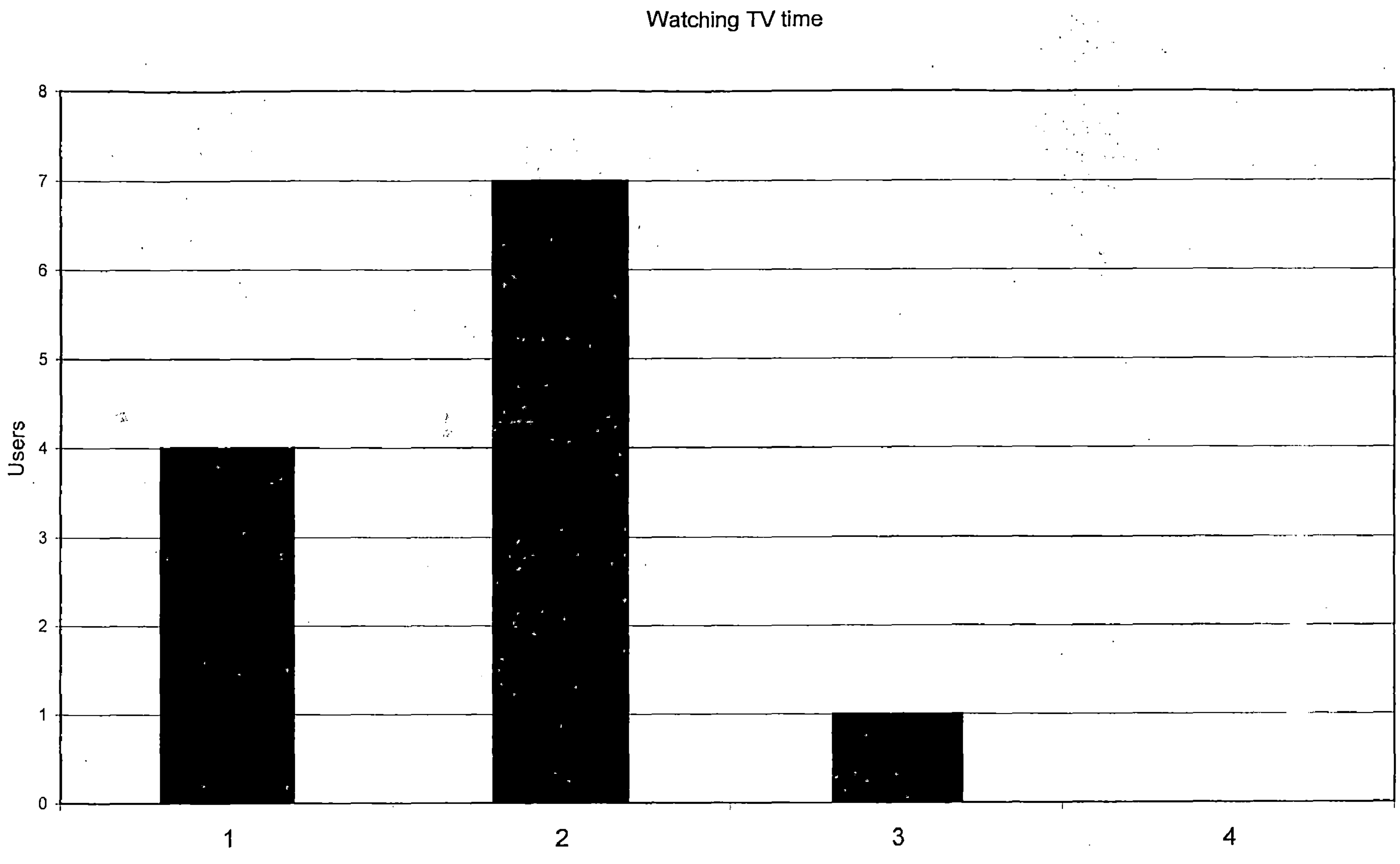

Electricty essential for leisure
Users
0
1
2
3
4
5
6
1
2
3
4
5
6
7
8
9
10
Leisure hour
No. 11


Electricty essential for leisure
Users
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
9
10
Leisure hour
No. 12



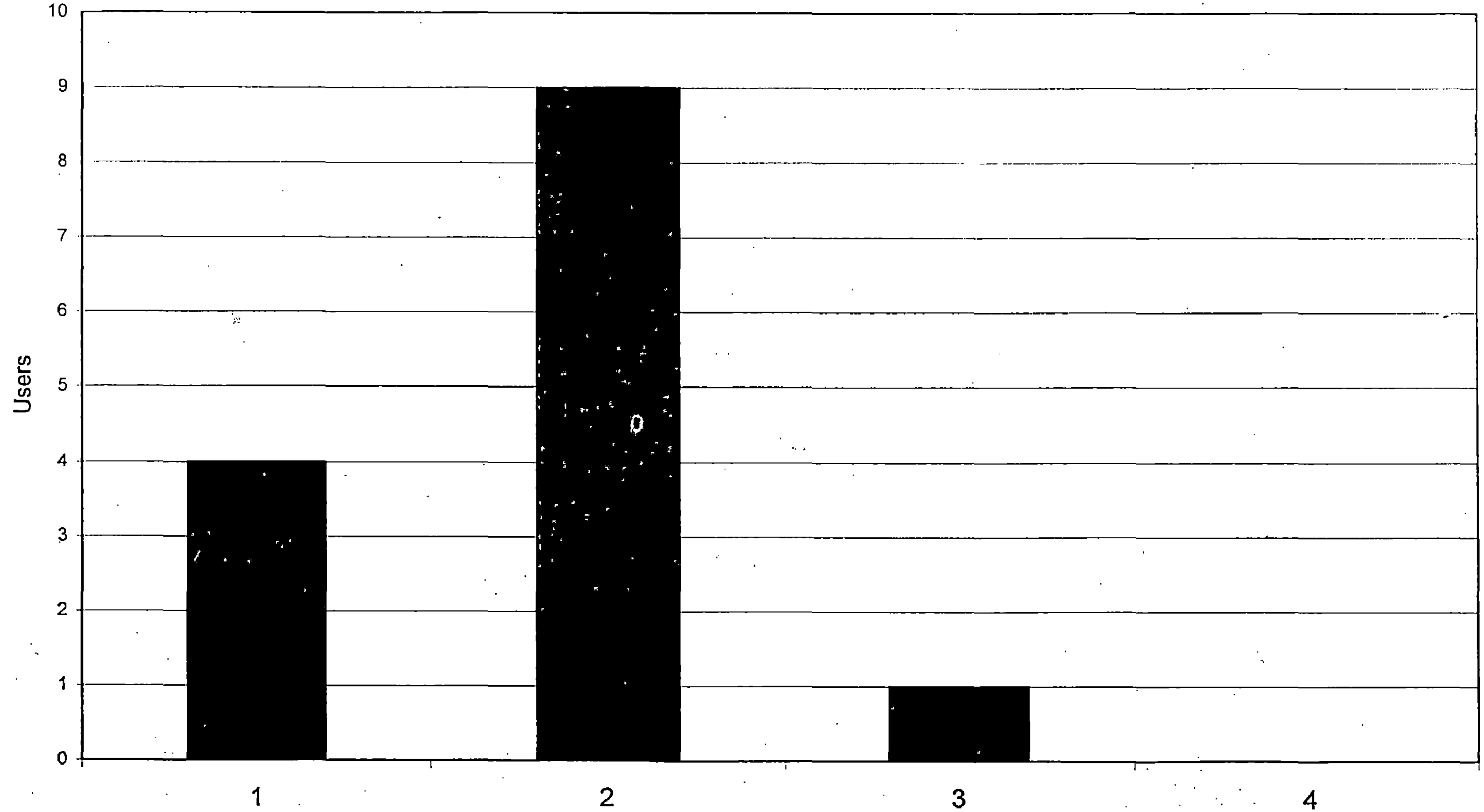
No. 13


Watching TV time
Users
7
6
5
4
3
2
1
0
1
2
3
4
Hours
No. 14



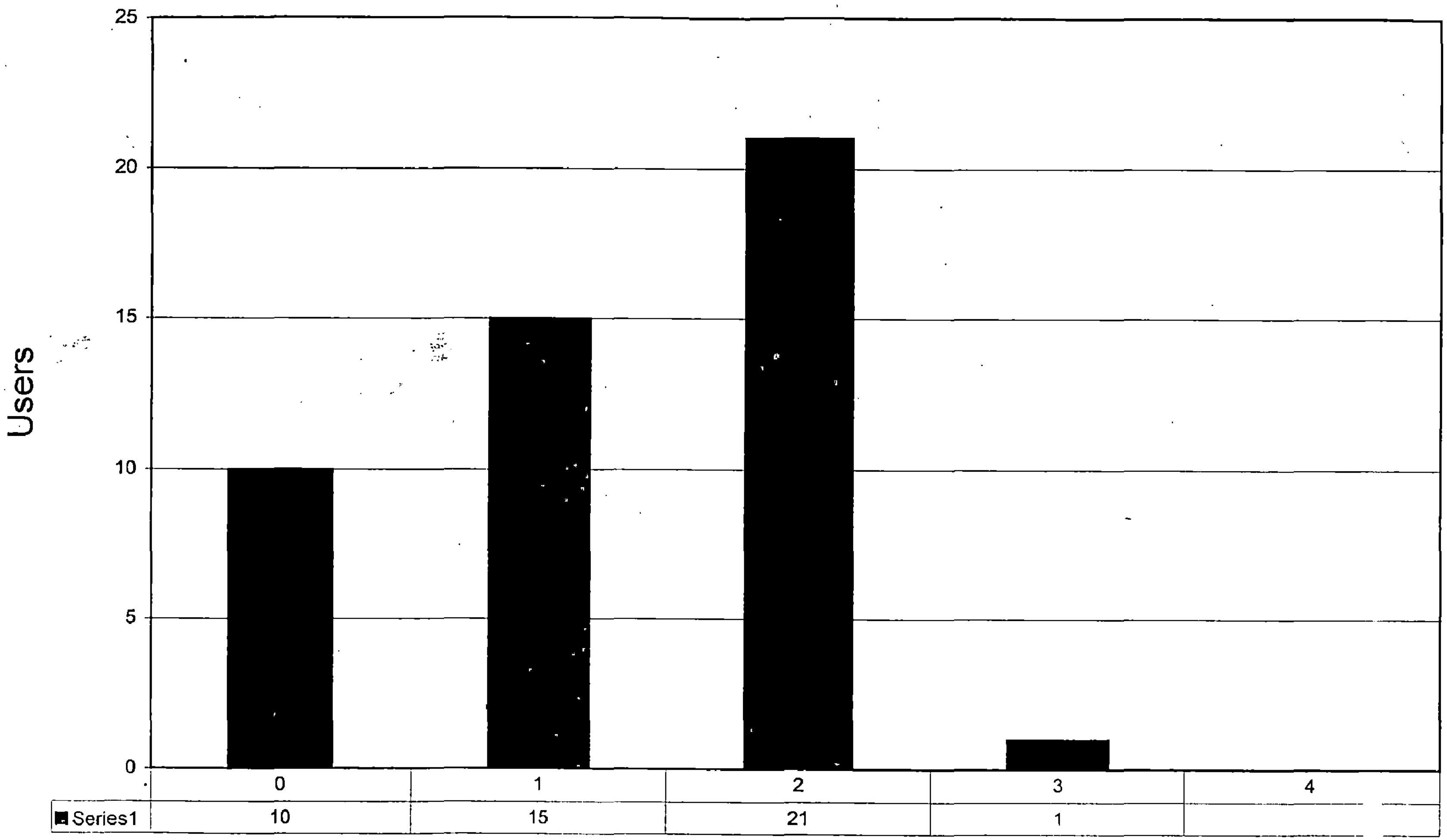
No.15

Watching TV time



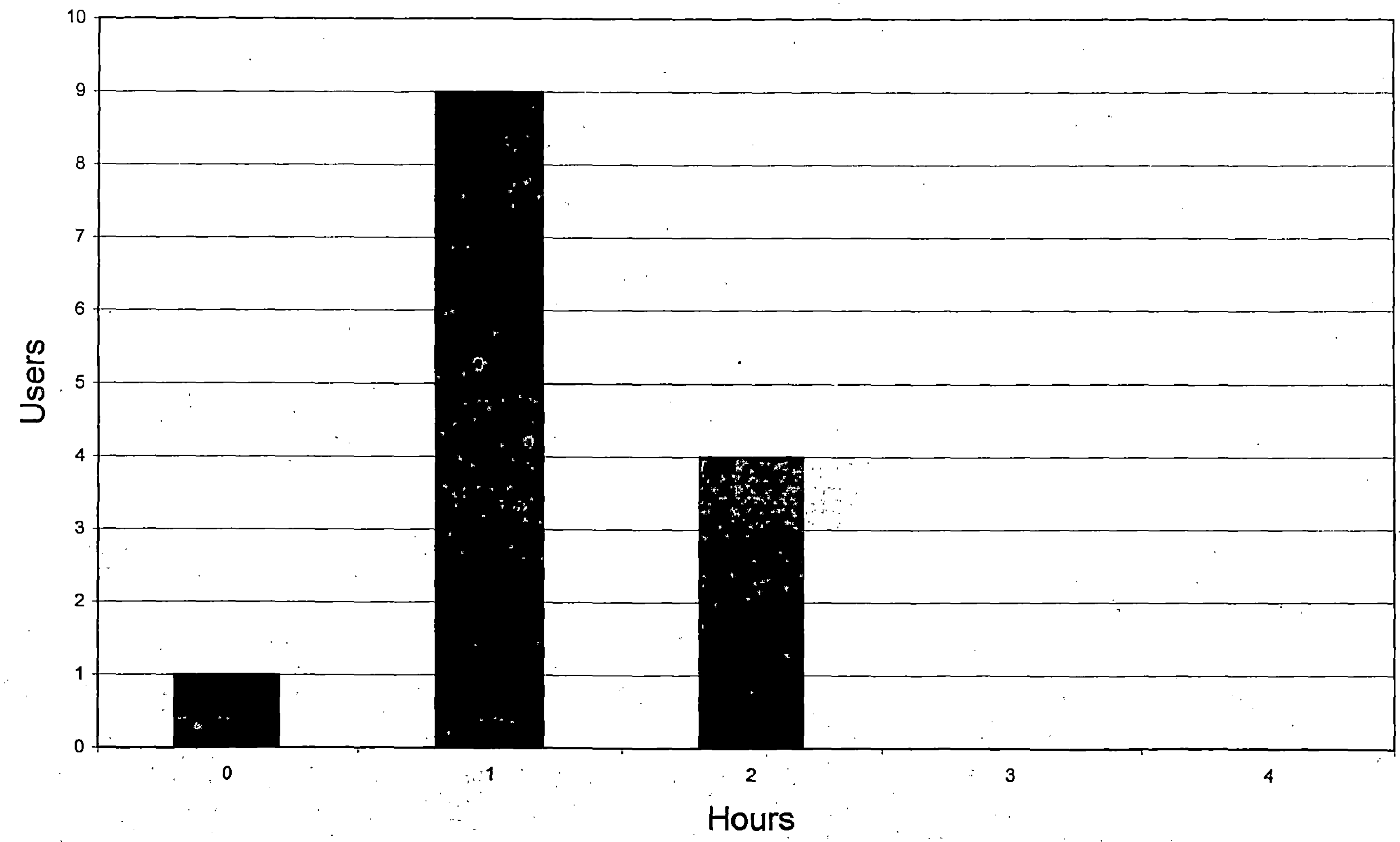
Hours
No. 16

Reading time

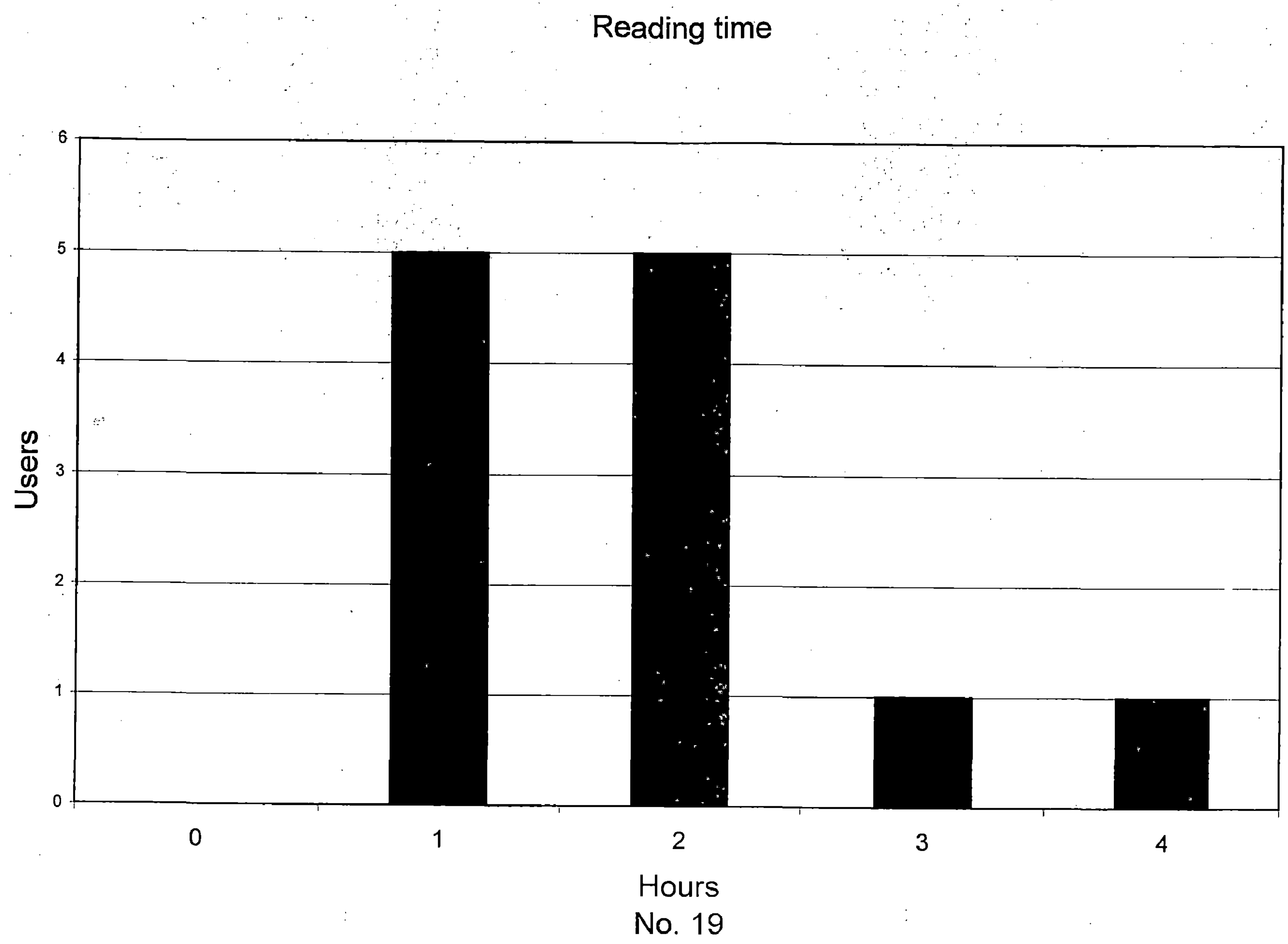


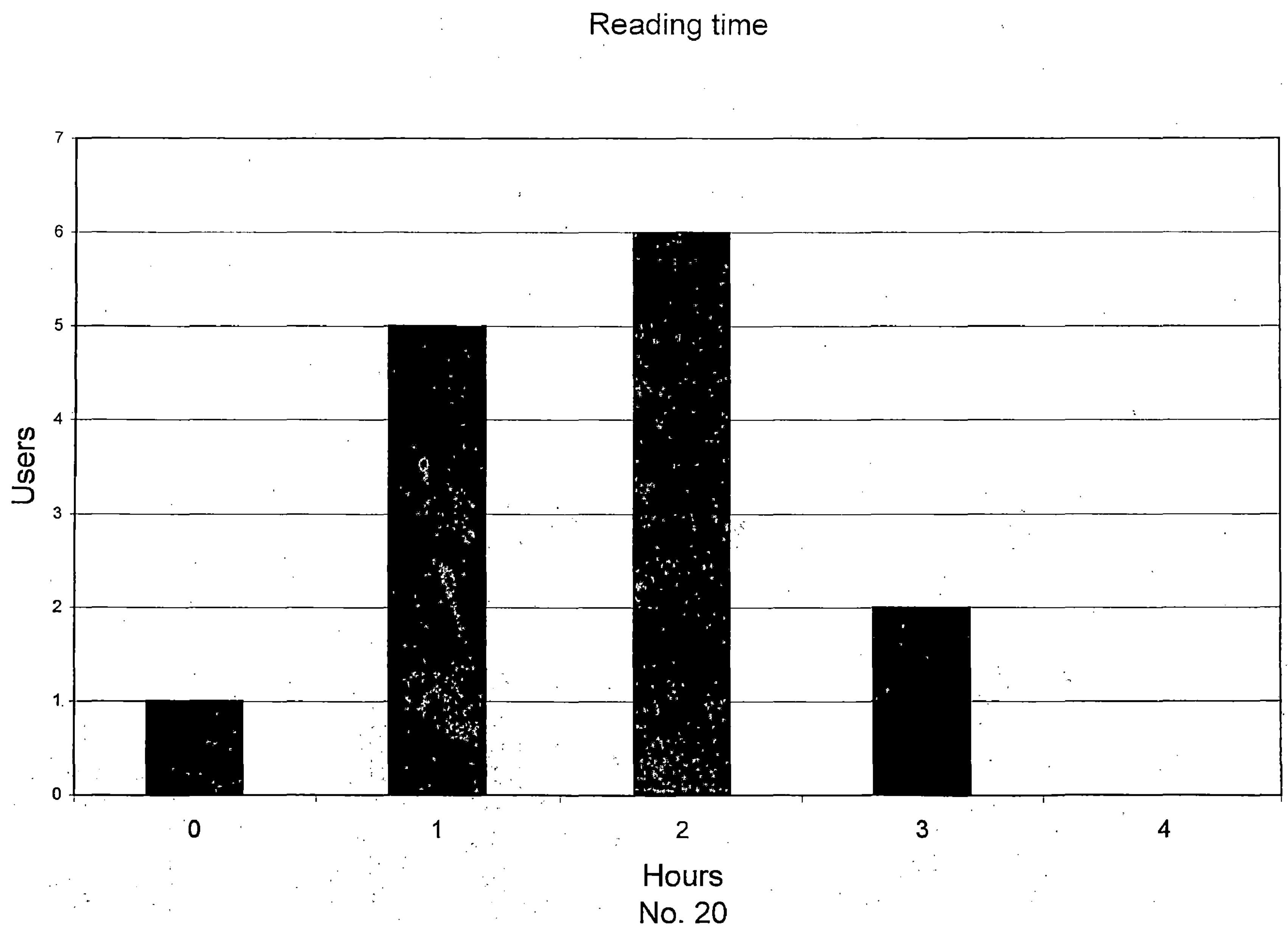
Hours
No.17

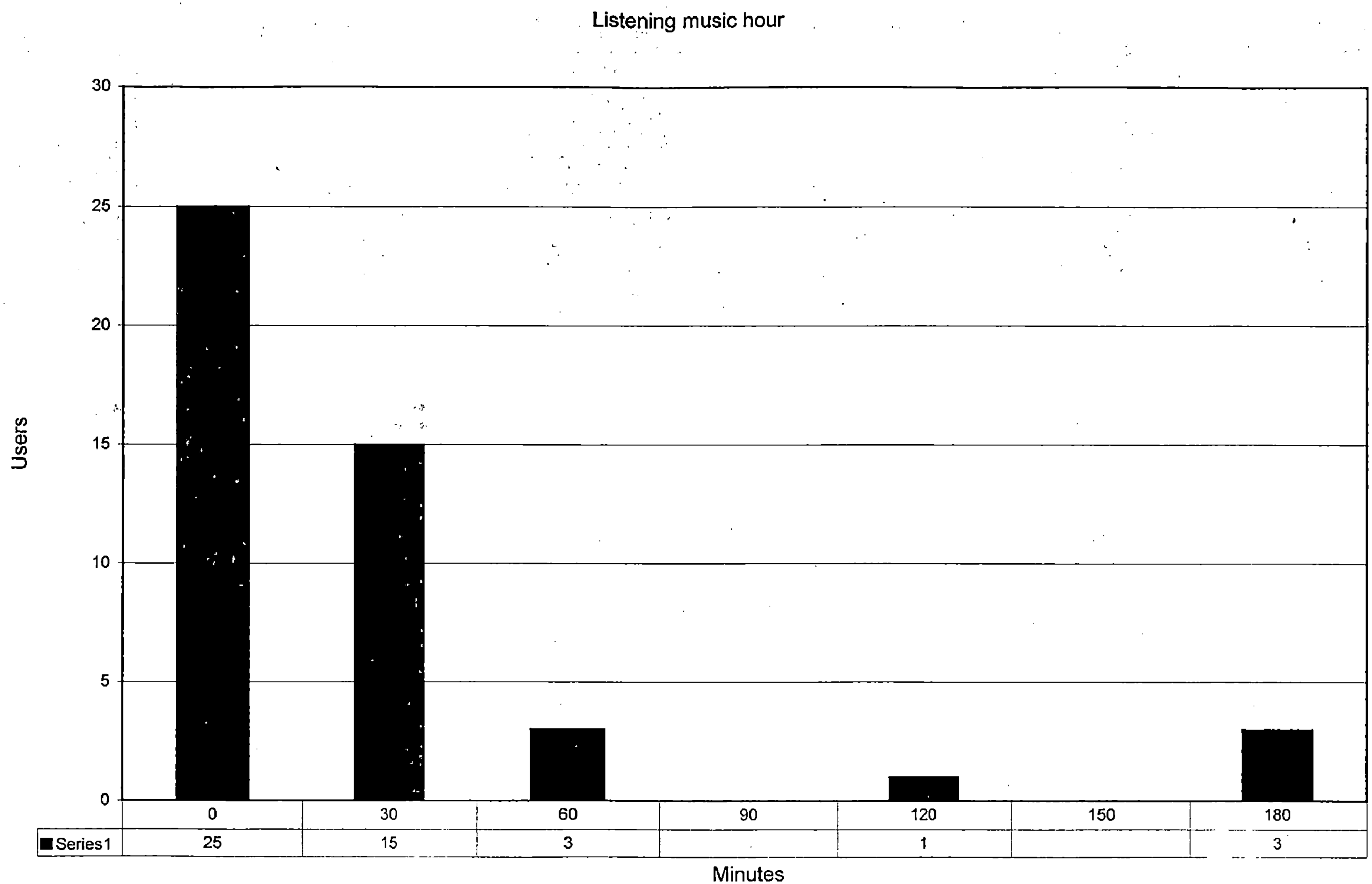
Reading time



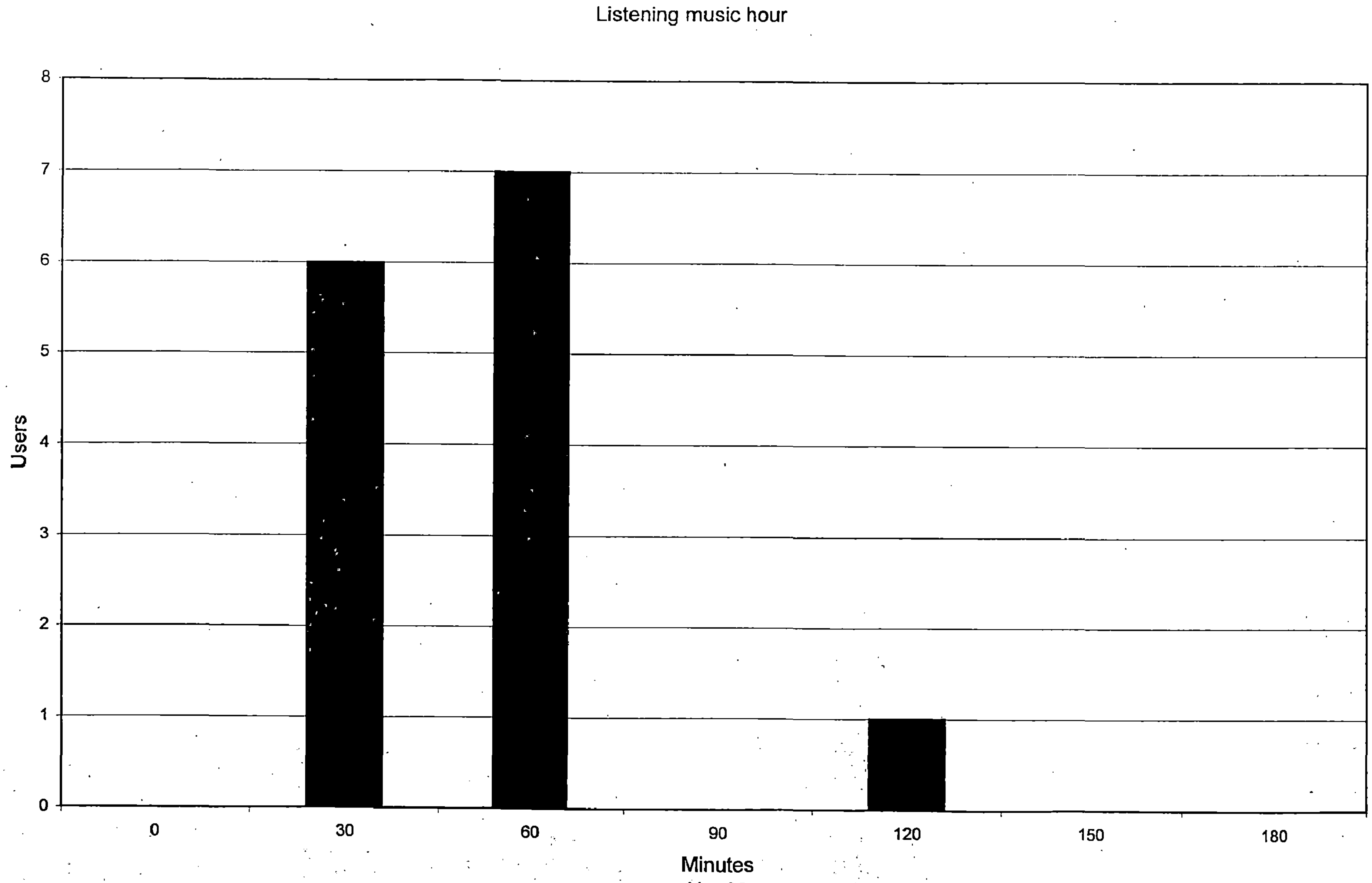
No.18

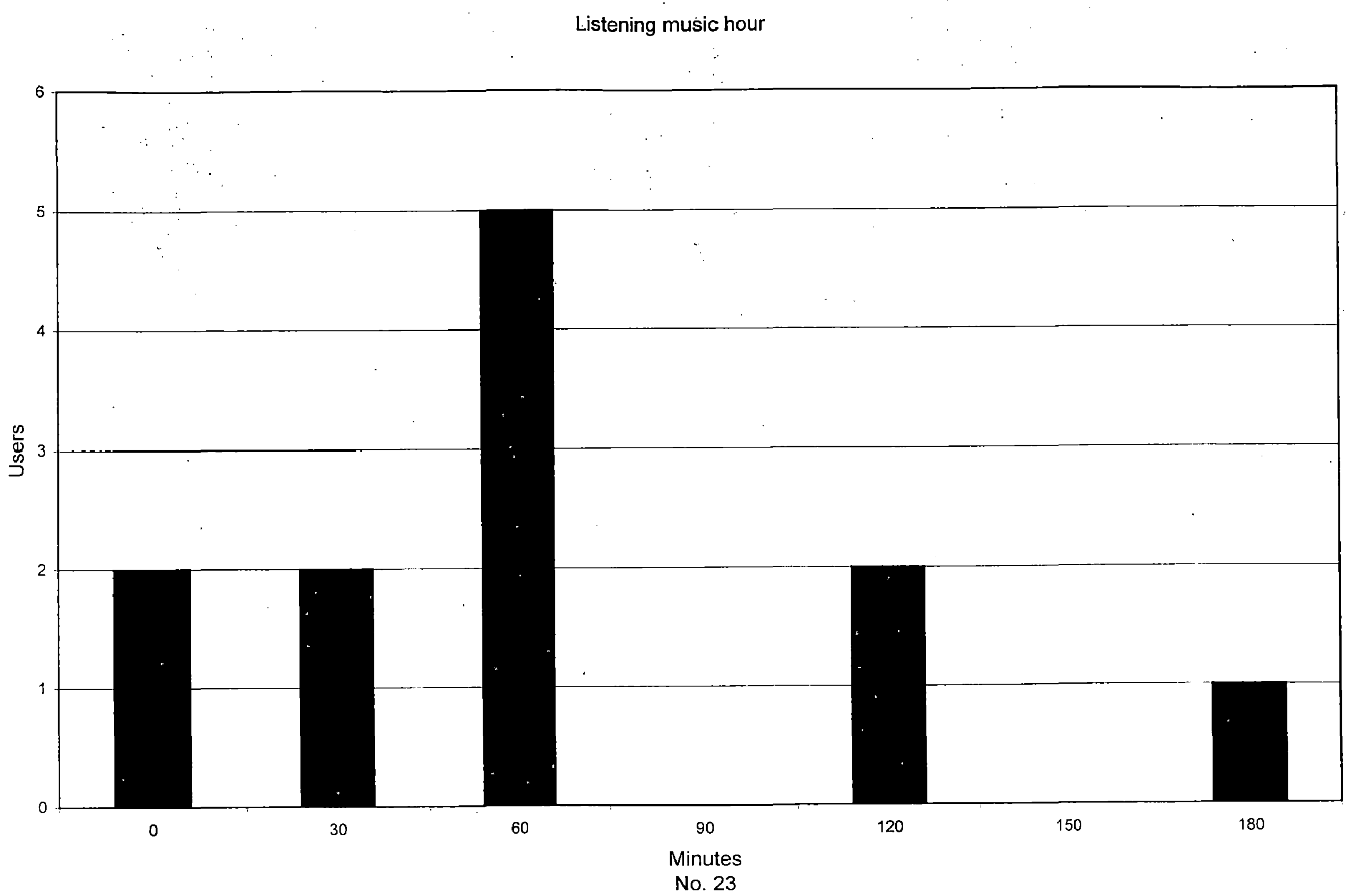

Reading time
Users
0
1
2
3
4
5
6
0
1
2
3
4
Hours
No. 19


Reading time
Users
0
1
2
3
4
5
6
7
0
1
2
3
4
Hours
No. 20

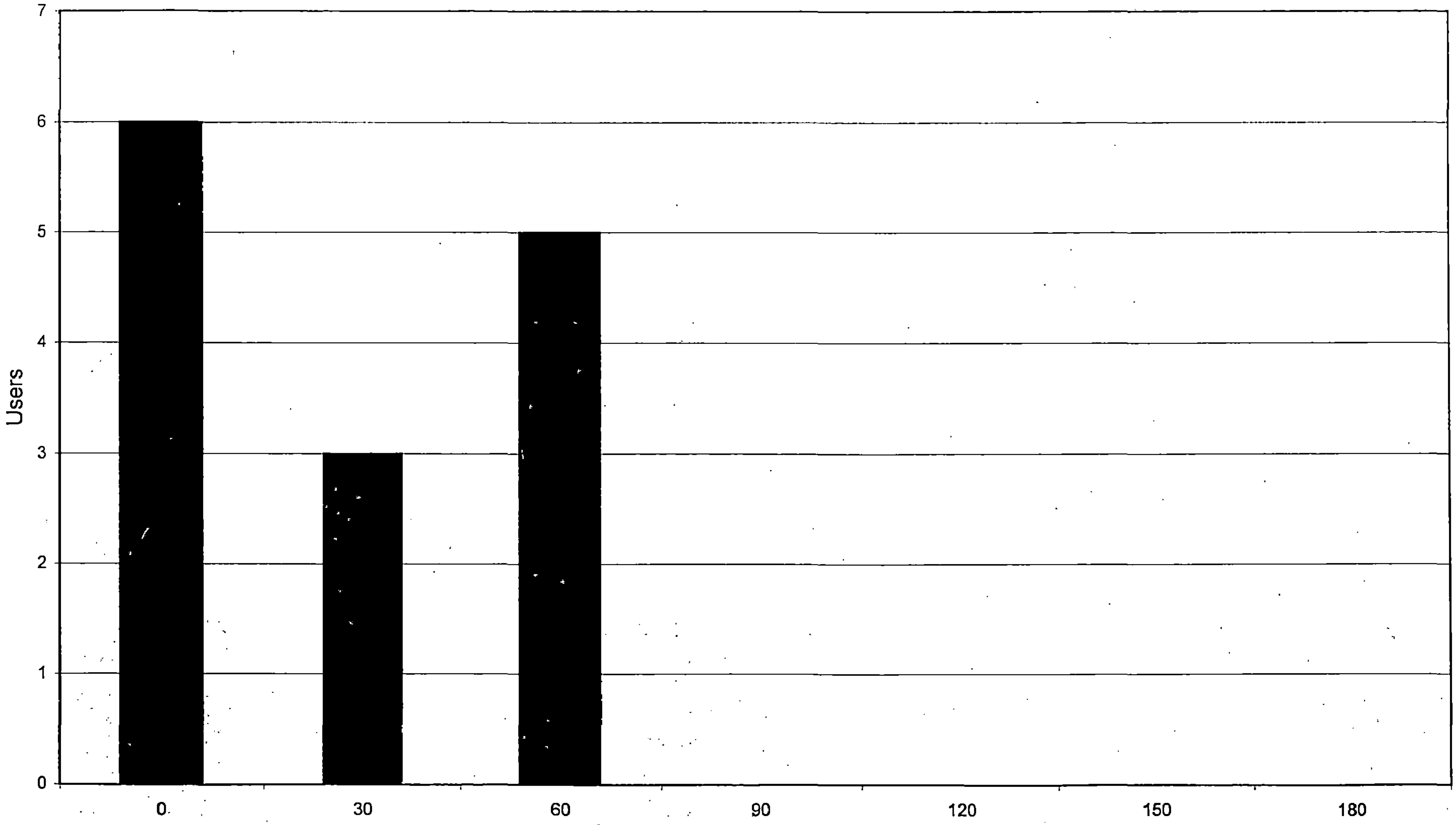

Listening music hour
Users
30
25
20
15
10
5
0
0
30
60
90
120
150
180
Series1
25
15
3
1
3
Minutes

No. 21

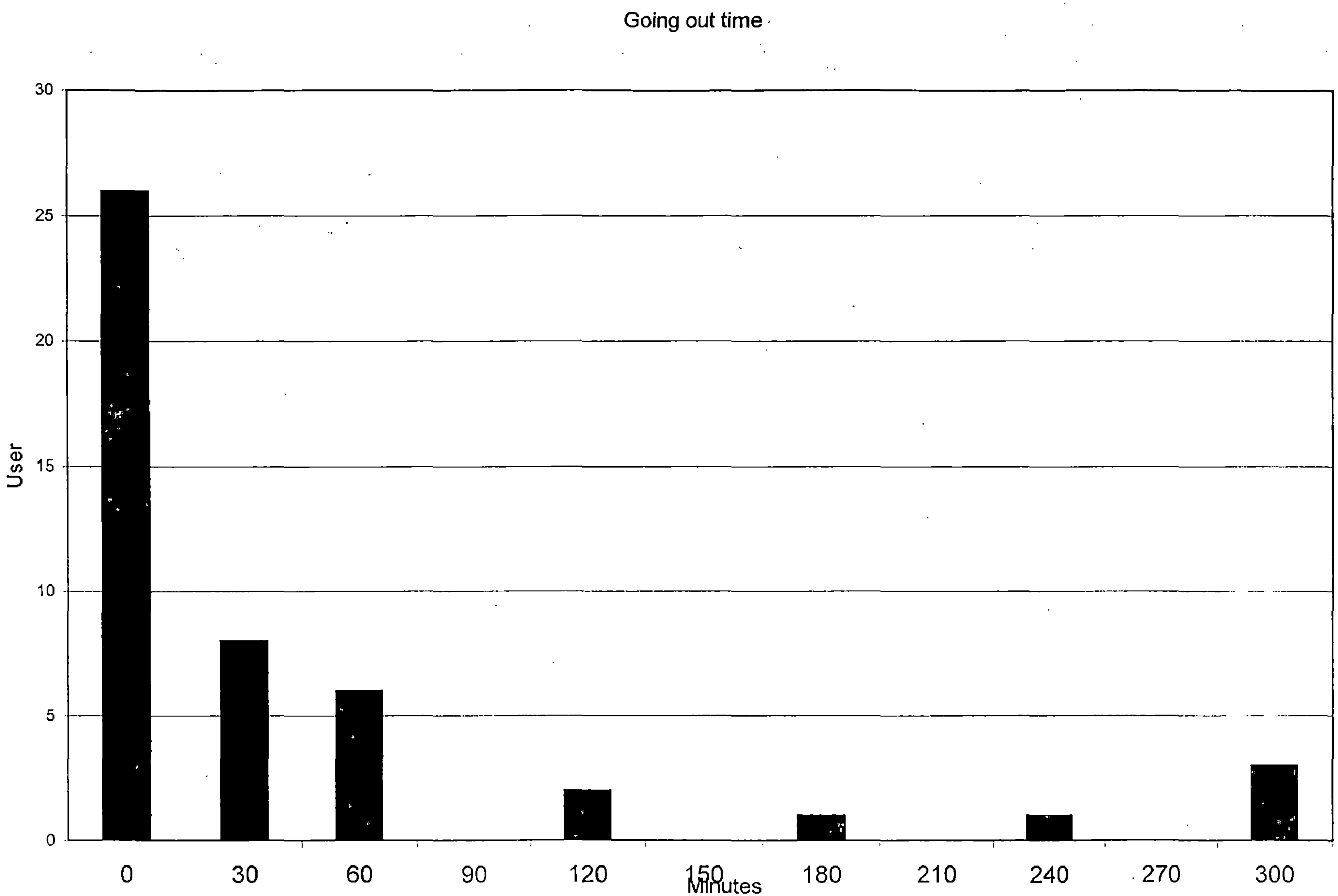

Listening music hour
Users
8
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
Minutes
No. 22

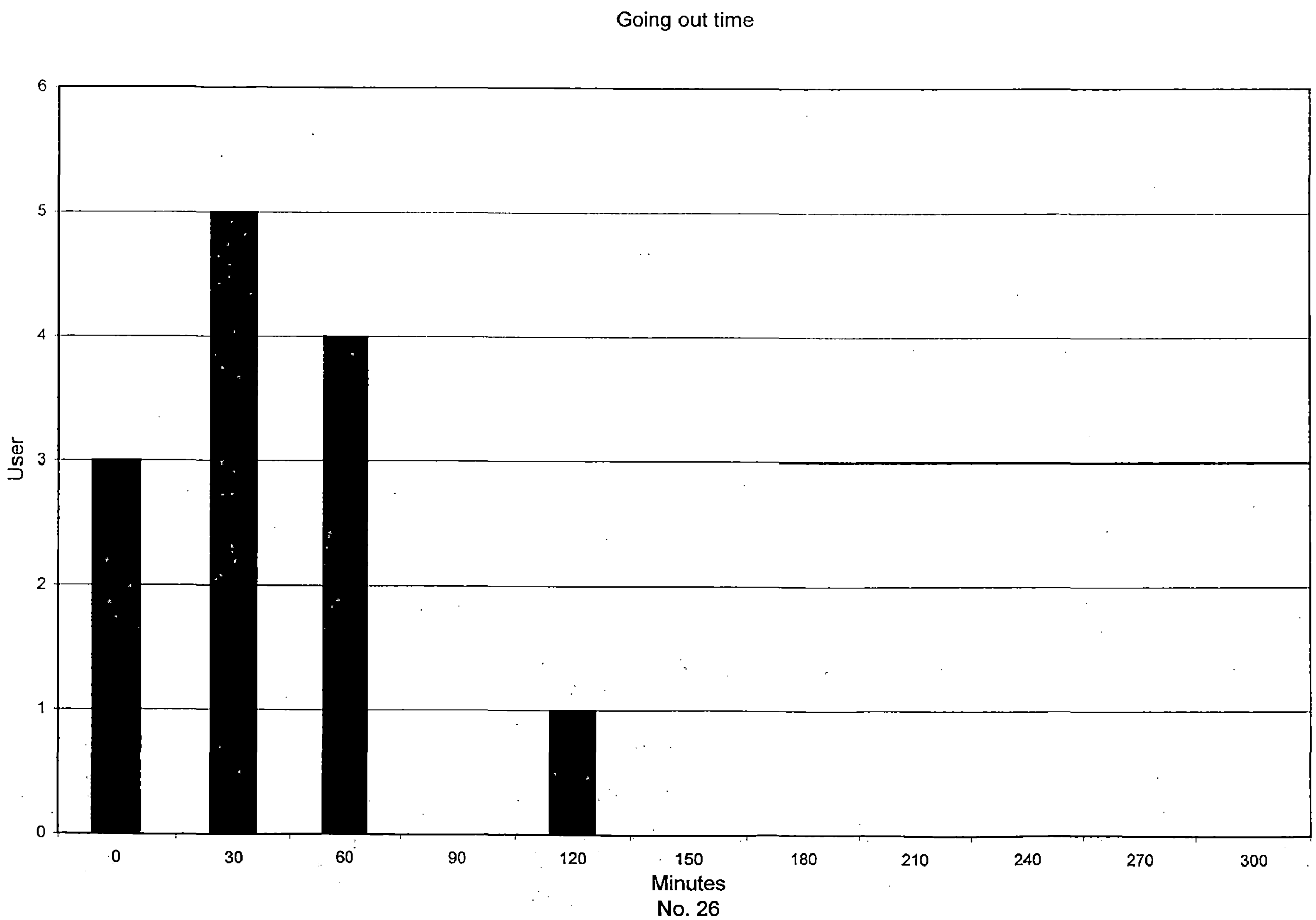

Listening music hour
Users
0
1
2
3
4
5
6
0
30
60
90
120
150
180
Minutes
No. 23

Listening music hour

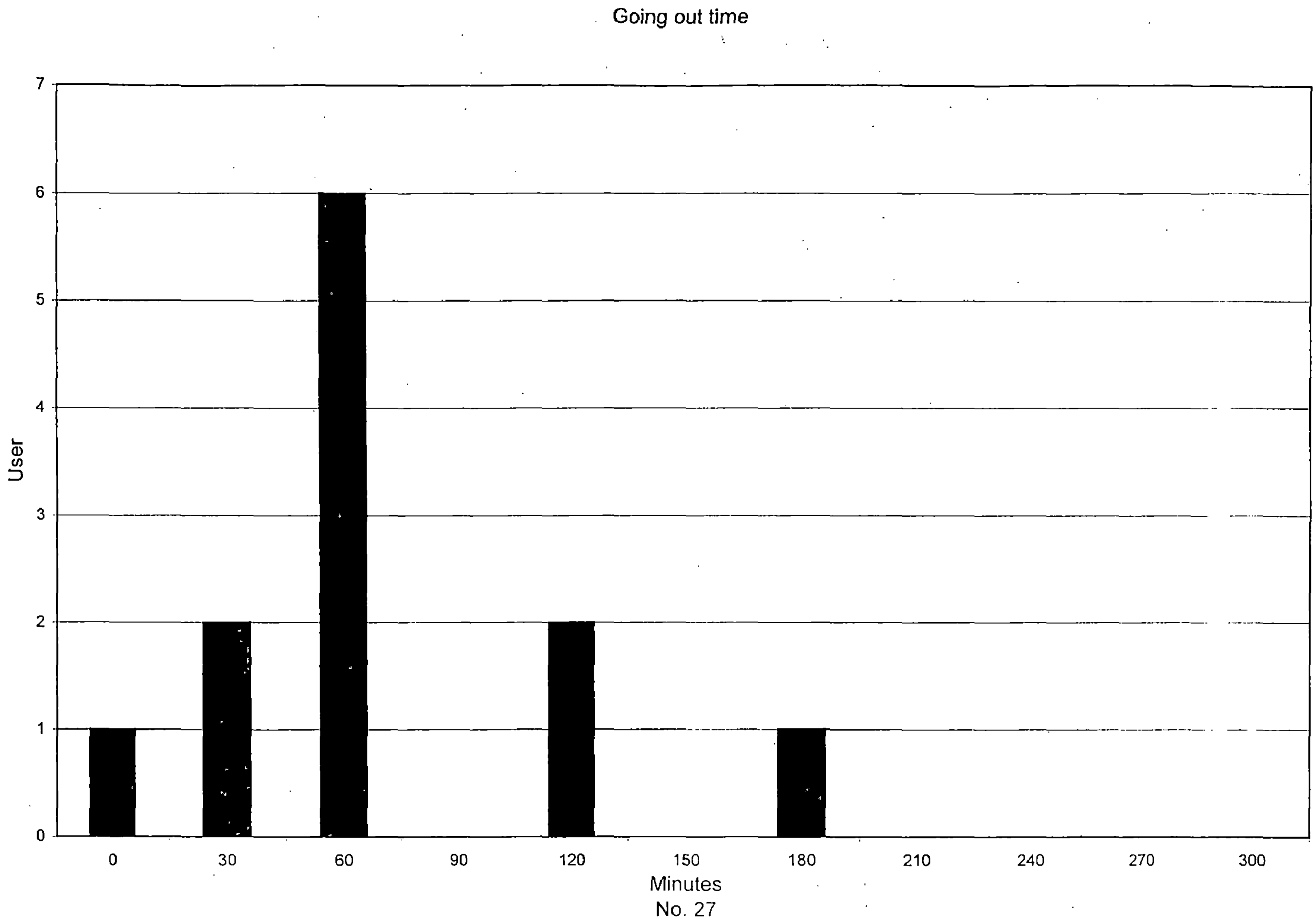


No. 24


Going out time
User
30
25
20
15
10
5
0
0
30
60
90
120
150
180
210
240
270
300
Minutes
No. 25

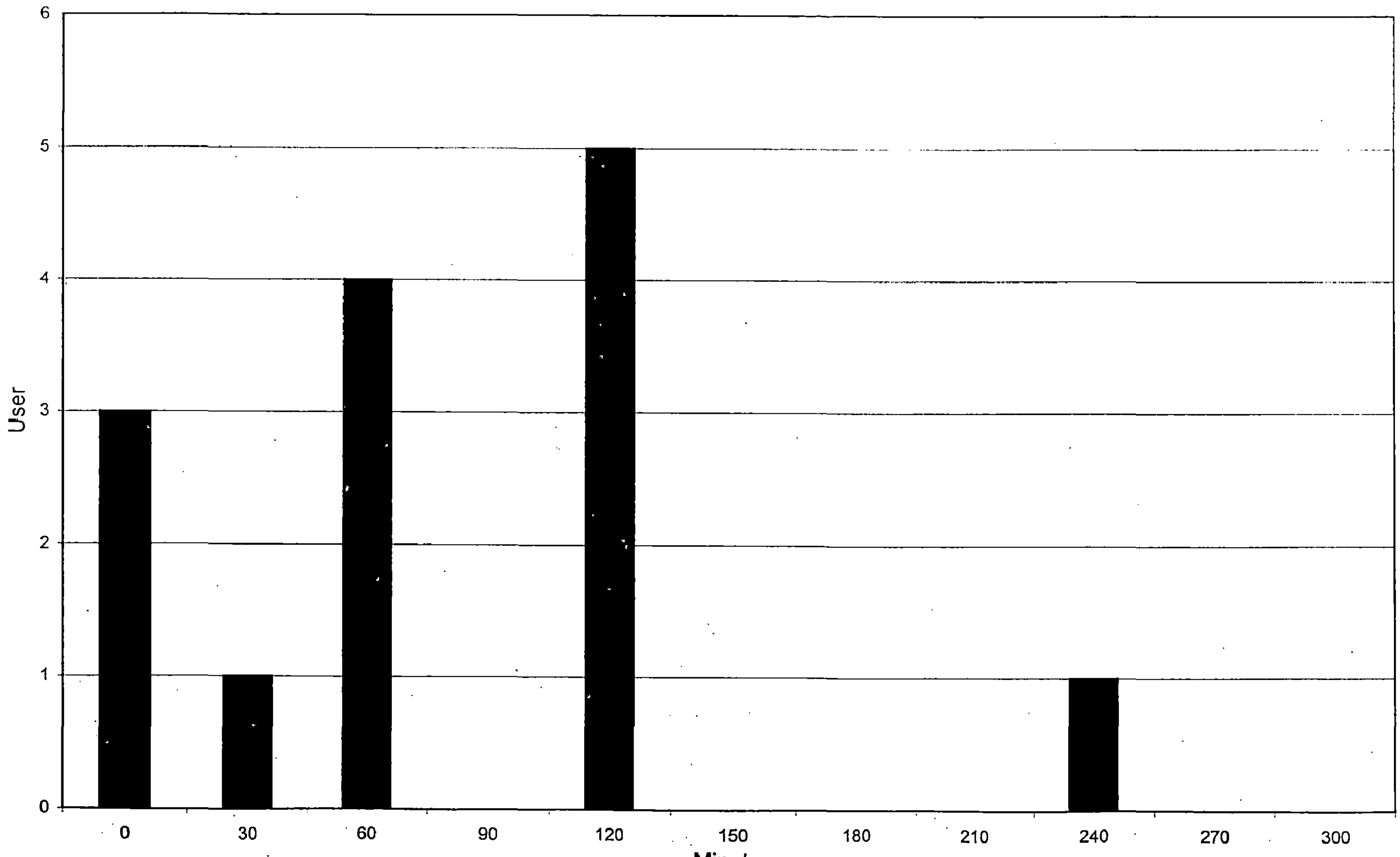


Going out time
User
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
Minutes
No. 26



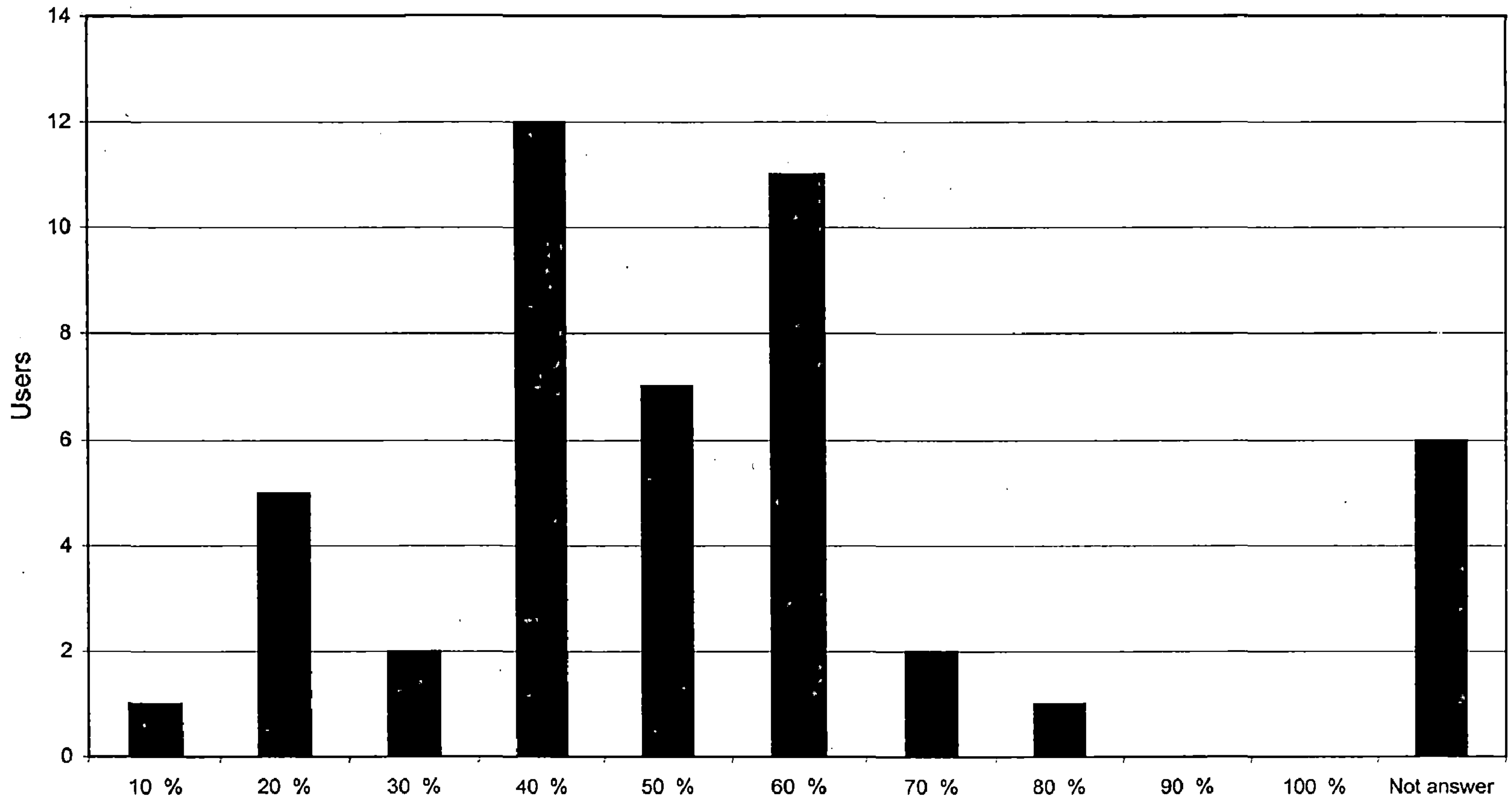
Going out time
User
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
Minutes
No. 27

Going out time



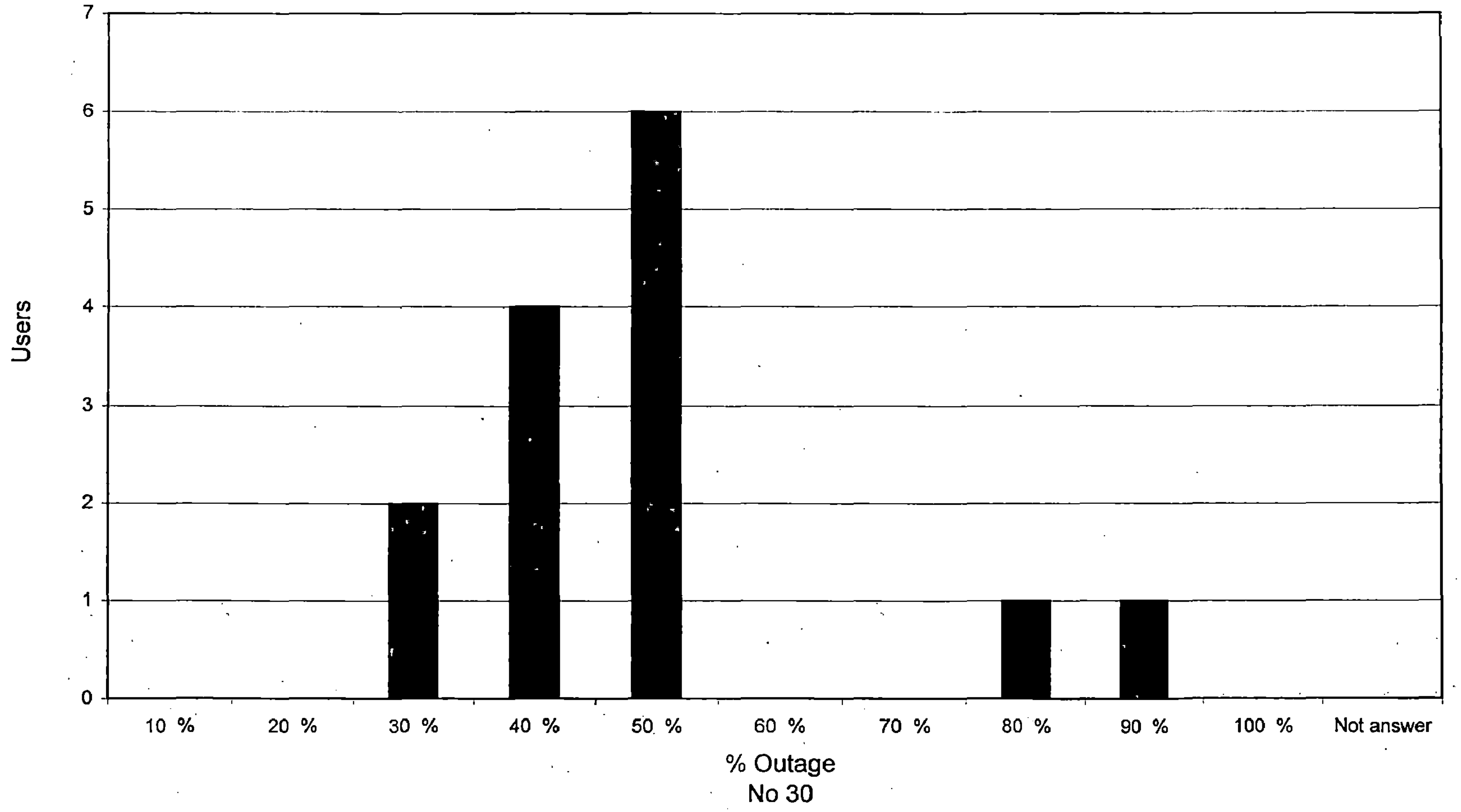
No. 28

Outage occours in critical period

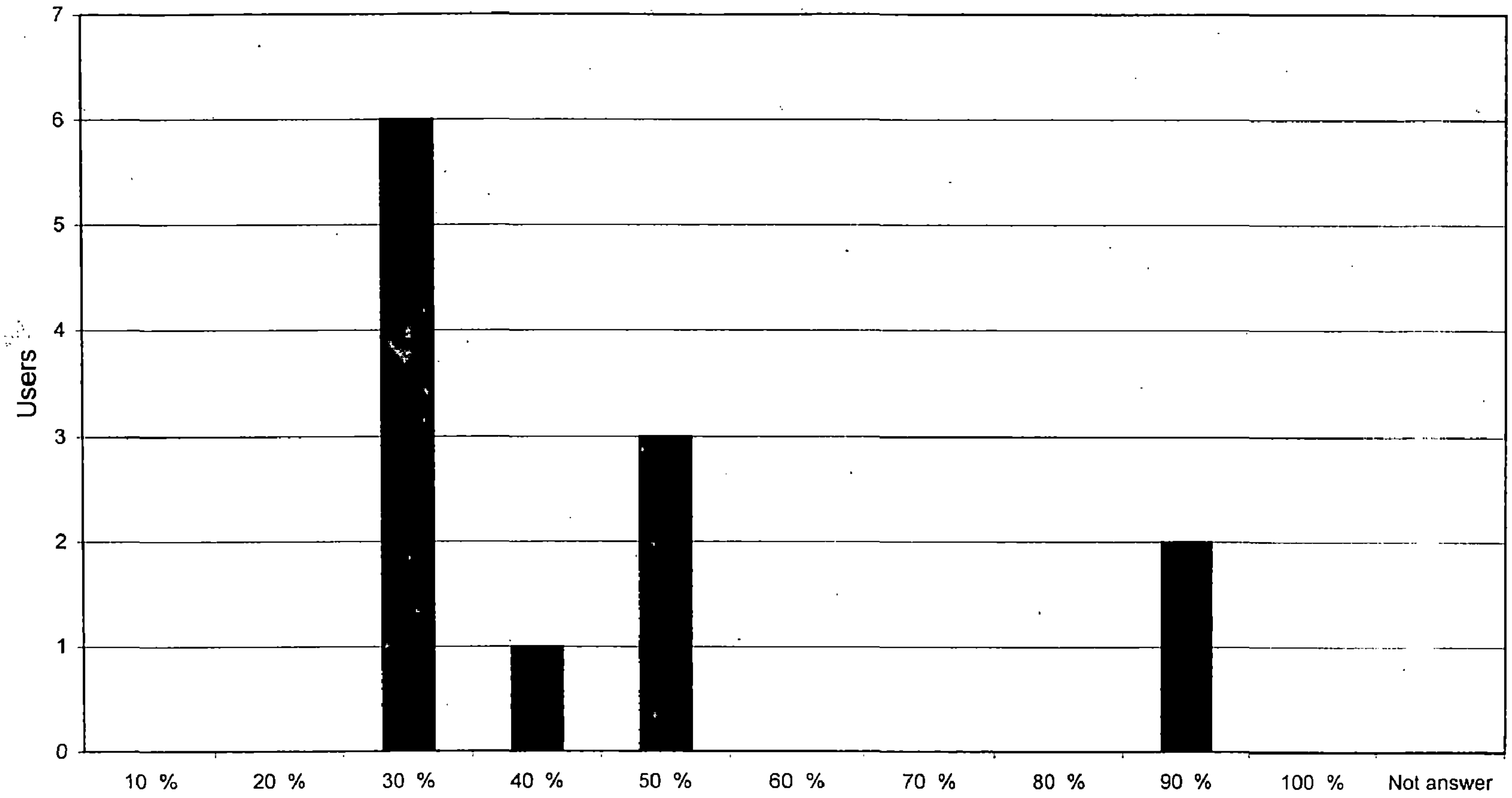


% Outage
No. 29

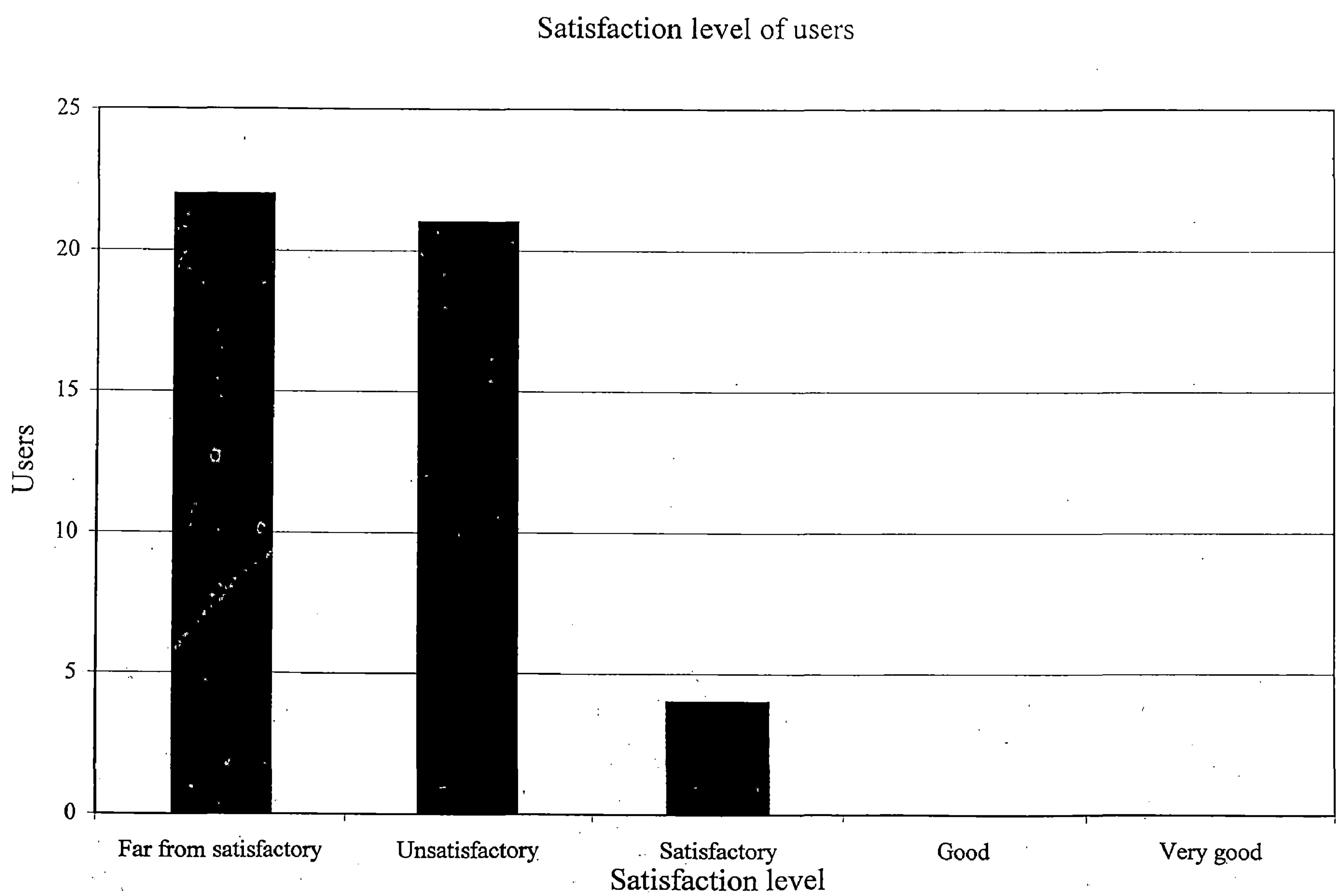
Outage occours in critical period



Outage occours in critical period

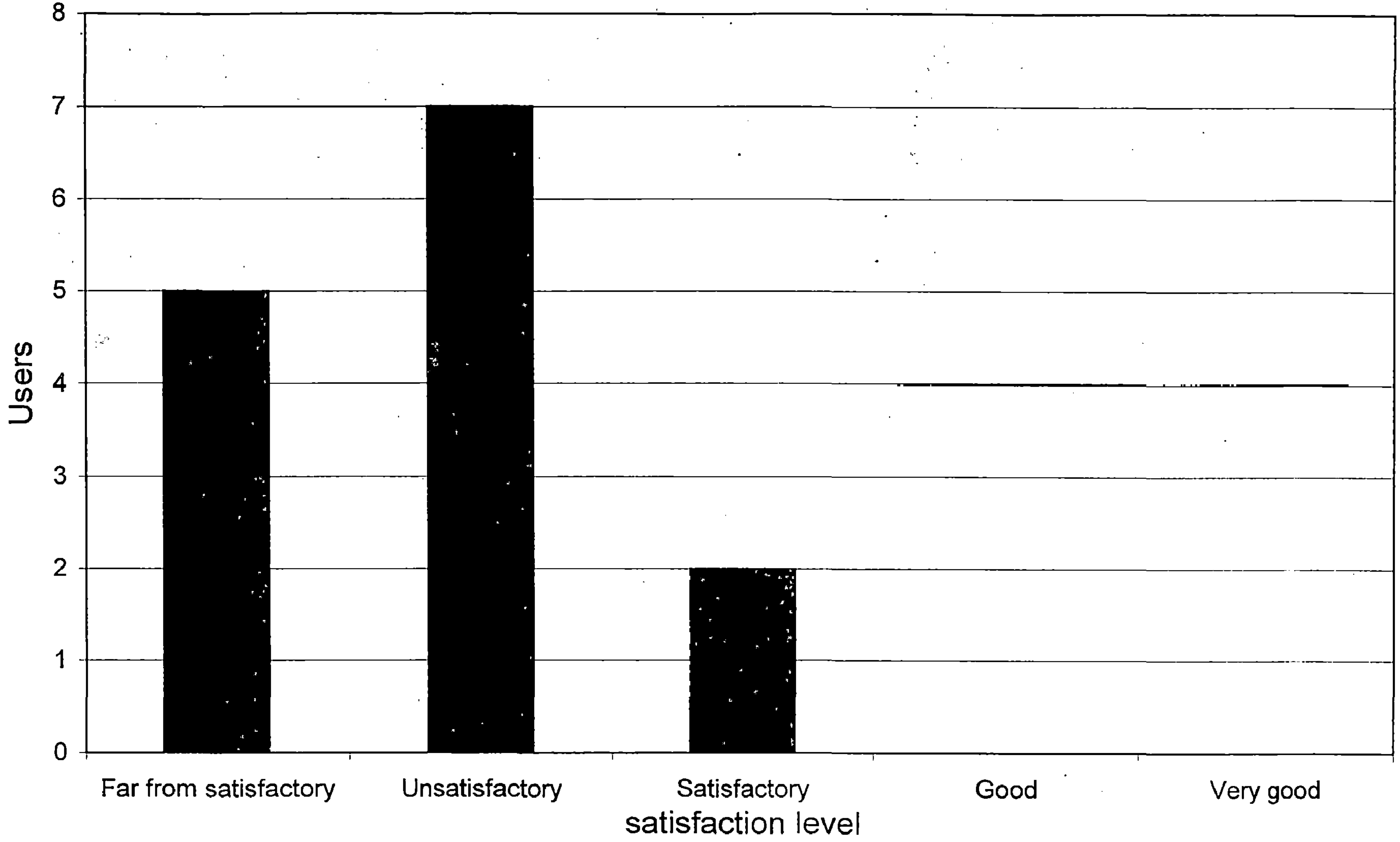


No. 31

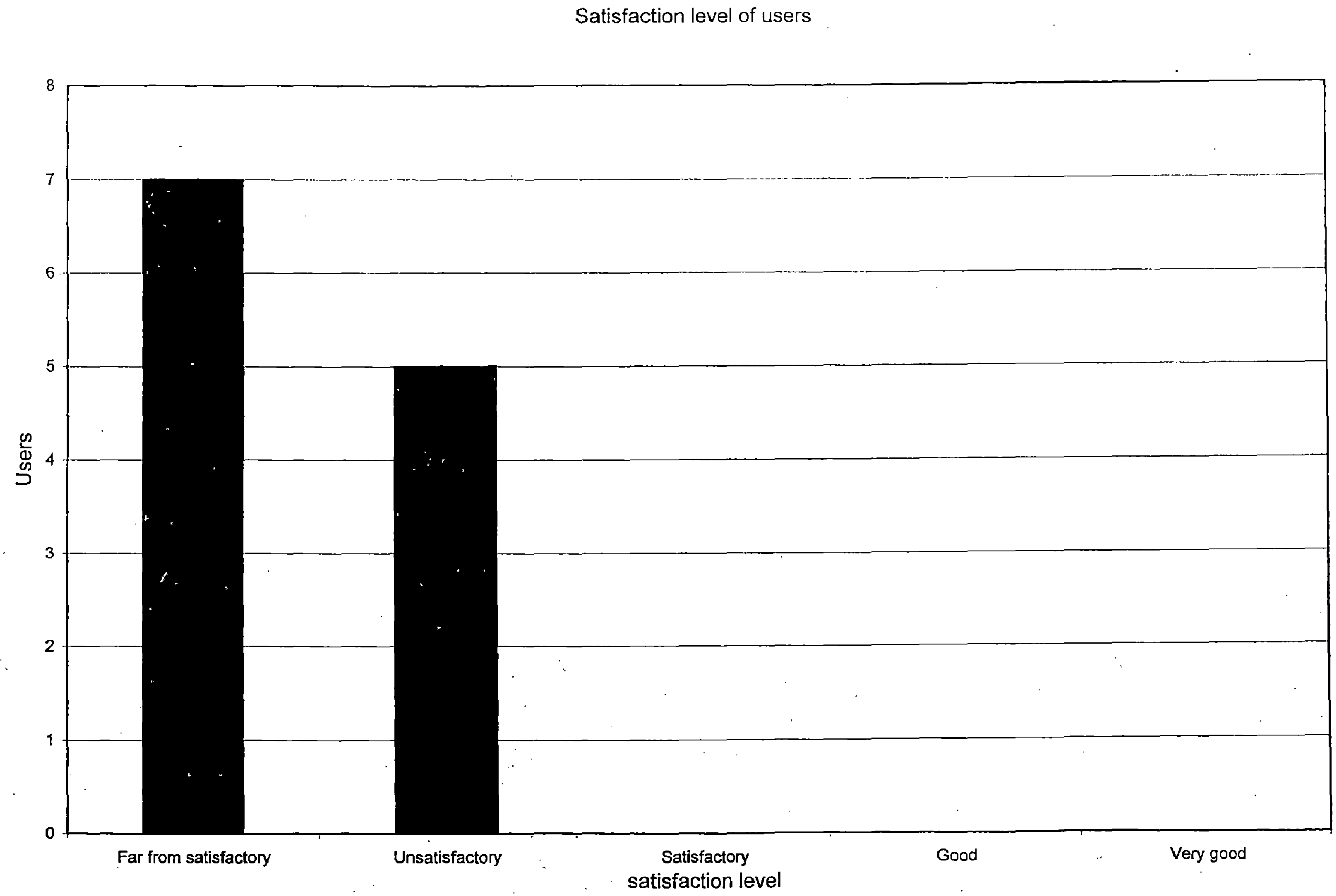

Satisfaction level of users
Users
0
5
10
15
20
25
Far from satisfactory
Unsatisfactory
Satisfactory
Good
Very good
Satisfaction level

No. 33

Satisfaction level of users

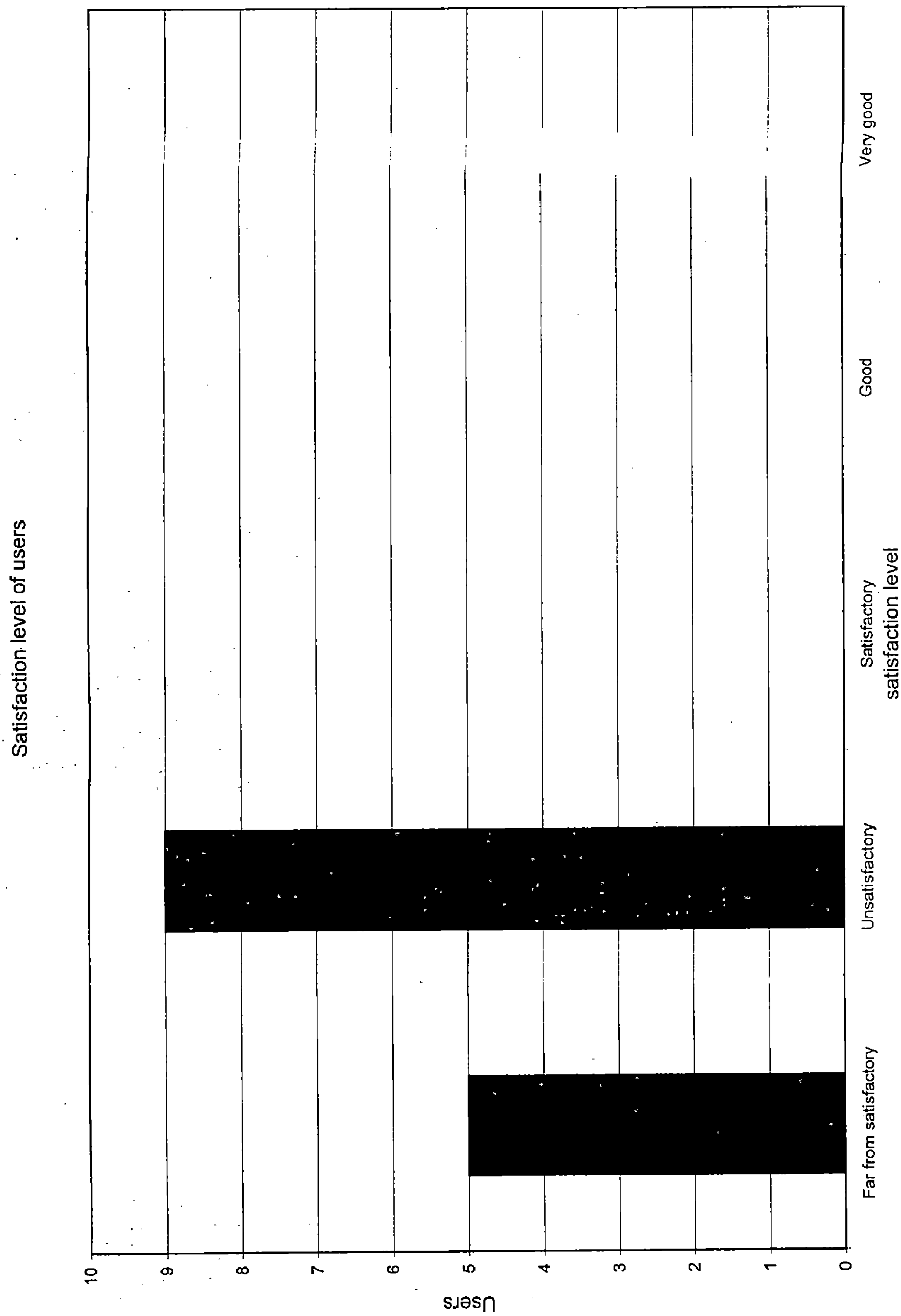


No. 34



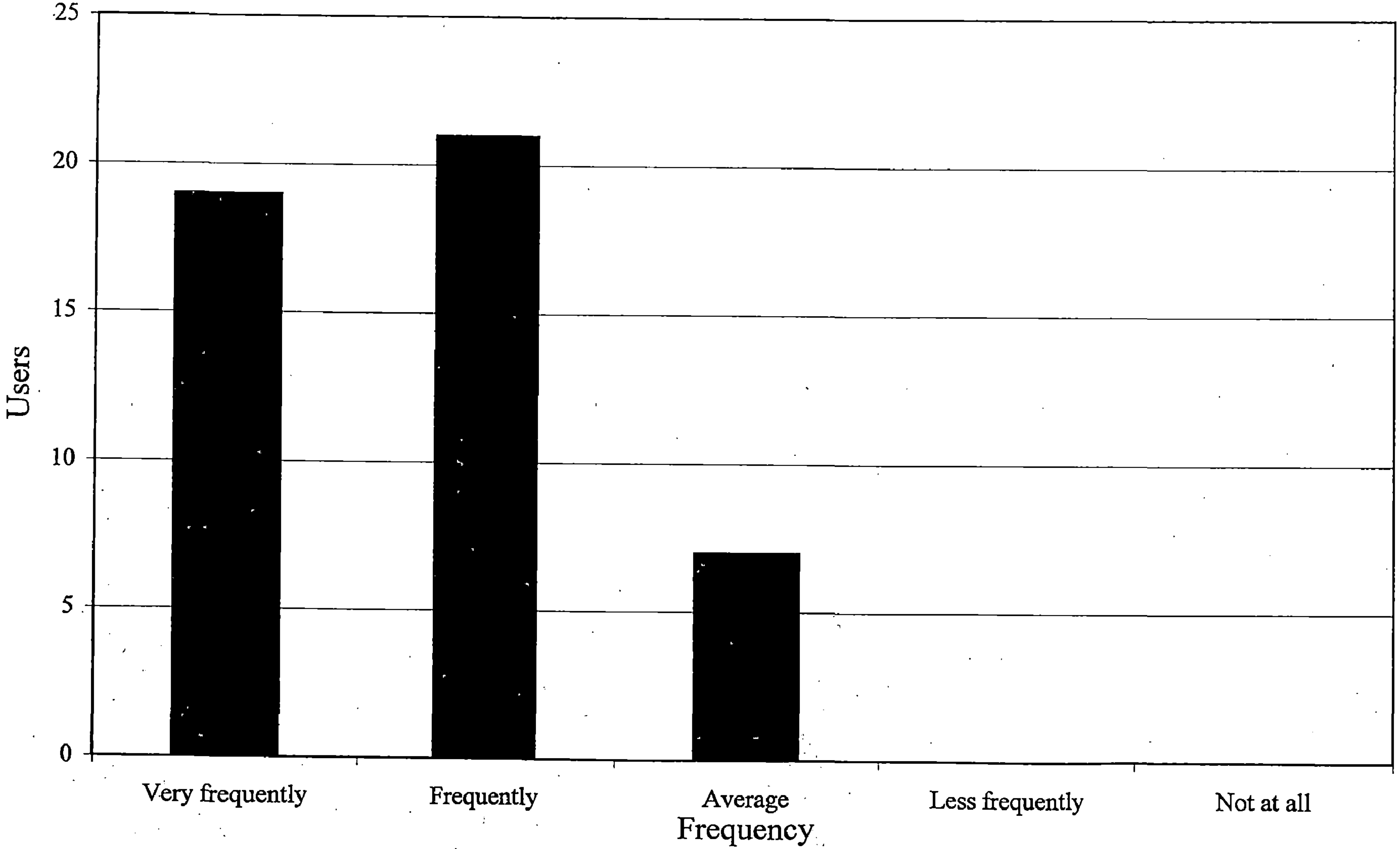
Satisfaction level of users
Users
0
1
2
3
4
5
6
7
8
Far from satisfactory
Unsatisfactory
Satisfactory
Good
Very good
satisfaction level

No. 35

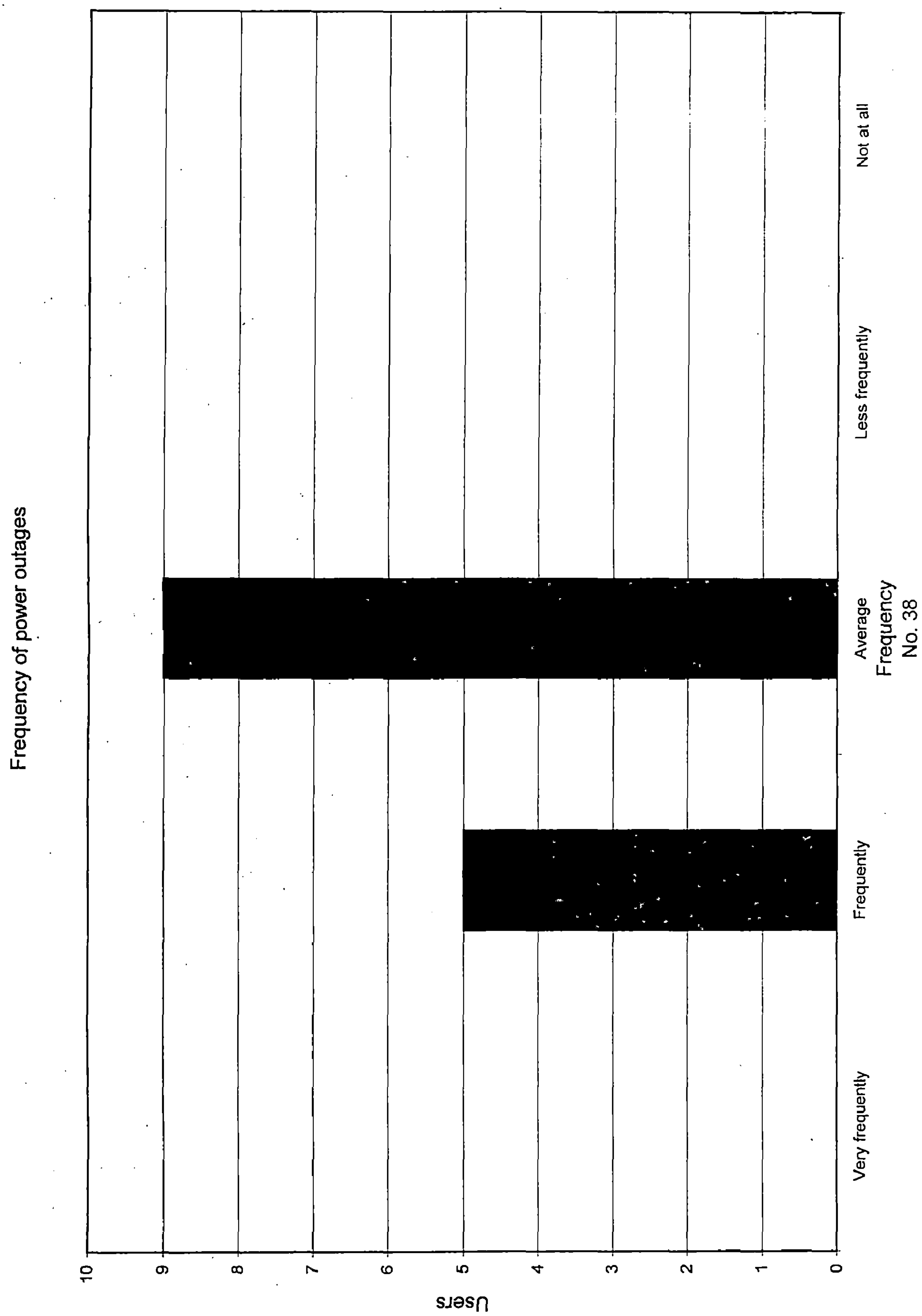

Satisfaction level of users
Users
0
1
2
3
4
5
6
7
8
9
10
Far from satisfactory
Unsatisfactory
Satisfactory
Good
Very good
satisfaction level

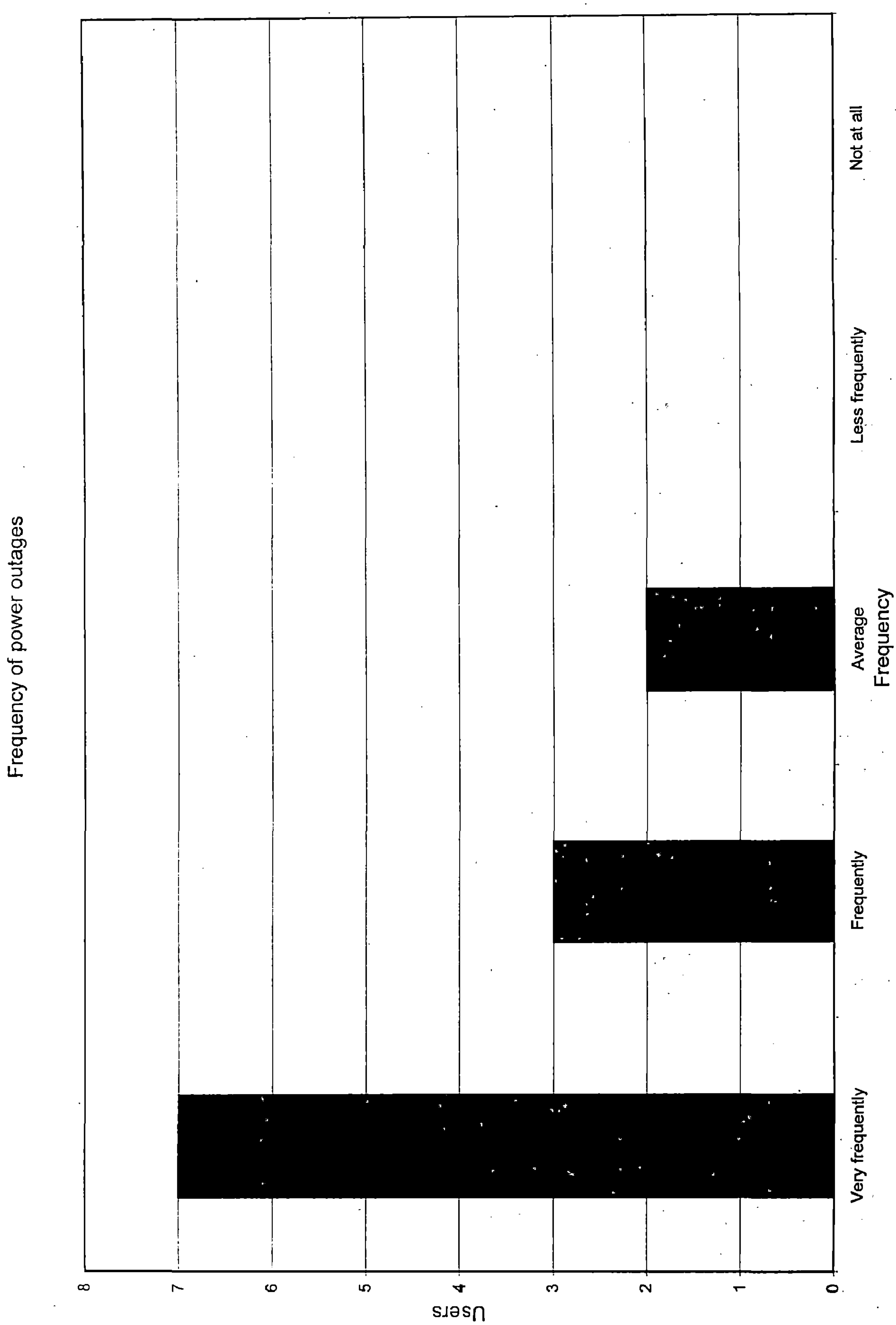
No. 36

Frequency of power outages

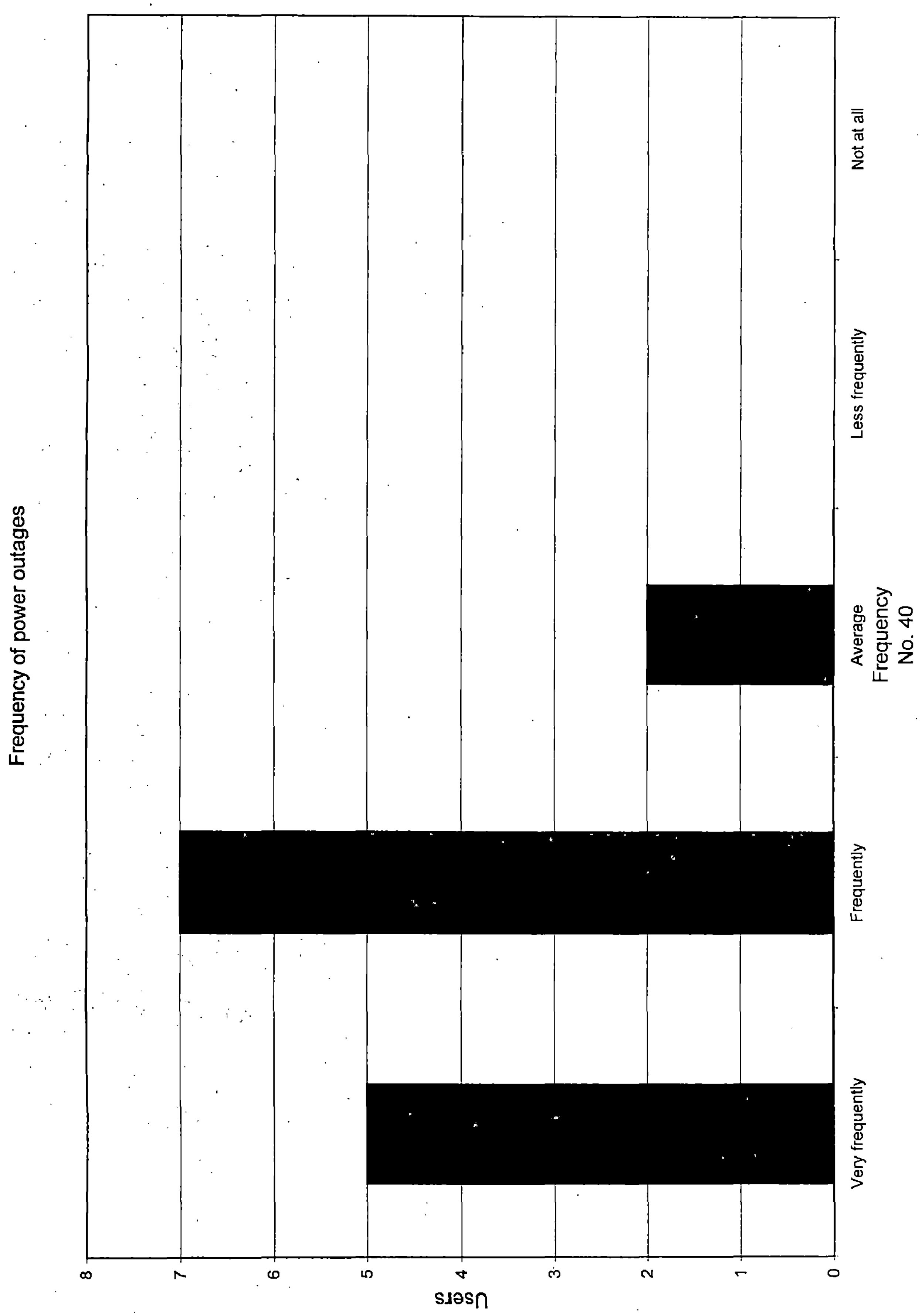


No. 37


Frequency of power outages
Users
0
1
2
3
4
5
6
7
8
9
10
Very frequently
Frequently
Average
Less frequently
Not at all
Frequency
No. 38

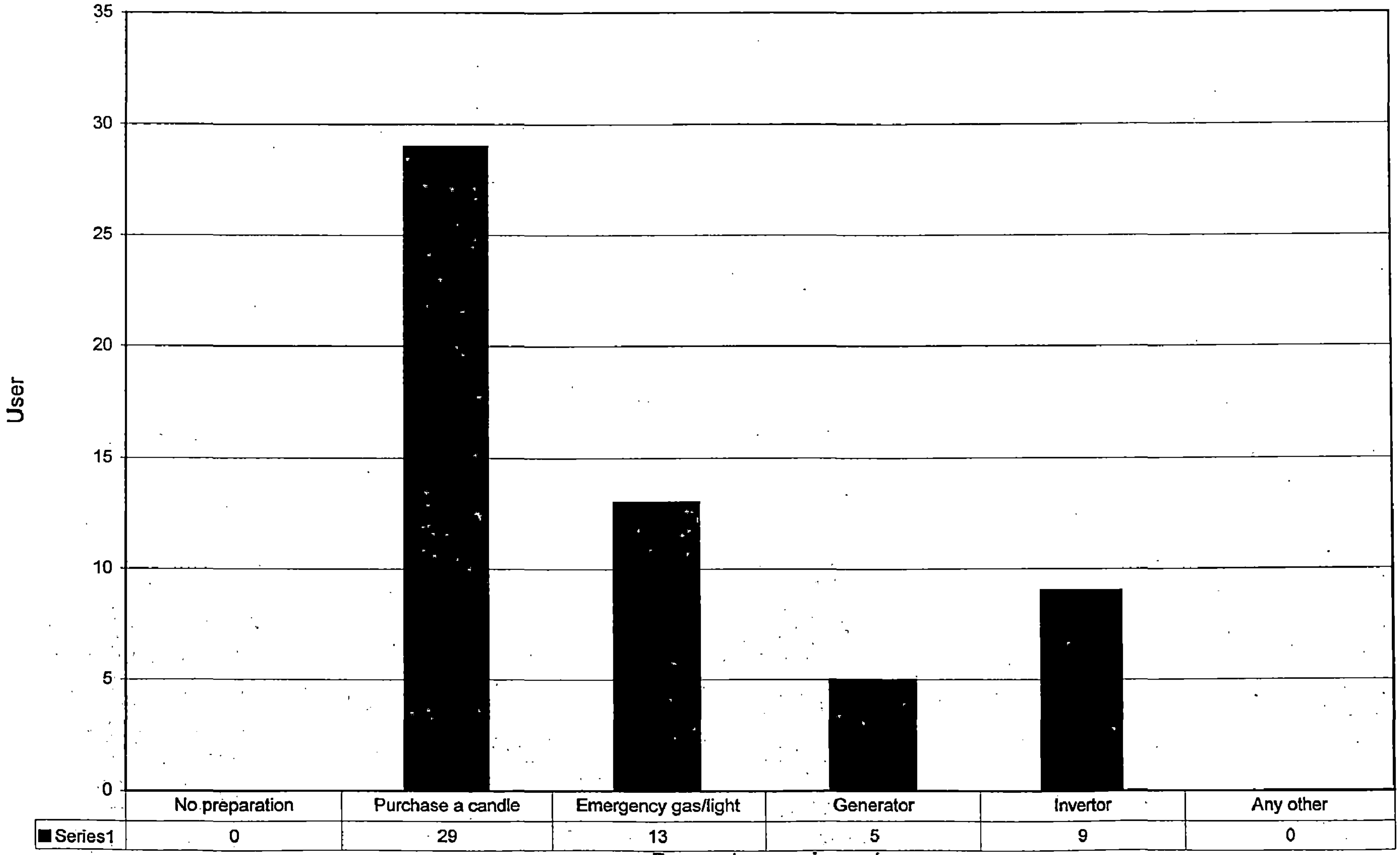

Frequency of power outages
Users
0
1
2
3
4
5
6
7
8
Very frequently
Frequently
Average
Less frequently
Not at all
Frequency

No. 39

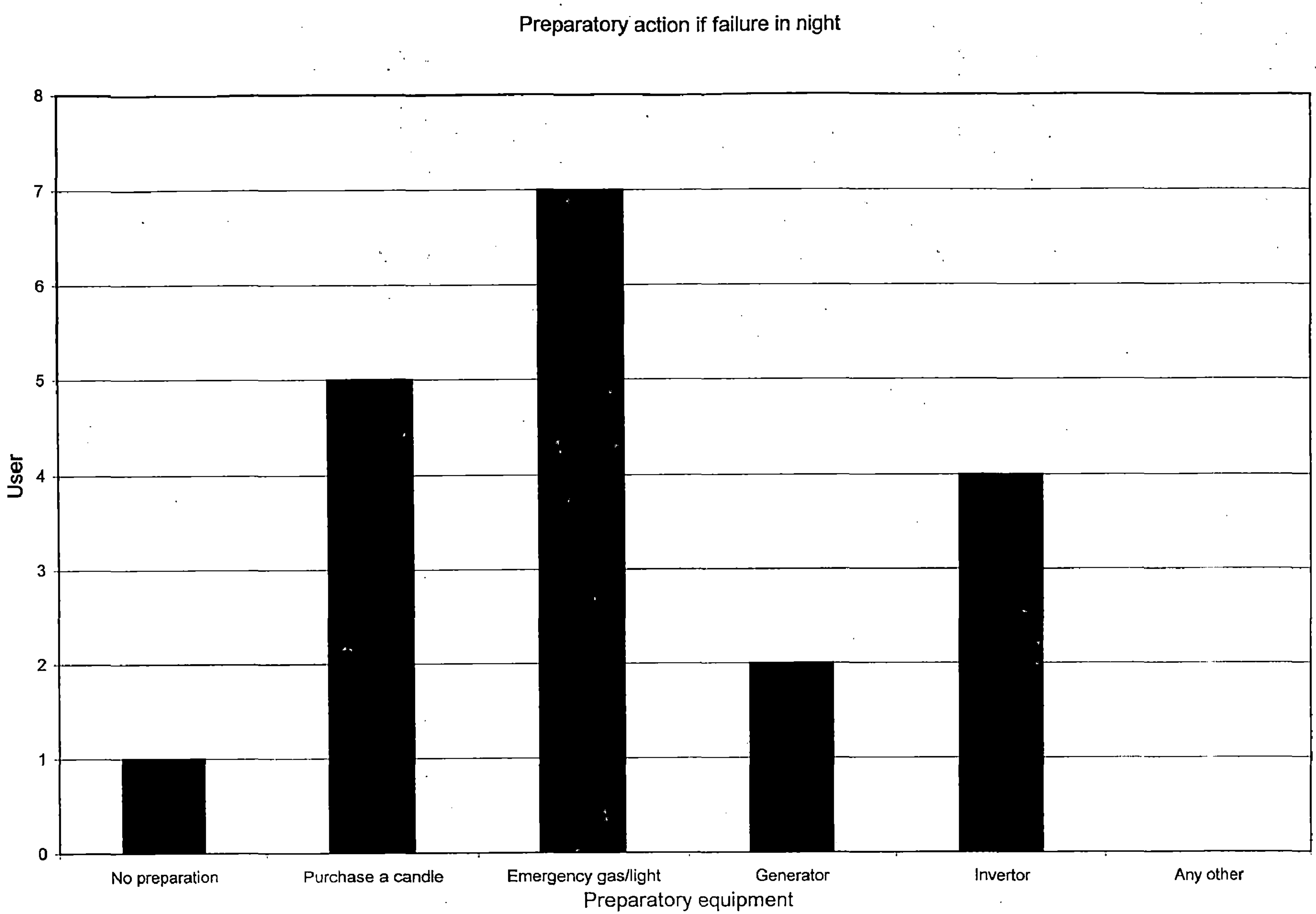


Frequency of power outages
Users
8
7
6
5
4
3
2
1
0
Very frequently
Frequently
Average
Less frequently
Not at all
Frequency
No. 40

Preparatory action if failure in night

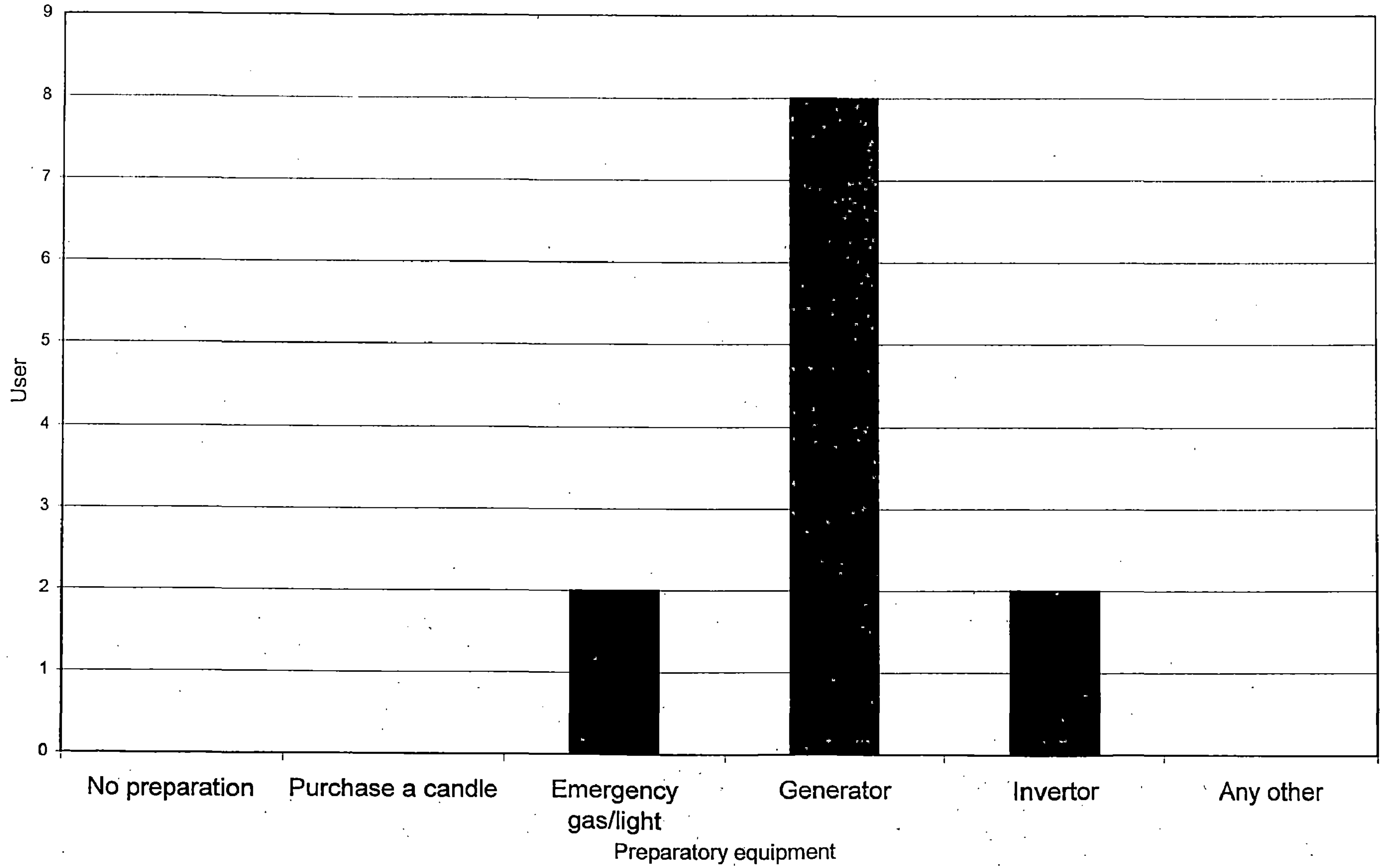


Preparatory equipment
No. 41

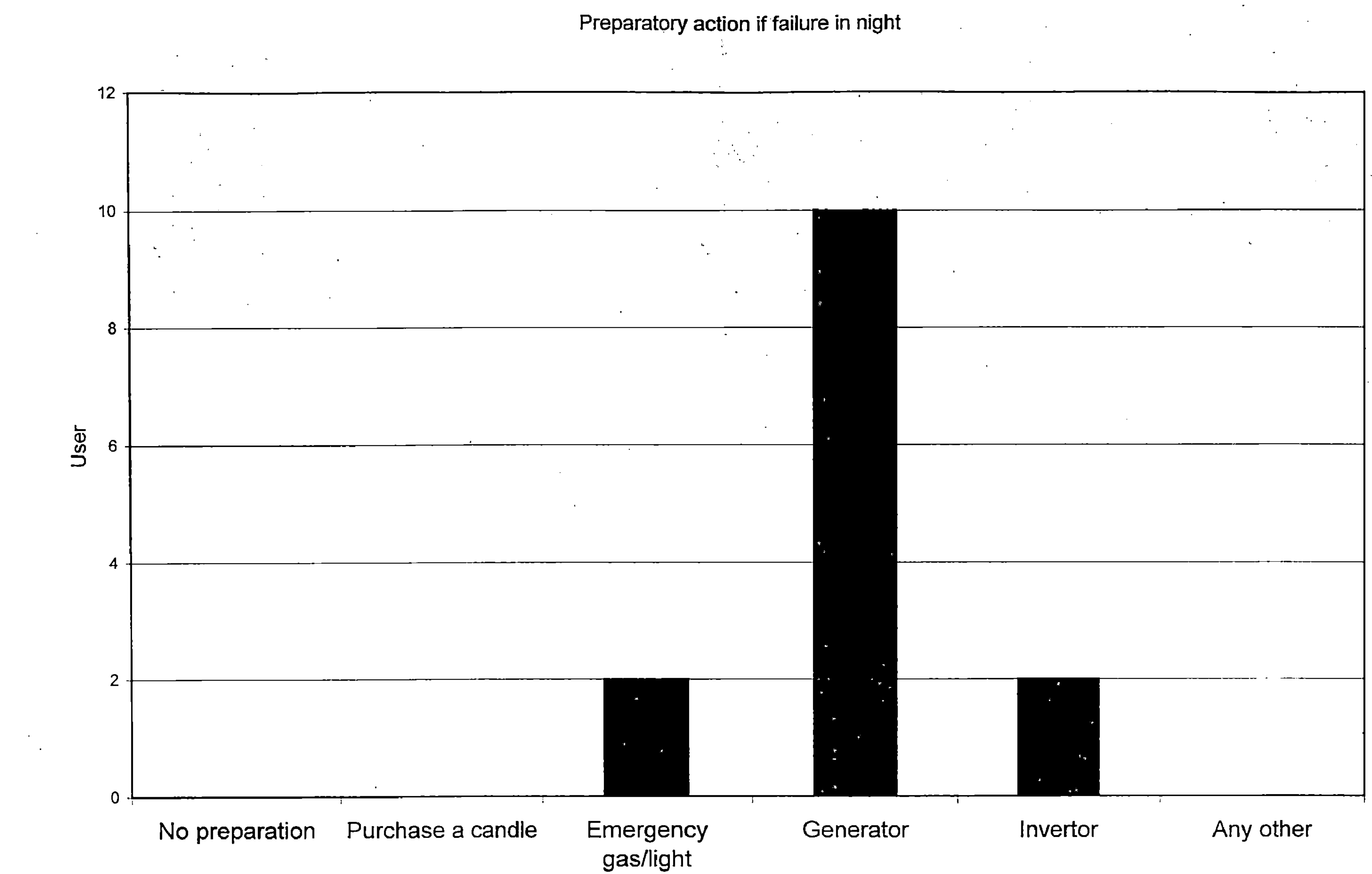

Preparatory action if failure in night
8
7
6
5
4
3
2
1
0
User
No preparation
Purchase a candle
Emergency gas/light
Generator
Invertor
Any other
Preparatory equipment

No.42

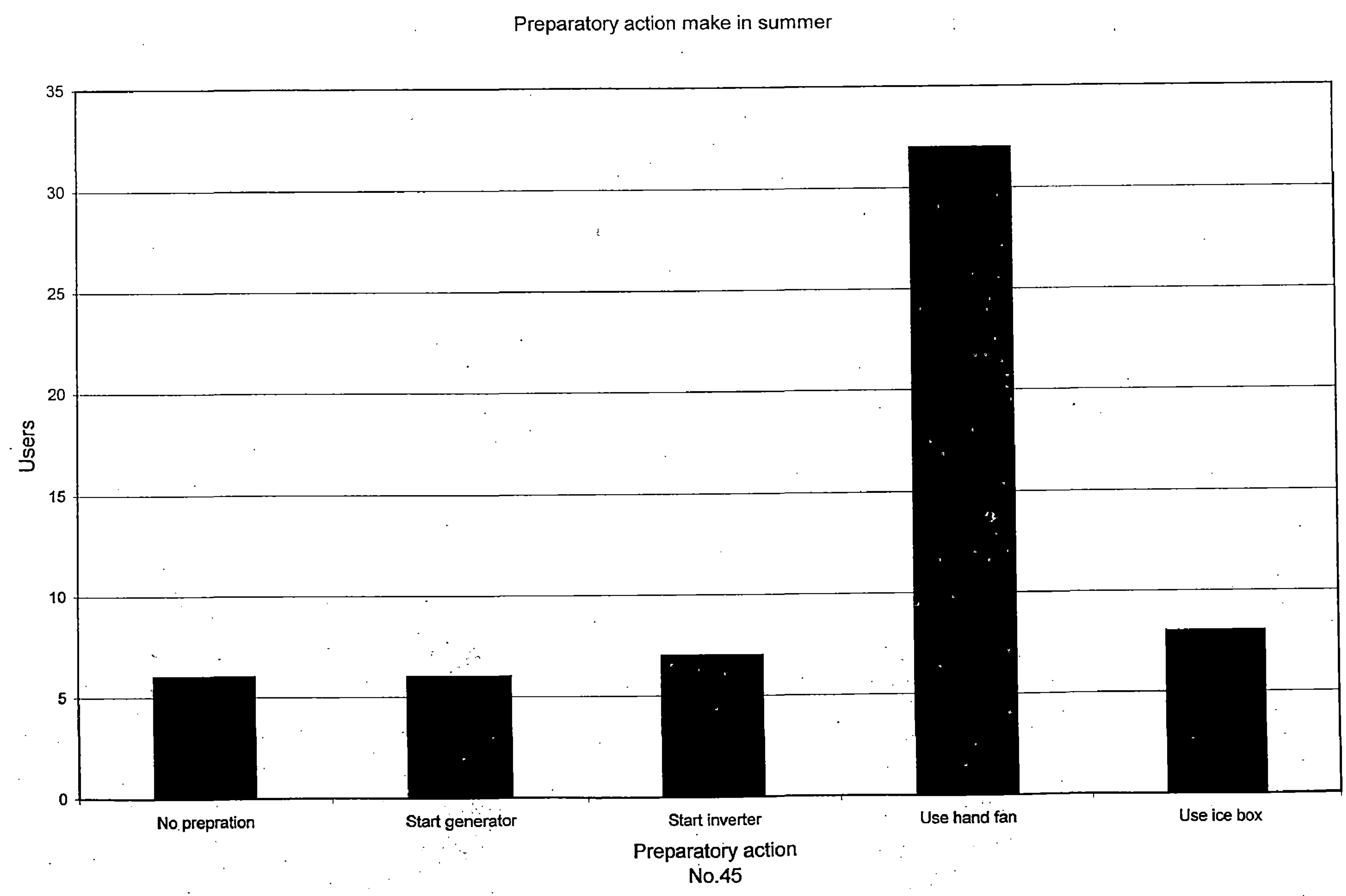
Preparatory action if failure in night



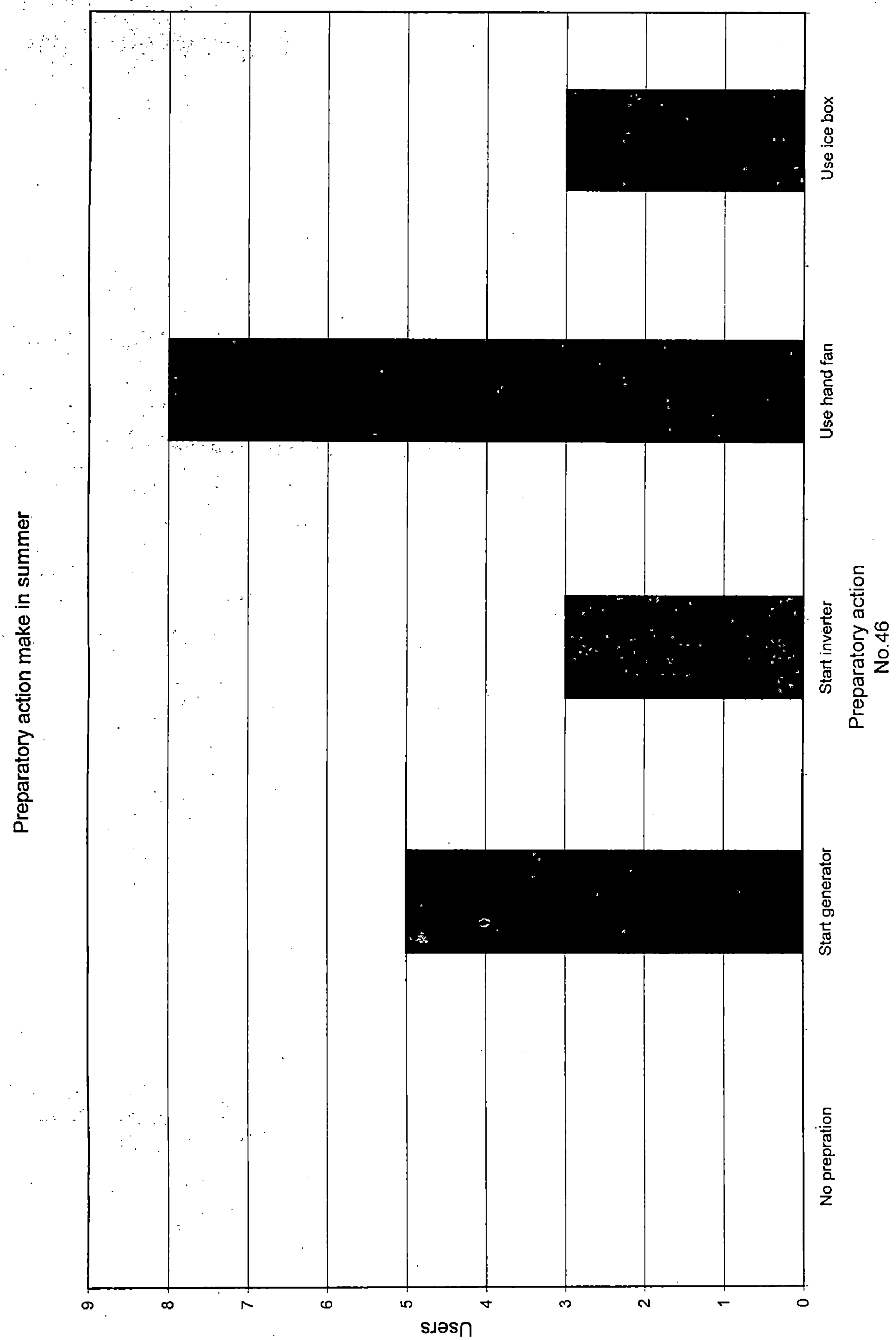
No. 43

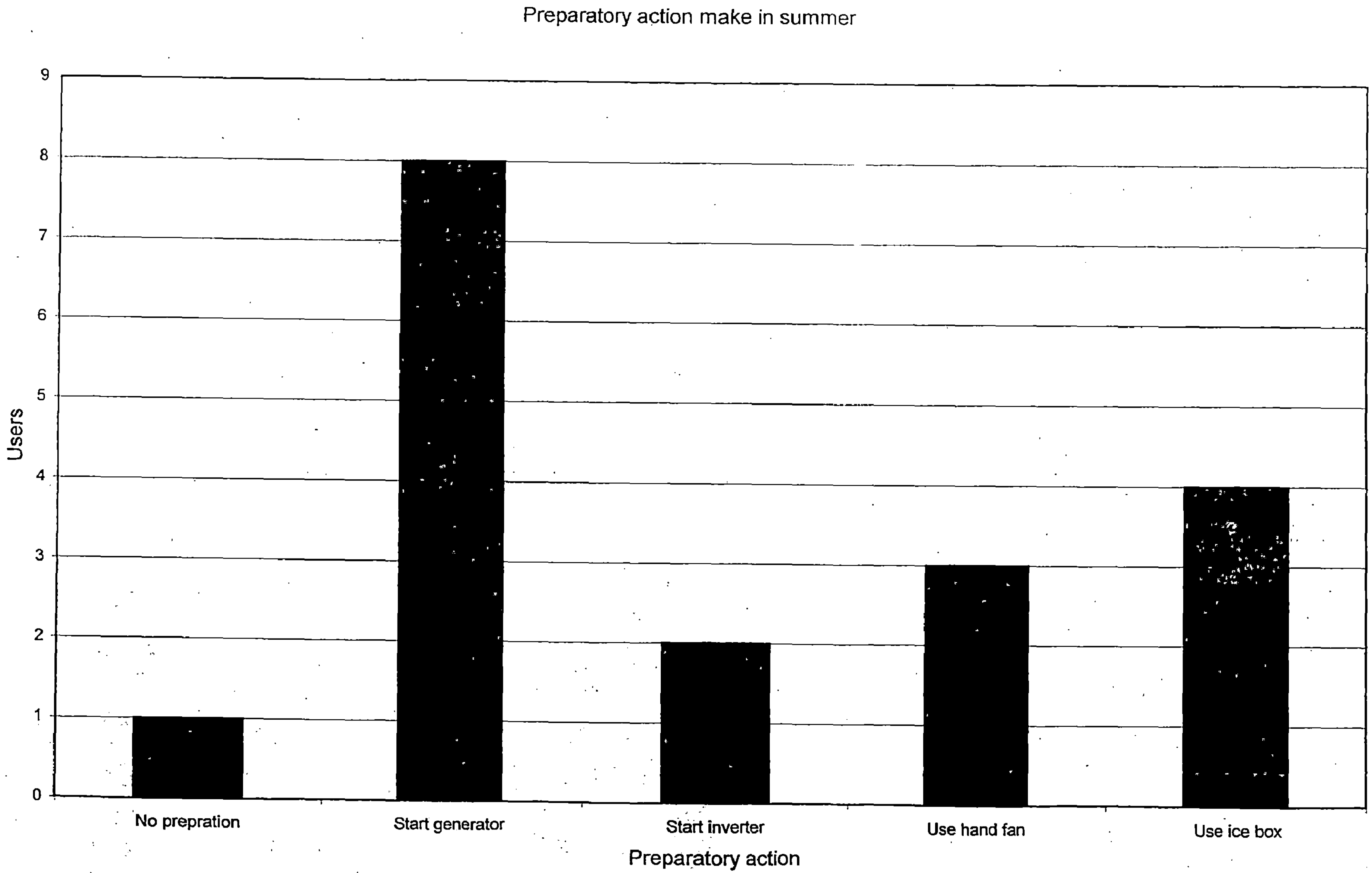

Preparatory action if failure in night
User
0
2
4
6
8
10
12
No preparation
Purchase a candle
Emergency gas/light
Generator
Invertor
Any other
Preparatory equipment

No. 44

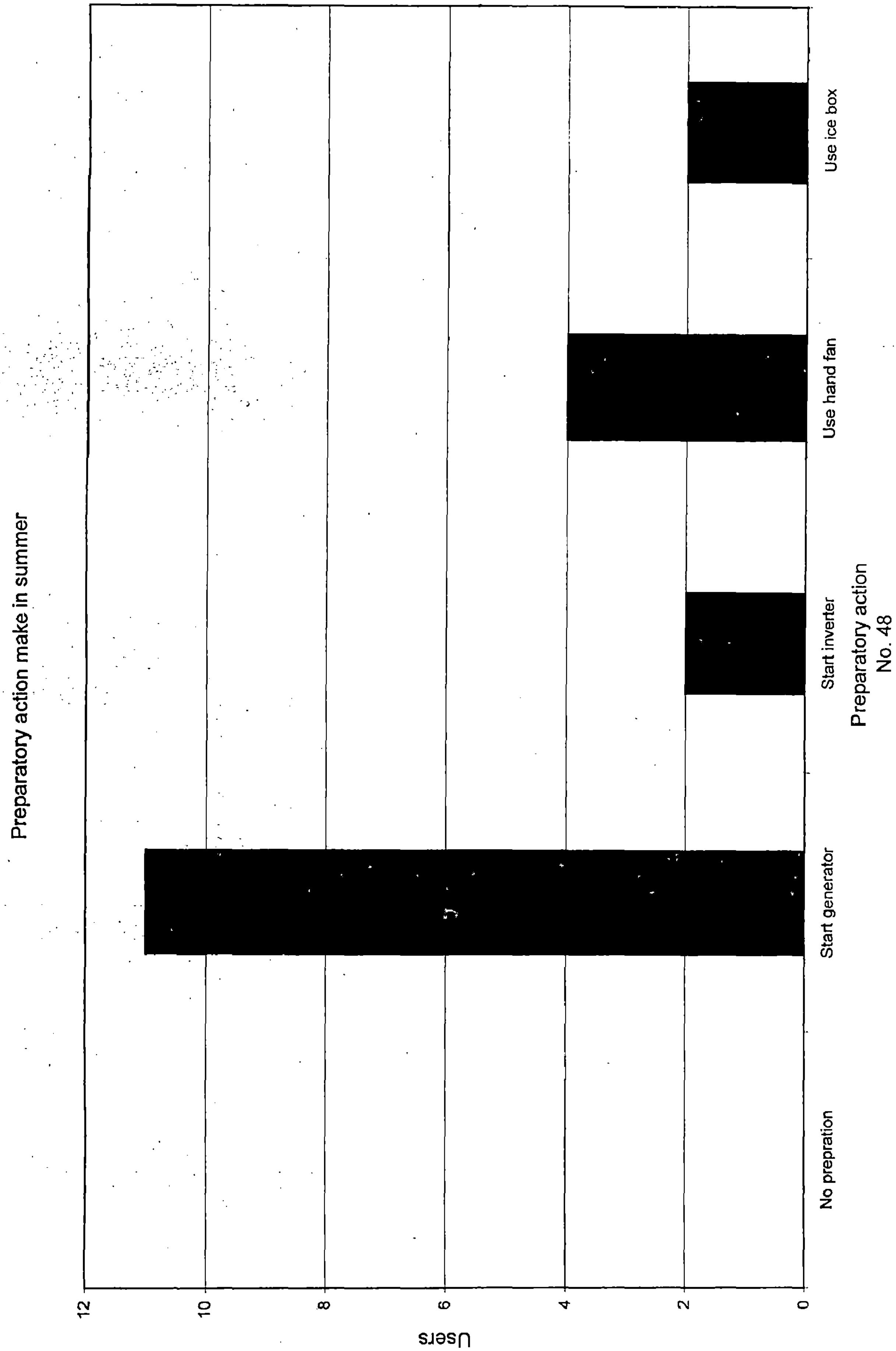


Preparatory action make in summer
Users
35
30
25
20
15
10
5
0
No prepration
Start generator
Start inverter
Use hand fan
Use ice box
Preparatory action
No.45

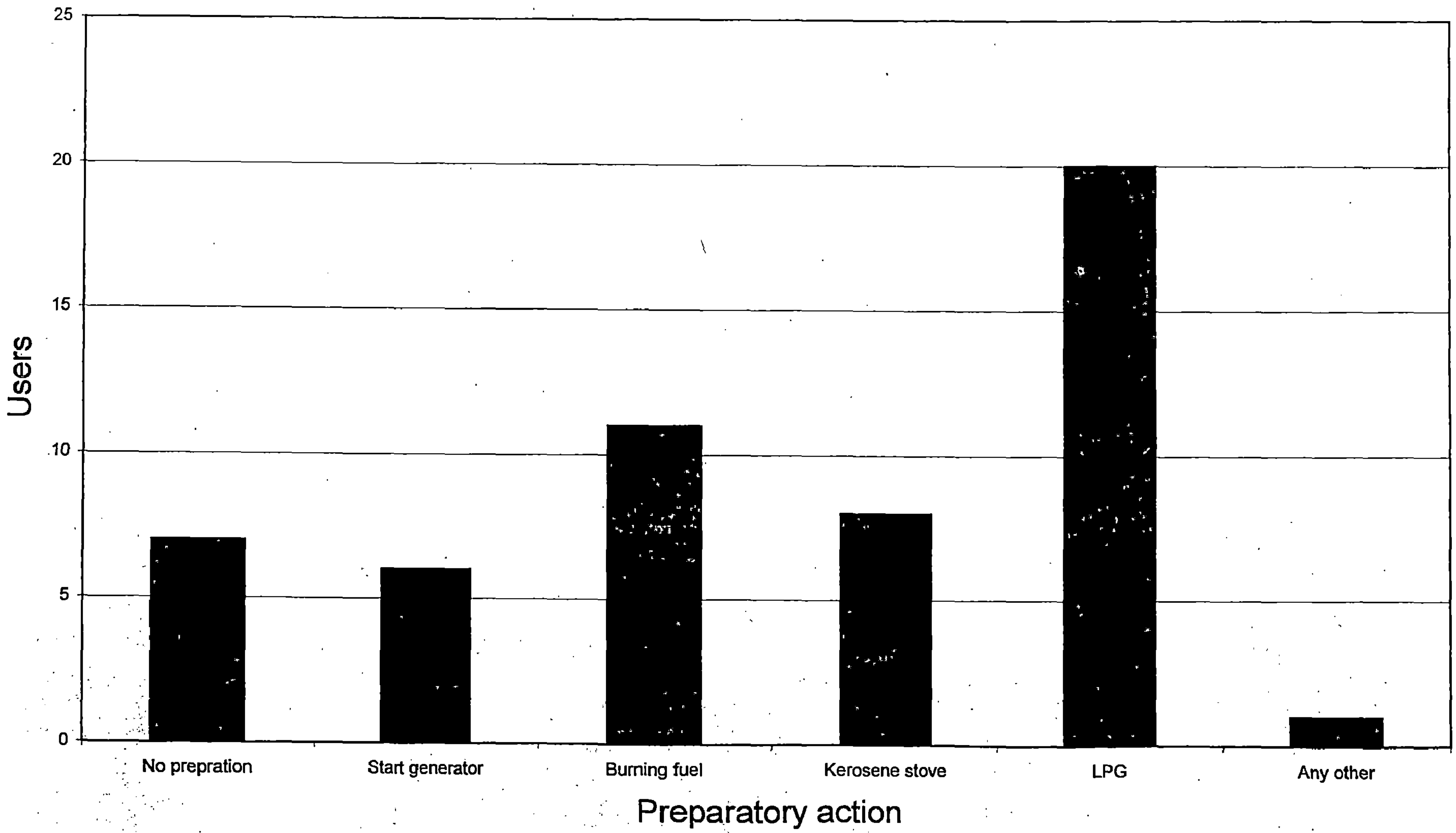

Preparatory action make in summer
Users
0
1
2
3
4
5
6
7
8
9
No prepration
Start generator
Start inverter
Use hand fan
Use ice box
Preparatory action
No.46


Preparatory action make in summer
Users
9
8
7
6
5
4
3
2
1
0
No prepration
Start generator
Start inverter
Use hand fan
Use ice box
Preparatory action

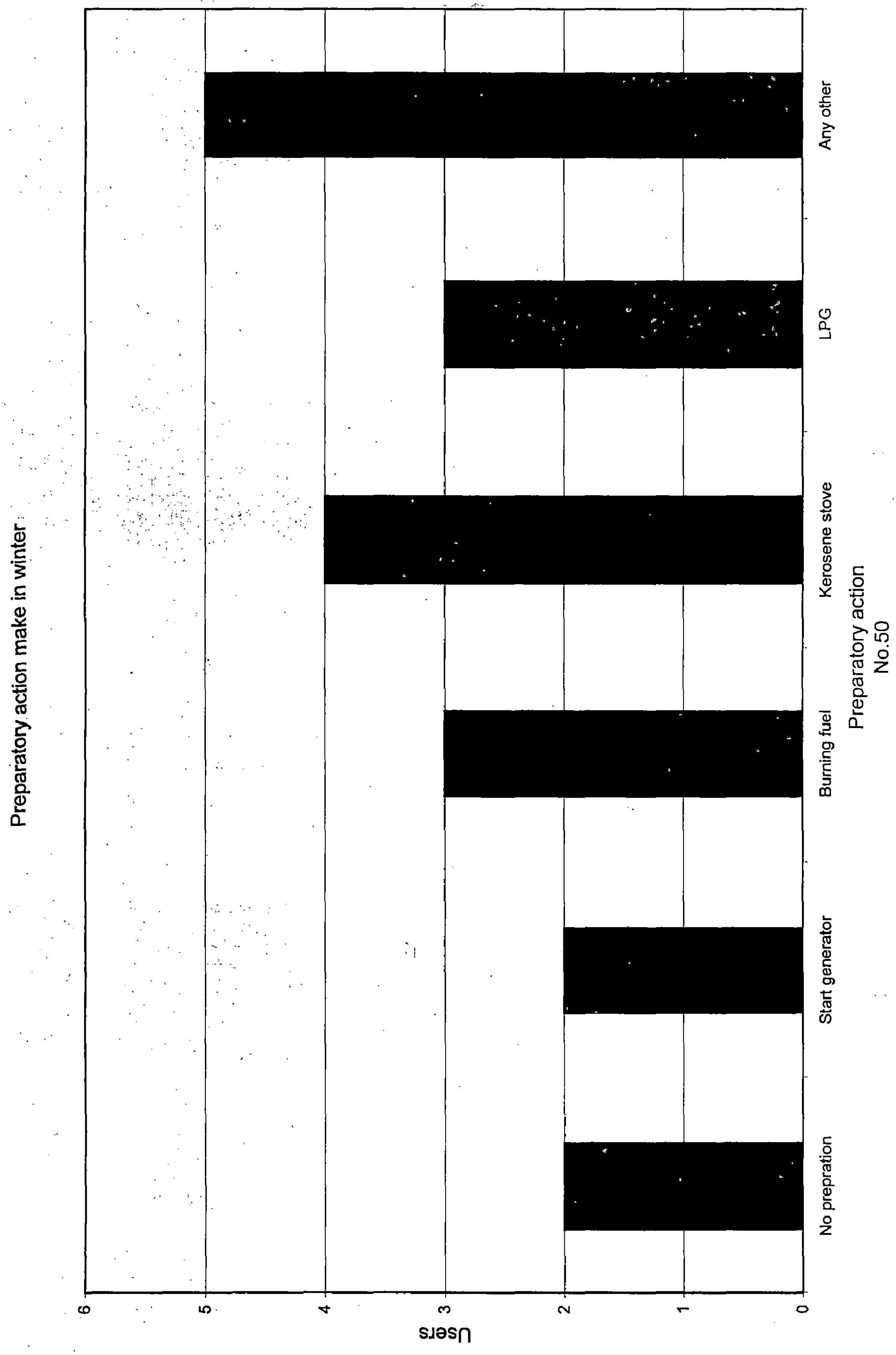
No. 47


Preparatory action make in summer
Users
12
10
8
6
4
2
0
No prepration
Start generator
Start inverter
Use hand fan
Use ice box
Preparatory action
No. 48

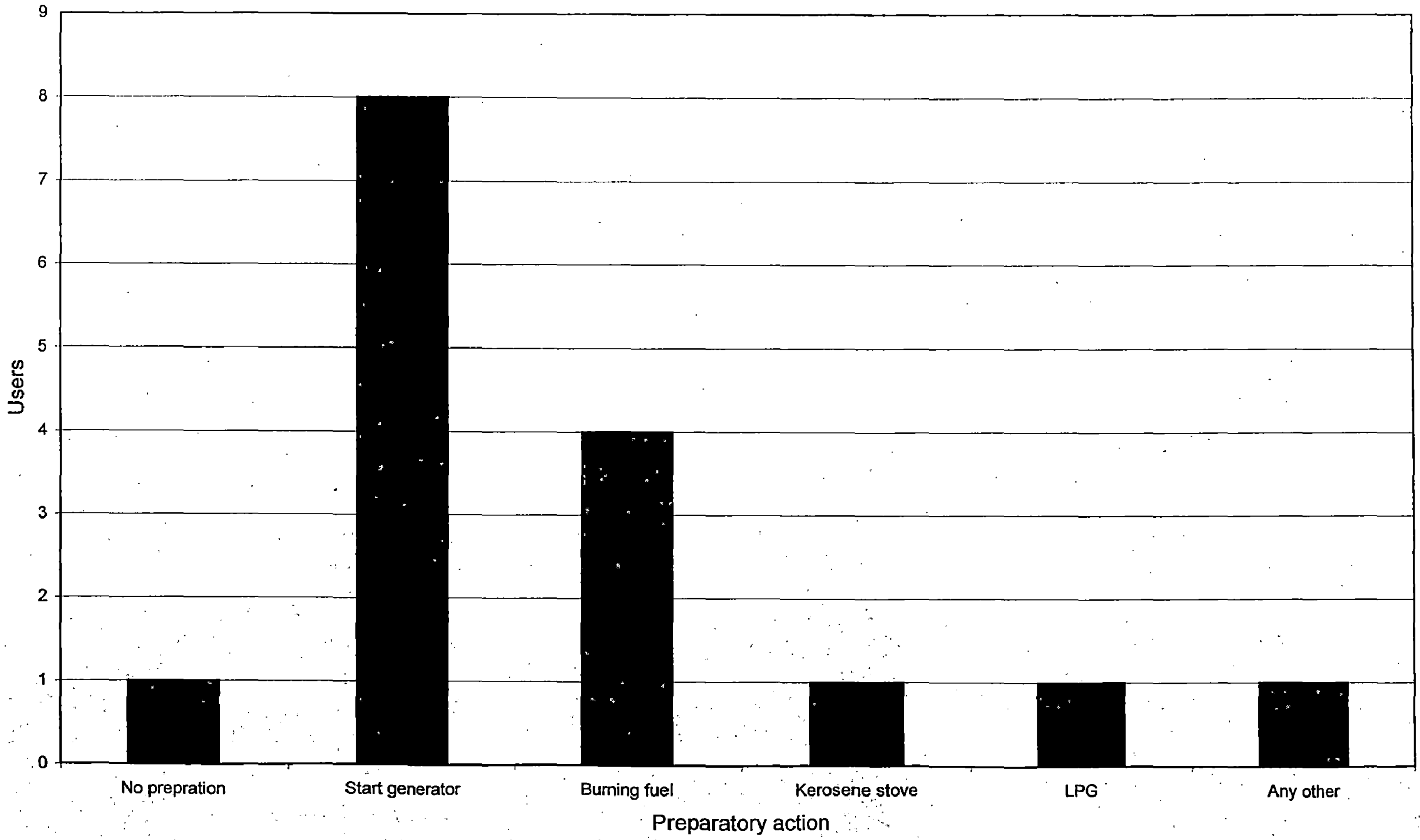
Preparatory action make in winter



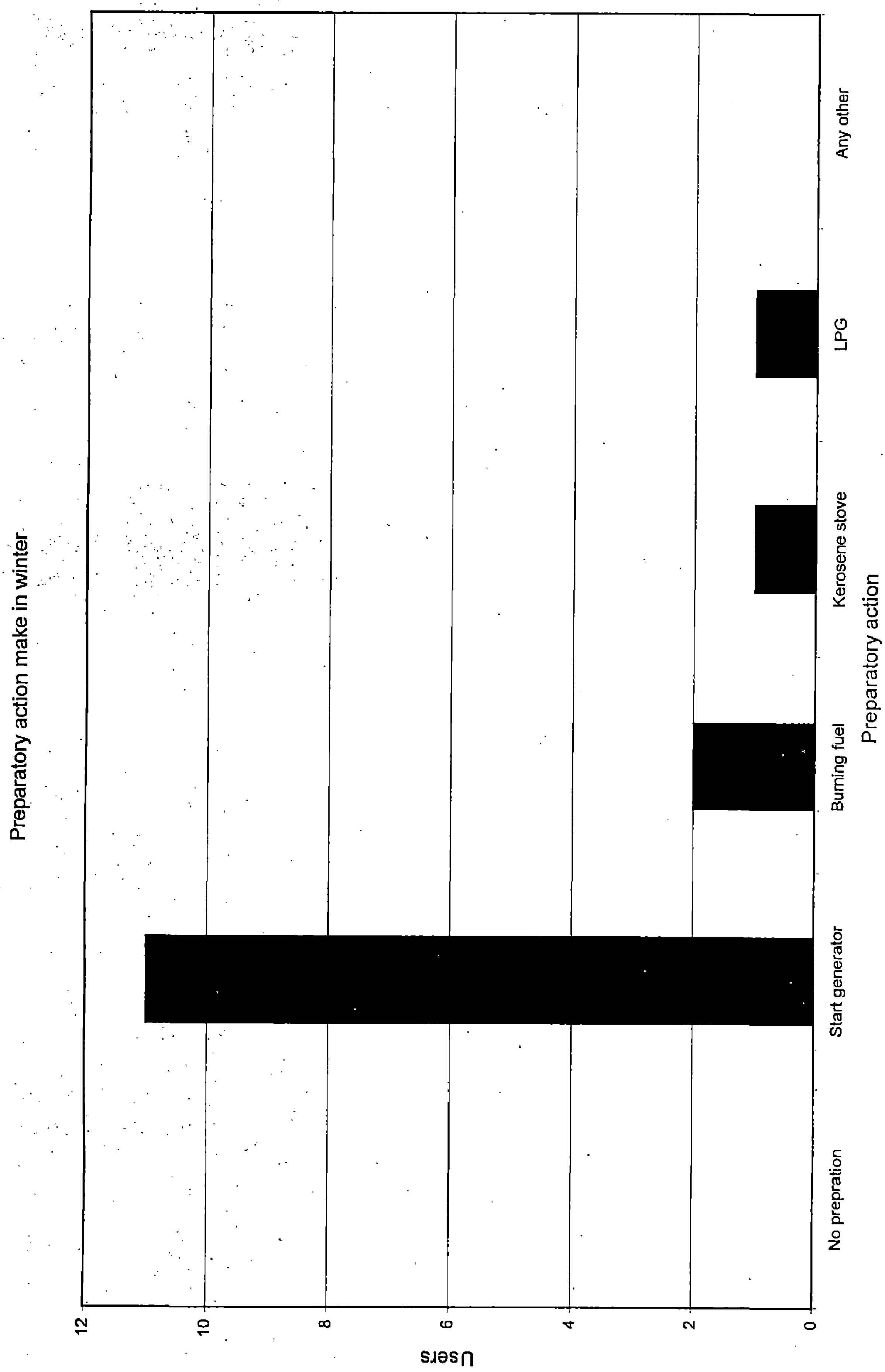
No. 49


Preparatory action make in winter
Users
0
1
2
3
4
5
6
No prepration
Start generator
Burning fuel
Kerosene stove
LPG
Any other
Preparatory action
No.50

Preparatory action make in winter



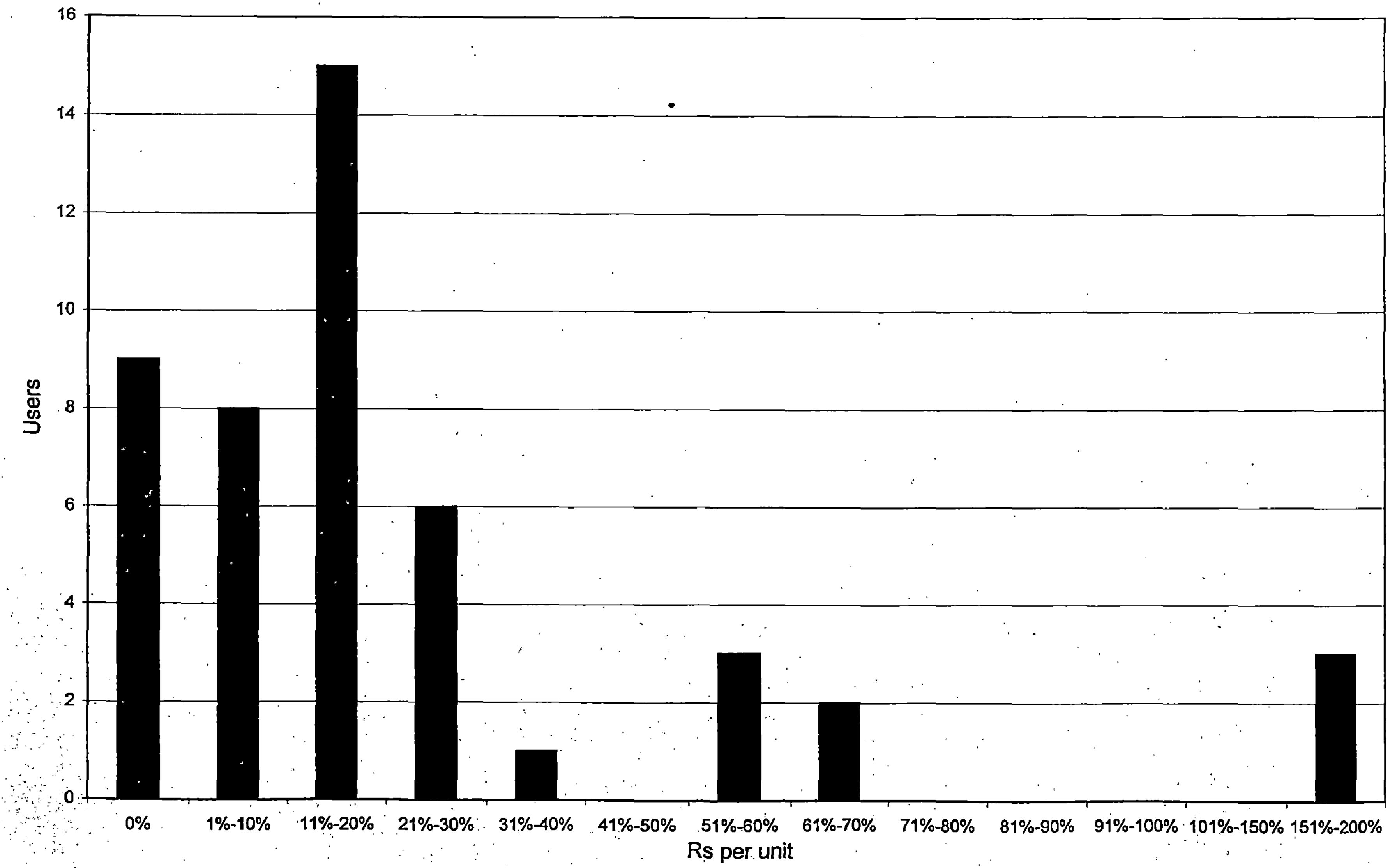
No. 51



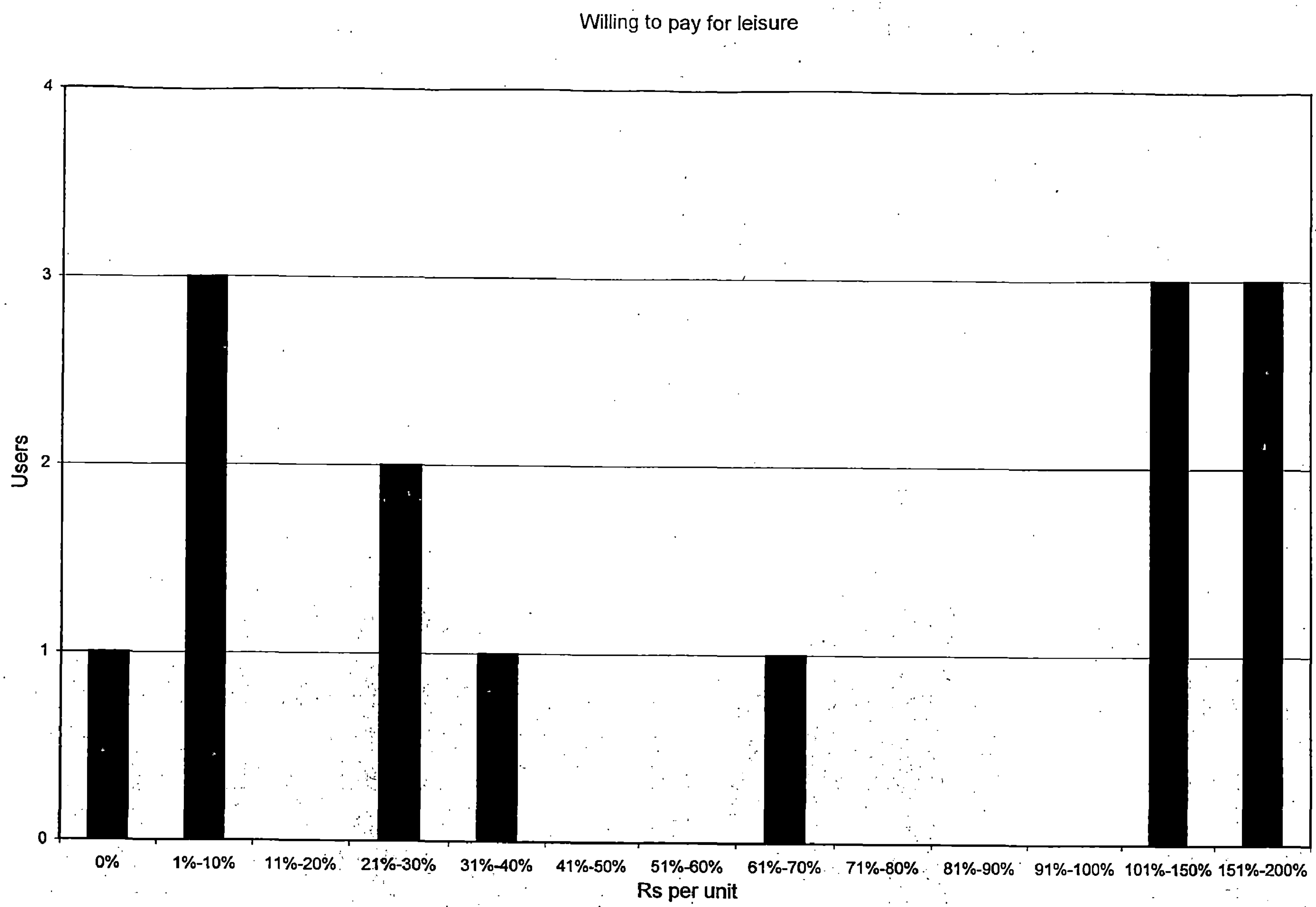
Preparatory action make in winter
Users
12
10
8
6
4
2
0
No prepration
Start generator
Burning fuel
Kerosene stove
LPG
Any other
Preparatory action

No. 52

Willing to pay for leisure

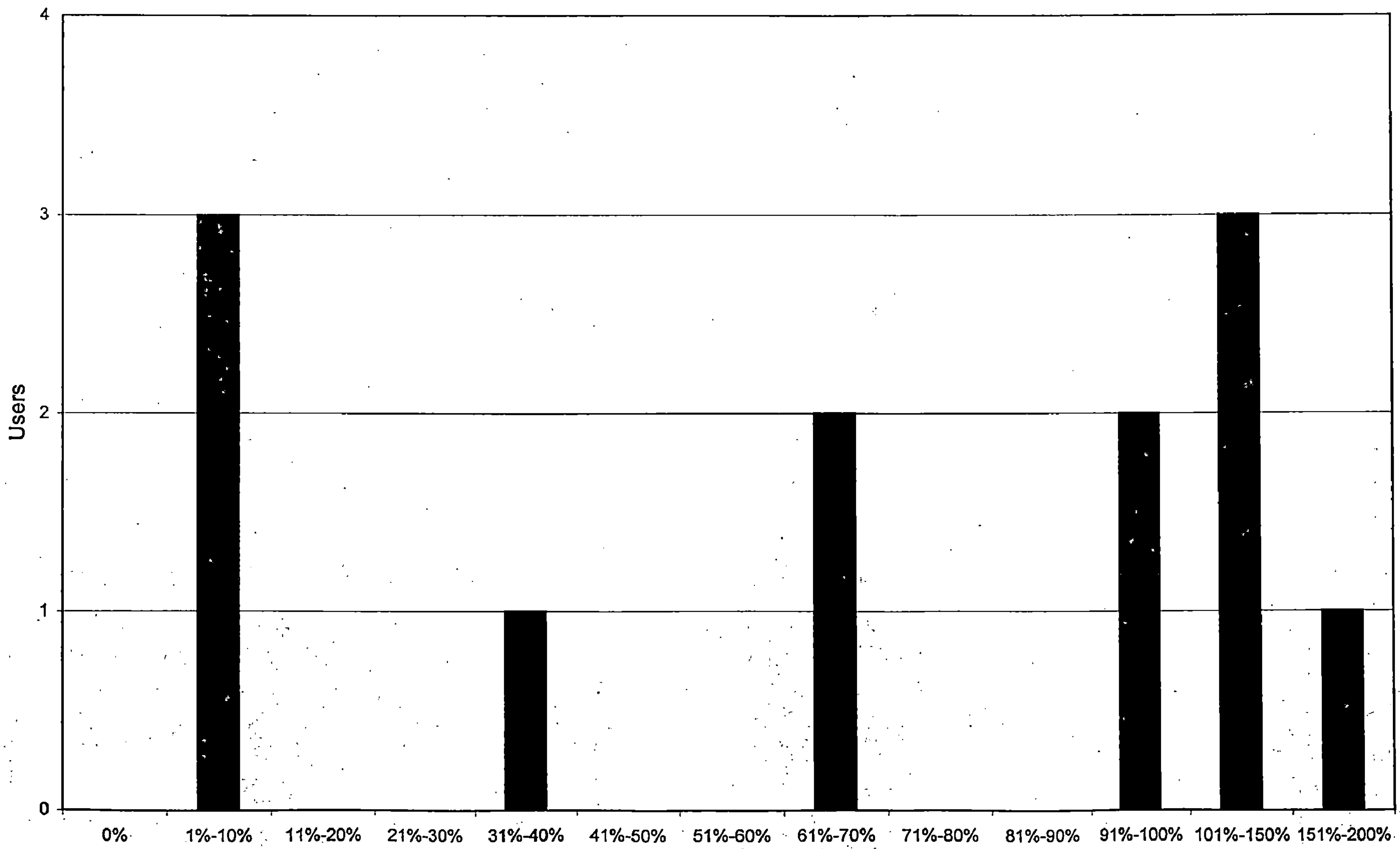


No. 53


Willing to pay for leisure
Users
4
3
2
1
0
0%
1%-10%
11%-20%
21%-30%
31%-40%
41%-50%
51%-60%
61%-70%
71%-80%
81%-90%
91%-100%
101%-150%
151%-200%
Rs per unit

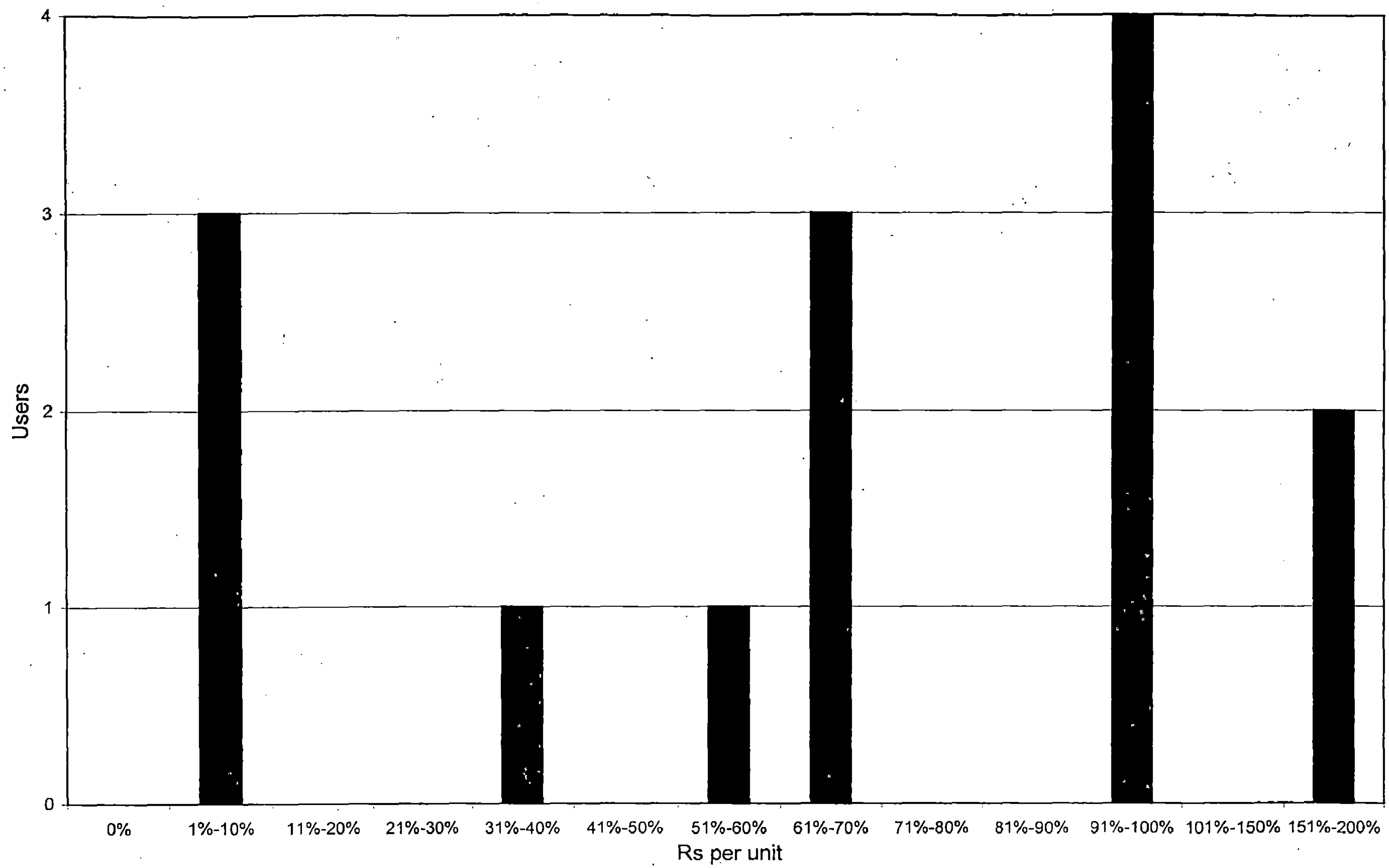
No. 54

Willing to pay for leisure



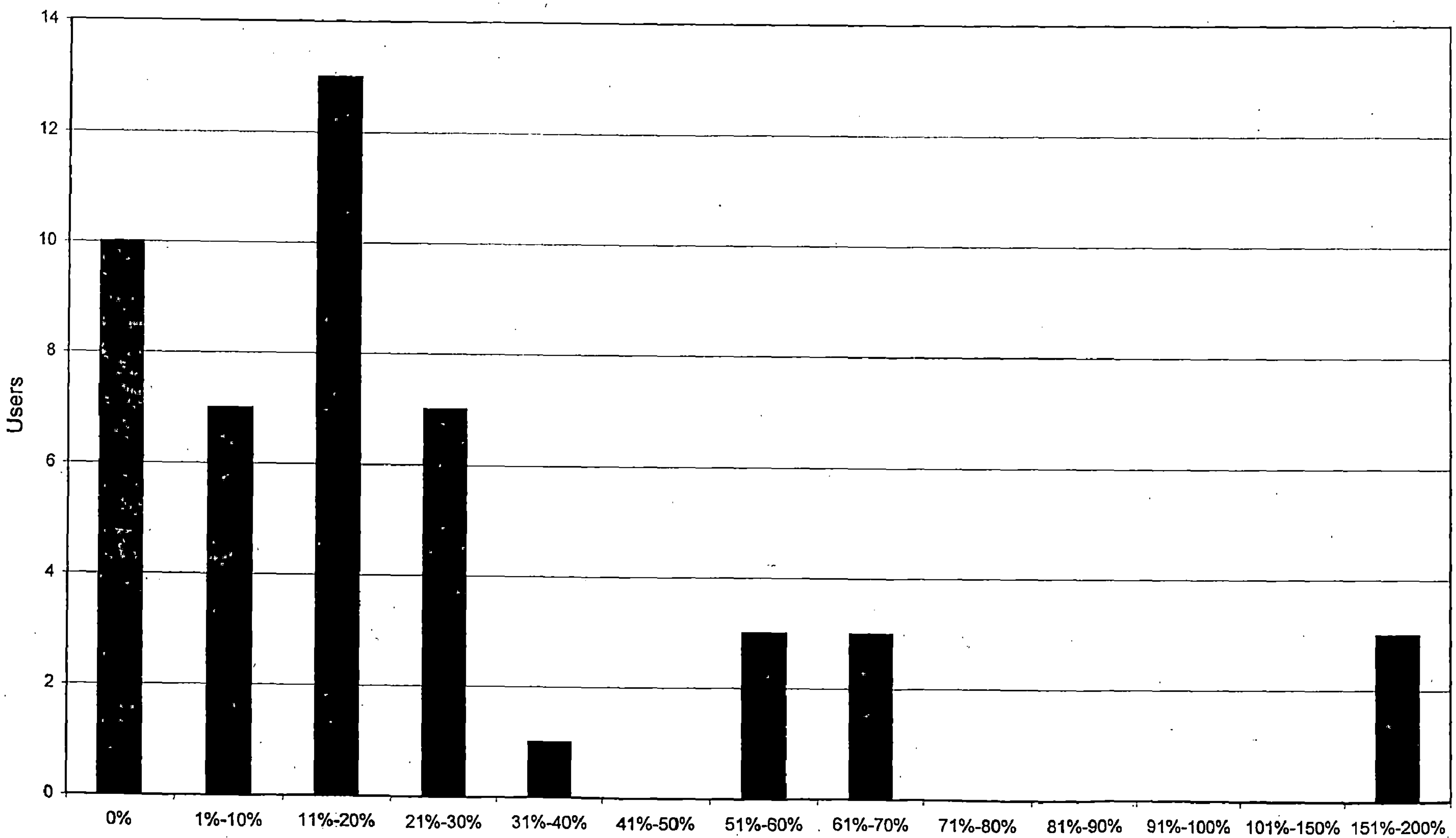
No. 55

Willing to pay for leisure



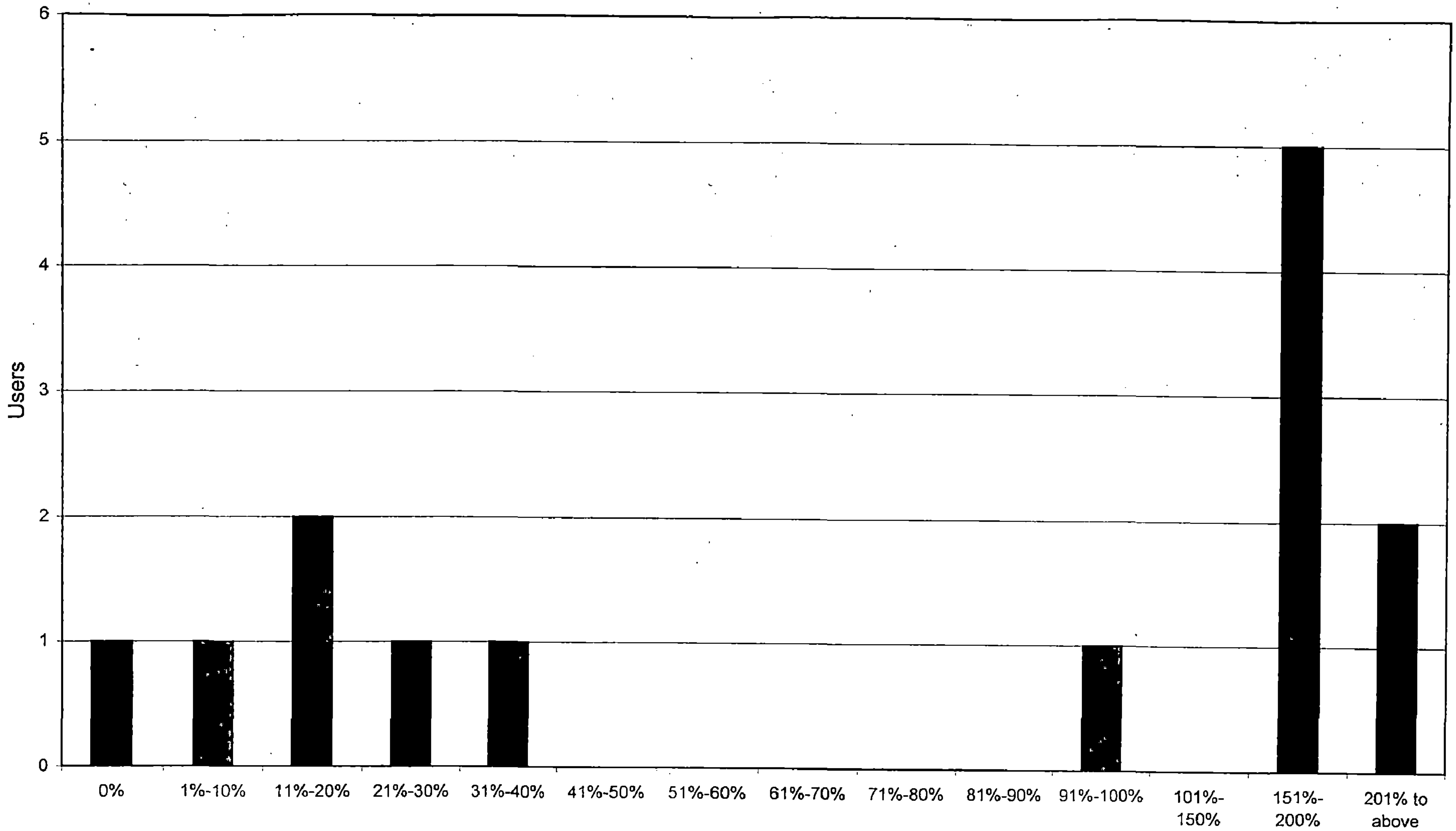
No. 56

Extra willing to pay in summer

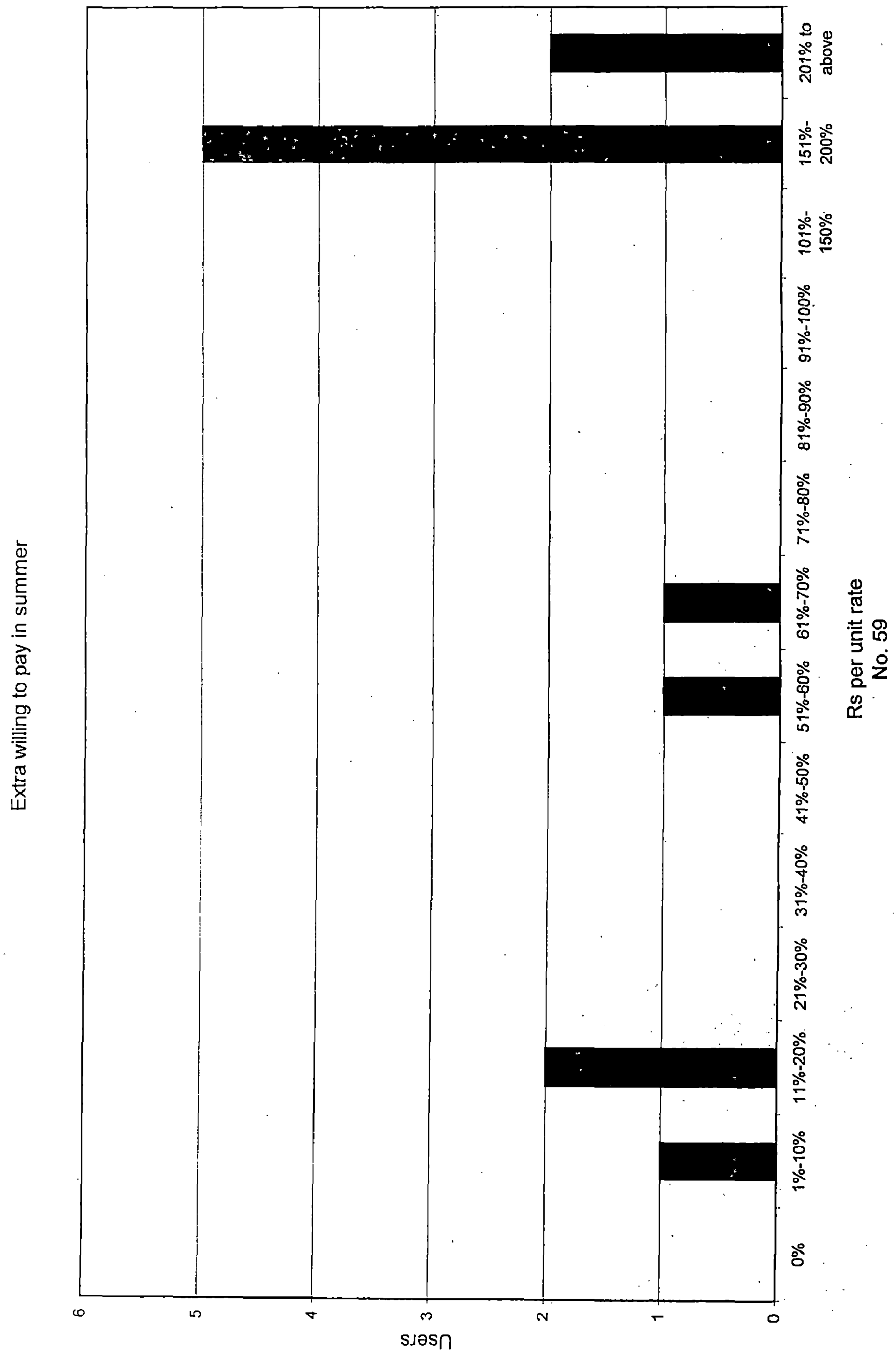


No.57

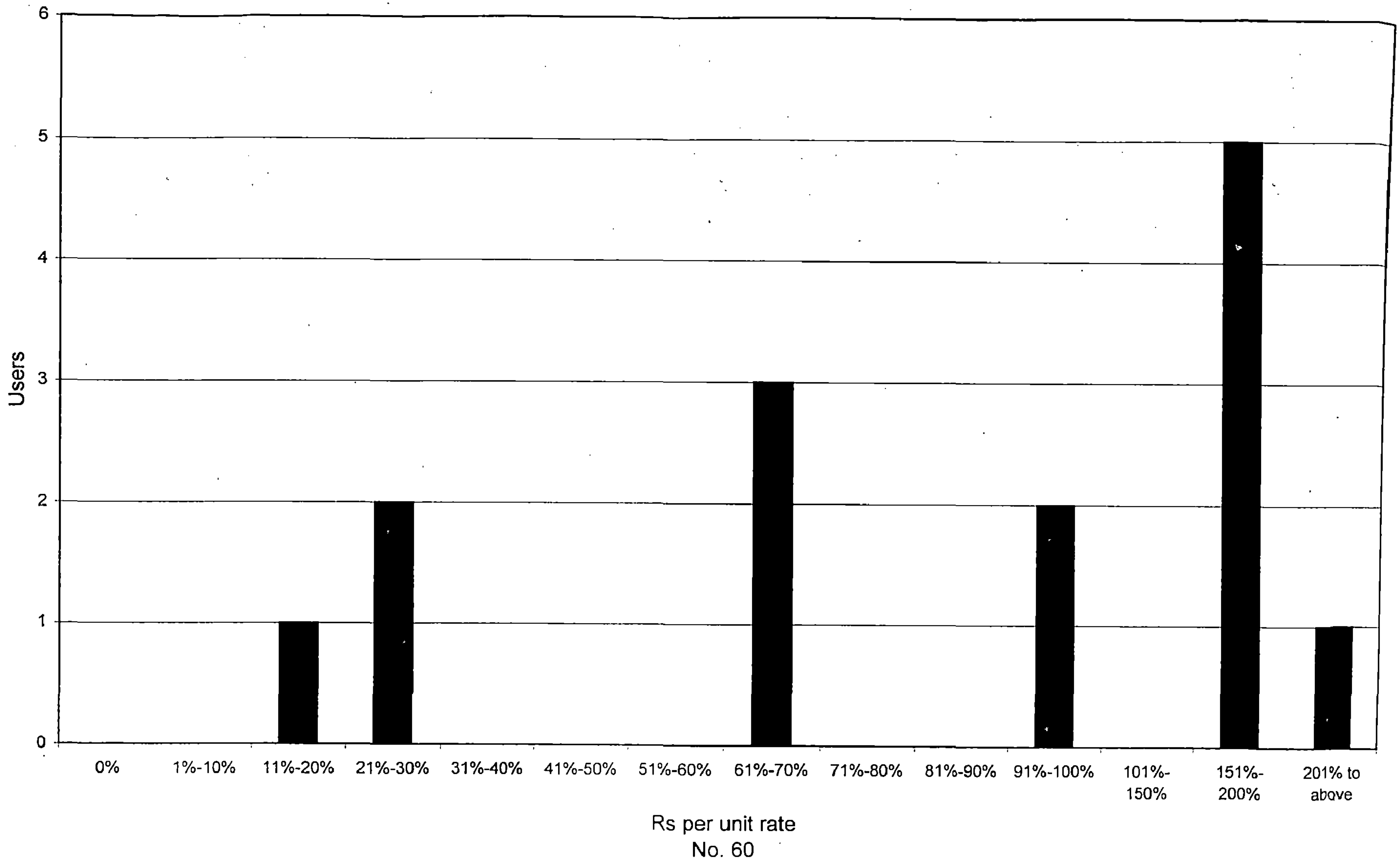
Extra willing to pay in summer

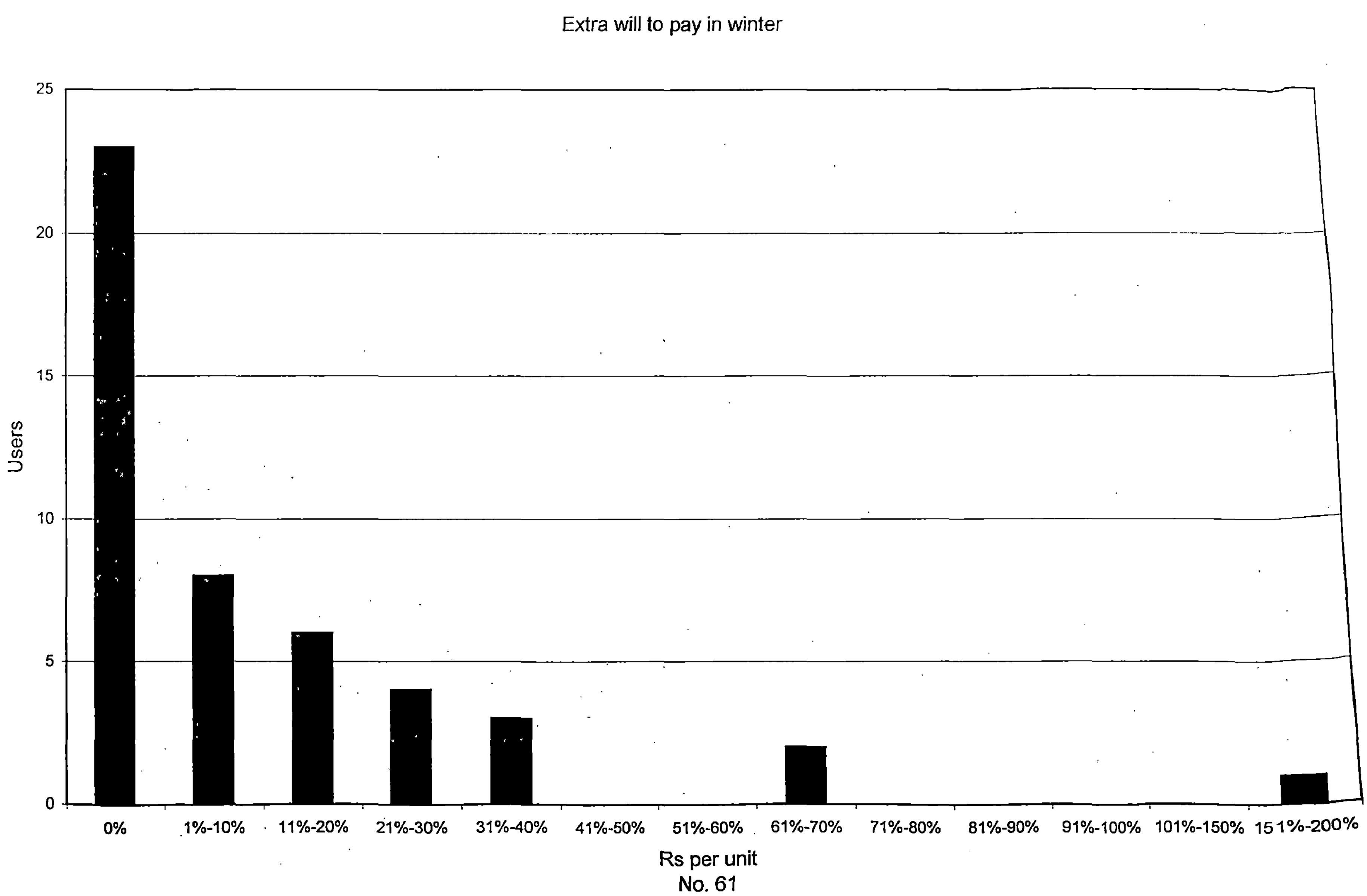


No. 58

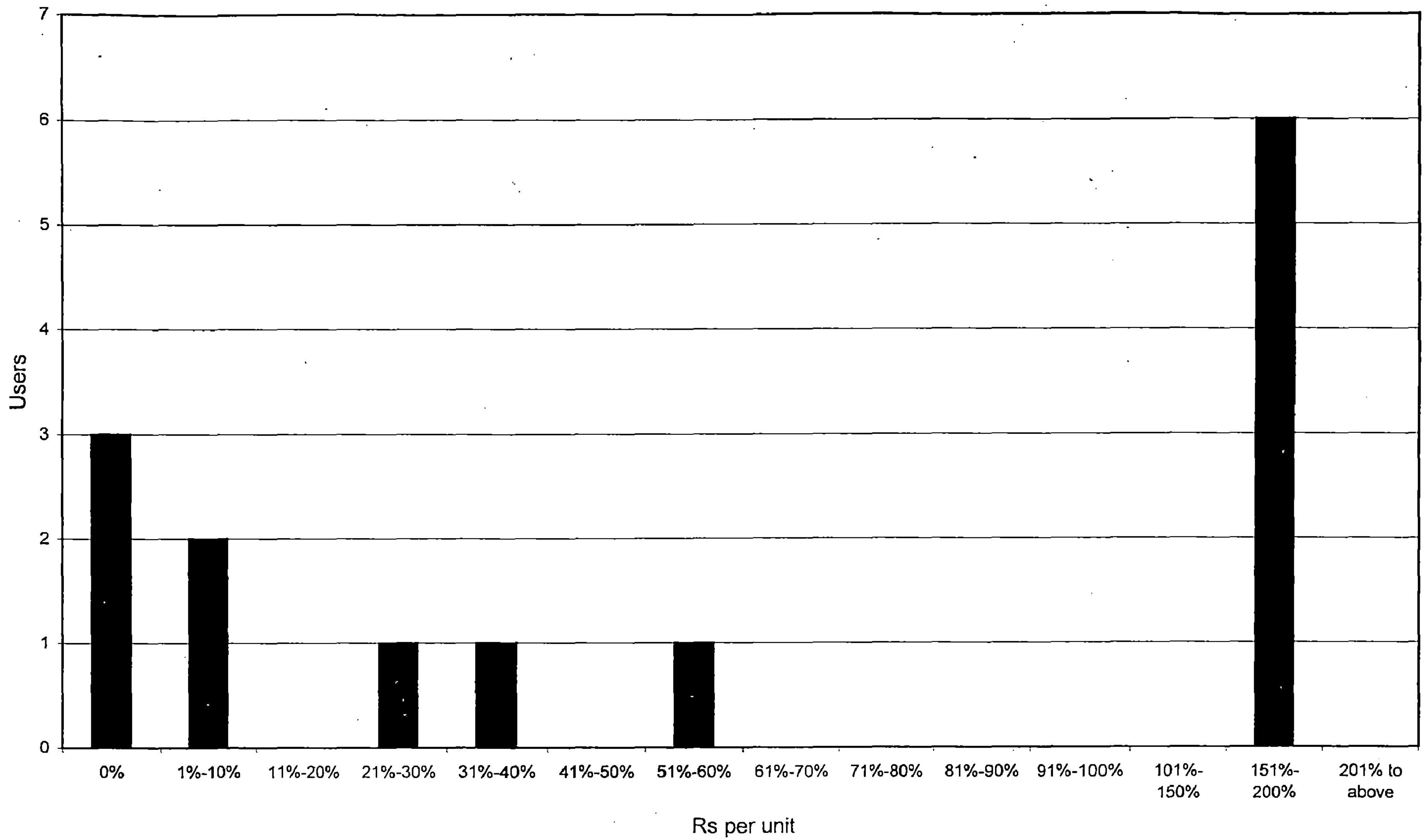

Extra willing to pay in summer
Users
0
1
2
3
4
5
6
0%
1%-10%
11%-20%
21%-30%
31%-40%
41%-50%
51%-60%
61%-70%
71%-80%
81%-90%
91%-100%
101%-150%
151%-200%
201% to above
Rs per unit rate
No. 59

Extra willing to pay in summer

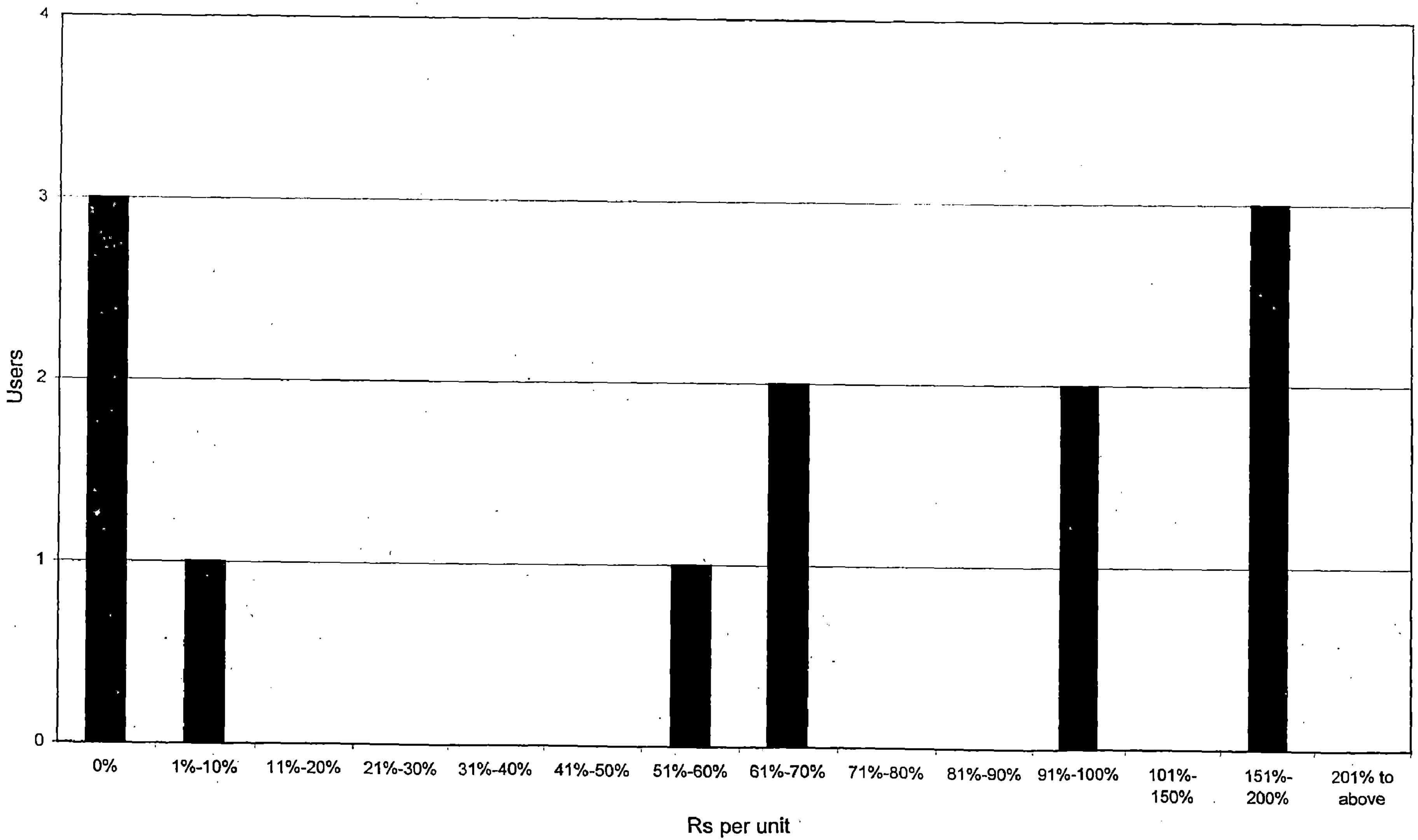



Extra will to pay in winter
25
20
15
10
5
0
Users
0%
1%-10%
11%-20%
21%-30%
31%-40%
41%-50%
51%-60%
61%-70%
71%-80%
81%-90%
91%-100%
101%-150%
151%-200%
Rs per unit
No. 61

Extra will to pay in winter

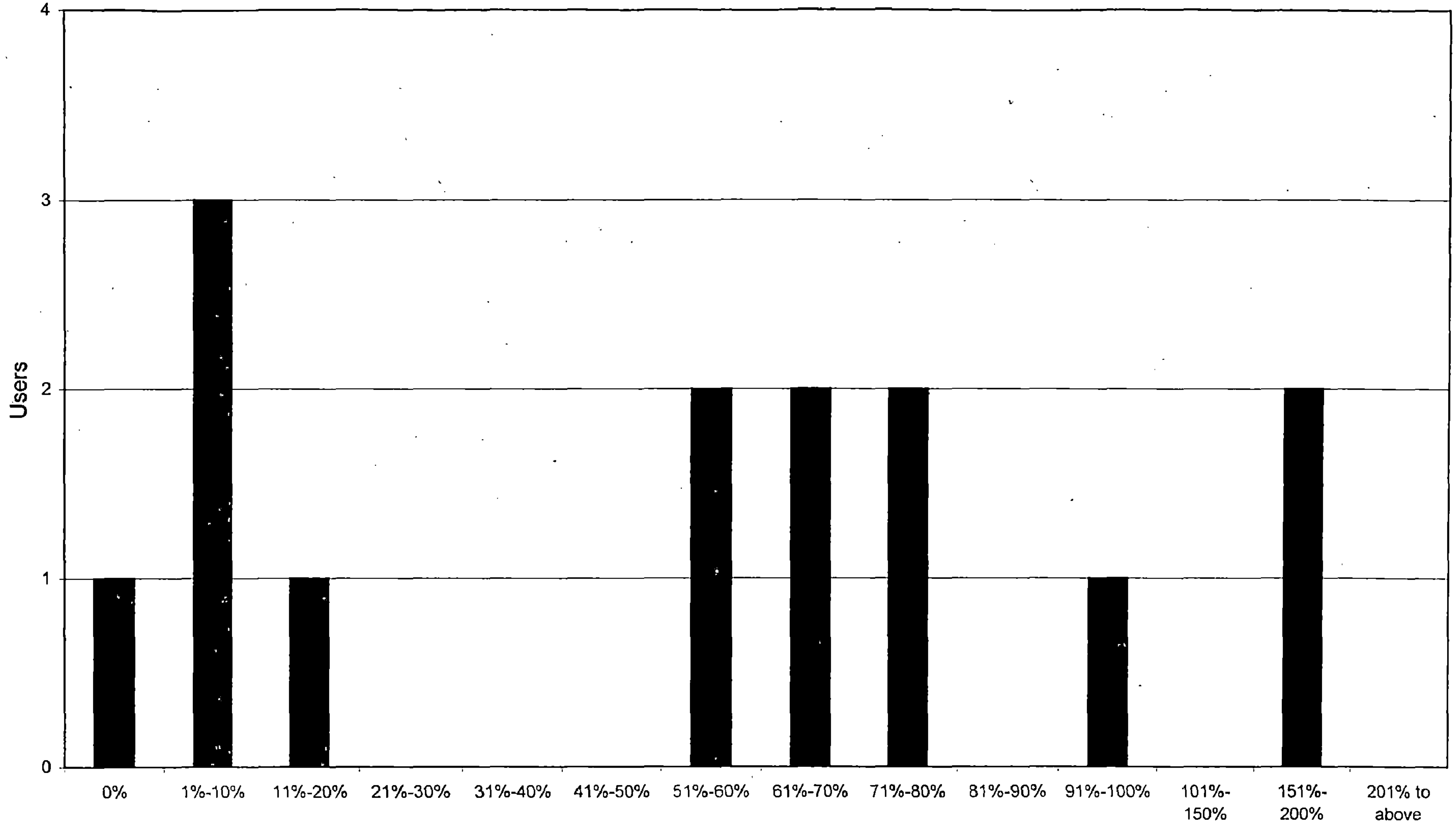


Extra will to pay in winter



No. 63

Extra will to pay in winter



Rs per unit
No. 64

APPENDIX-III

DATA USED FOR PROPOSED MODEL

The system having three generating units. The capacity of each generating units are 75kW, 75 kW and 100 kW respectively.

Table I

Generating unit reliability data

Unity size (kW)	No. of units	Failure rate	Repair rate
75	2	0.01	0.49
100	1	0.01	0.49

Load model data

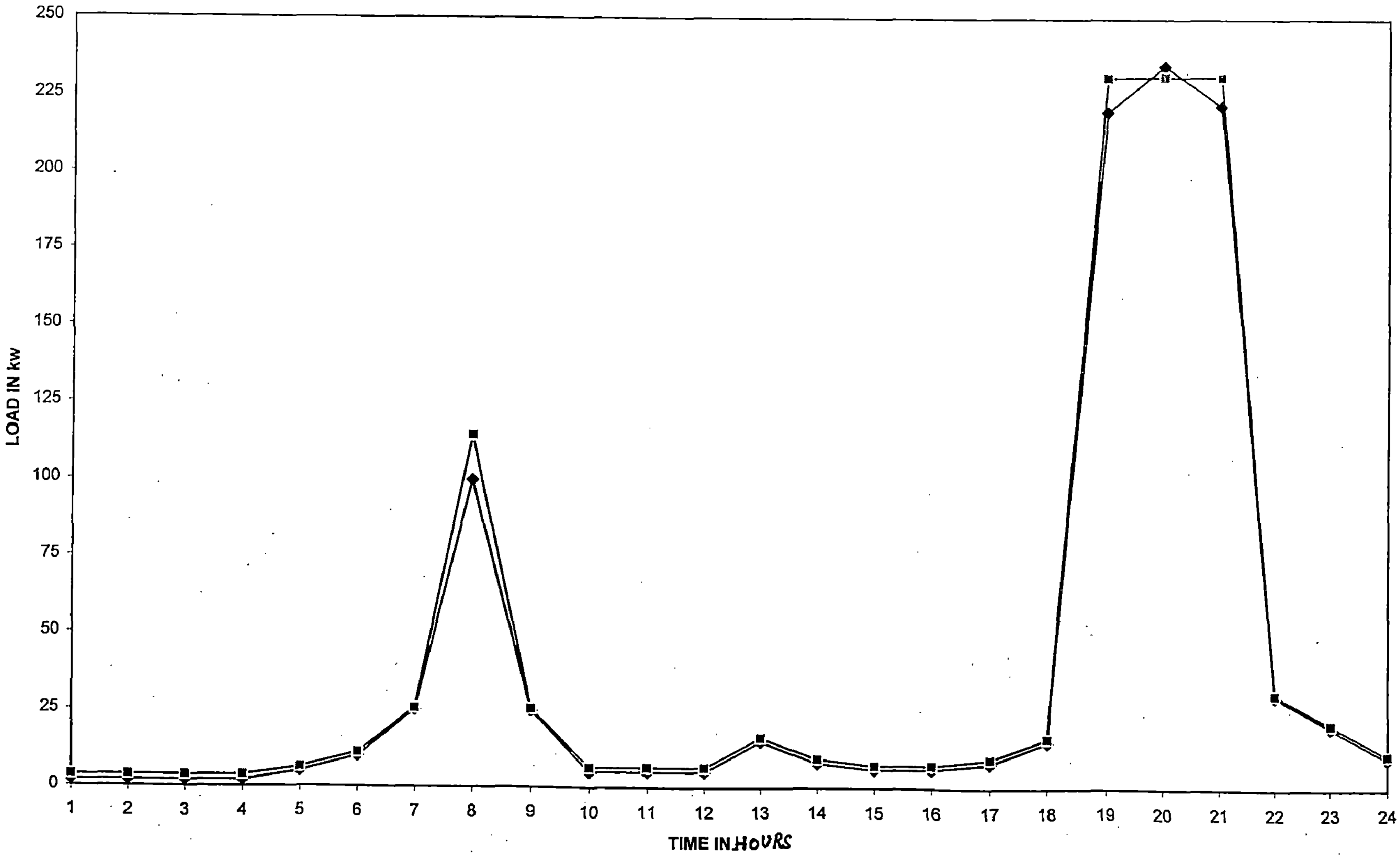
Hourly peak load for a twenty four hour duration is presented the load data are available from the Saket substation Meerut (U.P)

Table II

Hourly peak load data

Hour	Load (kW)	Hour	Load(kW)	Hour	Load(kW)
12-1 a.m.	2	8-9	25	4-5	8
1-2	2	9-10	5	5-6	15
2-3	2	10-11	5	6-7	220
3-4	2	11-12 a.m.	5	7-8	235
4-5	5	12-1pm	15	8-9	222
5-6	10	1-2	8	9-10	30
6-7	25	2-3	6	10-11	20
7-8	100	3-4	6	11-12	10

LOAD DURATION CURVE



APPENDIX - IV

RESIDENTIAL CONSUMER SURVEY QUESTIONNAIRE*

CITY NAME:

EMPLOYMENT:

TOTAL NUMBER OF FAMILY MEMBERS:

GROSS ANNUAL INCOME :

(Q.NO.1): What was your average monthly electricity consumption during the last three months?

______________Units per month _________________Rs per month.

(Q.NO.2): Do you feel that your electricity supply is:

Far from satisfactory	Unsatisfactory	Satisfactory	Good	Very good
☐	☐	☐	☐	☐

(Q.NO.3): Do you feel that here electric power outages are:

Very frequently	frequently	average	Less frequently	Not at all
☐	☐	☐	☐	☐

Q.NO.4): a). On average, how many minutes /hours of unexpected outages per month have you experienced during the last three month?

_____________________________ Minutes/hours per month.

---

* The information requested in this Questionnaire is for research purposes only and will be used with strict confidentiality.

b). During what hours is electricity essential for the enjoyment of your leisure?

____.

c). Approximately what fraction of outages occurred during these critical hours?

____ %.

(Q.NO.5) If an unexpected outage occurred during these critical hours while you were enjoying your leisure (e.g., watching TV, listening to the music system, reading, having dinner, etc.), how much extra Would you be pay to avoid:

a) A 5-minute interruption ____________________Rs/unit.
b) A 15-minute interruption ____________________Rs/unit.
c) A 30-minute interruption ____________________Rs/unit.
d) A two-hour interruption ____________________Rs/unit.
e) A four-hour interruption ____________________Rs/unit.

(Q.NO.6) If an unexpected outage occurred at any other time (e.g. while house keeping) how much extra would you be willing to pay to avoid:

a) A30-minute interruption ____________________ Rs/unit.
b) A one-hour interruption ____________________ Rs/unit.
c) A two-hour interruption ____________________ Rs/unit.
d) A four-hour interruption ____________________ Rs/unit.
e) An eight-hour interruption ____________________ Rs/unit.

(Q.NO.7) Do you feel that :

a) Electricity is an important service Yes No
b) The service is too expensive Yes No

(Q.NO.8) On the average, how do you spend your evening / nighttime leisure hours?

a) Watching TV ____________________hours.
b) Listening to the music system __________hours.
c) Reading ____________________hours.
d) Having dinner ____________________hours.
e) Going out ____________________hours.
f) Other ____________________hours.

(Q.NO.9) Which preparatory action you make in case of failure in the night?

1. Make no preparation
2. Purchase a candle

3. Emergency gas stove / Emergency light
4. Generator
5. Inverter
6. Any other

(Q.NO.10) When do you normally go to sleep?

______________________________.

(Q.NO.11) Which appliances you are using for the cooking?

Electrical stove LPG Kerosene stove Burning fuel

(Q.NO.12) If an unexpected outage occurred at any time (e.g. Preparation of food) how mush extra would you be willing to pay to avoid?

a) A15-minute interruption ____________________ Rs/unit.
b) A 45-minute interruption ____________________ Rs/unit.
c) A 90-minute interruption ____________________ Rs/unit.
d) A four-hour interruption ____________________ Rs/unit.
e) A six-hour interruption ____________________ Rs/unit.

(Q.NO.13) Which appliances you generally use in summer.

	Appliances name	No
1.	Fan	
2.	Table fan	
3.	Summer cooler	
4.	Air conditioner	
5.	Refrigerator	
6.	Any other	

(Q.NO.14) Which preparatory action you make in case of failure?

1. Make no preparation
2. Start the generator
3. Start inverter
4. Use hand fan
5. Use ice box
6. Any other

(Q.NO.15) If an unexpected outage occurred at peak summer time how mush extra would you be willing to pay to avoid?

a) A30-minute interruption ____________________ Rs/unit.
b) A one-hour interruption ____________________ Rs/unit.
c) A two-hour interruption ____________________ Rs/unit.
d) A four-hour interruption ____________________ Rs/unit.
e) An eight-hour interruption ____________________ Rs/unit.

Q.NO.16) Which appliances you generally use in winter?

Appliances name	No
1. Electrical heater	
2. Heat convector	
3. A.C.	
4. Geyser / electrical rod	
5. Any other	

(Q.NO.17) Which preparatory action you make in case of failure?

1. Make no preparation
2. Start generator
3. Burning fuel
4. Kerosene stove
5. LPG
6. Any other

(Q.NO.18) If an unexpected outage occurred at peak winter time how mush extra would you be willing to pay to avoid?

a) A30-minute interruption ____________________ Rs/unit.
b) A one-hour interruption ____________________ Rs/unit.
c) A two-hour interruption ____________________ Rs/unit.
d) A four-hour interruption ____________________ Rs/unit.
e) An eight-hour interruption ____________________ Rs/unit.

(Q.NO.19) If we were to reduce the incidence of unexpected outages to half its present level, how mush Extra would you be willing to pay on your monthly electricity bill?

____.

(Q.NO.20) If the level of unexpected outages were to double what reduction in your monthly electricity Bill would you consider being fair?

____.

APPENDIX - V

COMPUTER PROGRAM USED IN PROPOSED MODEL

PROGRAM FOR GENERATION CAPACITY OUTAGE

```
#include<iostream.h>
#include<conio.h>
#include<stdio.h>
#include<math.h>
void main()
{
FILE*f;
int t1,i,j,k,bit[100],bit1[100],ngen,bit_reqd;
float t,p[100],P[100],min,prob[100],probn[100],fo[100],fr[100],rr[100];
float lemp[100],lemp1[100],lemn[100],lemn1[100];
clrscr();
f=fopen("s3.res","w");
printf("\nNO. OF GENERATOR == ");
scanf("%d",&ngen);
for(i=1;i<=ngen;i++){
printf("\nINPUT GENERATION OF GENERATOR NO. %d == ",i);
scanf("%f",&p[i]);
printf("\nFAILURE RATE OF GENERATOR NO. %d == ",i);
scanf("%f",&fr[i]);
printf("\nREPAIR RATE OF GENERATOR NO. %d == ",i);
scanf("%f",&rr[i]);
fo[i]=fr[i]/(fr[i]+rr[i]);
}
clrscr();
bit_reqd=pow(2,ngen);
for(i=0;i<bit_reqd;i++){
bit1[0]=i; P[i]=0.0;
        for(j=1;j<=ngen;j++){
        bit1[j]=bit1[j-1]/2;
        bit[j]=bit1[j-1]-bit1[j]*2;
if(bit[j]==1)P[i]+=p[j];
        }
}
for(i=0;i<bit_reqd-1;i++){
        min=P[i];k=i;
        for(j=i+1;j<bit_reqd;j++){
        if(P[j]<min){min=P[j];k=j;
        t=P[k];
        P[k]=P[i];
        P[i]=t;
        }
        }
}
k=0;
P[k]=P[0];
for(i=1;i<bit_reqd;i++){
        if(P[i]!=P[i-1]){
        k+=1;
```

```
        P[k]=P[i];
        }
}
        for(i=0;i<=k;i++)
        {
        prob[i]=0.0;
        lemp[i]=0.0;
        lemn[i]=0.0;
        }
prob[0]=1-fo[1];
prob[1]=fo[1];
lemp[0]=0;
lemp[1]=rr[1];
lemn[0]=fr[1];
lemn[1]=0;
fprintf(f,"UNIT 1\n");
for(i=0;i<=k;i++)fprintf(f,"%f\t%f\t%f\t%f\n",P[i],prob[i],lemp[i],lemn[i]);
for(j=1;j<=ngen;j++){
        for(i=0;i<=k;i++){
                if(P[i]<p[j])
                {
                probn[i]=prob[i]*(1-fo[j]);
                lemp1[i]=(prob[i]*(1-fo[j])*lemp[i])/probn[i];
                lemn1[i]=(prob[i]*(1-fo[j])*(lemn[i]+fr[j]))/probn[i];
                }
                else{
                  for(t1=0;t1<=k;t1++){
                        if((P[i]-p[j])==P[t1])break;
                        }
                probn[i]=prob[i]*(1-fo[j])+prob[t1]*fo[j];
                lemp1[i]=(prob[i]*(1-fo[j])*lemp[i]+prob[t1]*fo[j]*(lemp[t1]+rr[j]))/probn[i];
                lemn1[i]=(prob[i]*(1-fo[j])*(lemn[i]+fr[j])+prob[t1]*fo[j]*lemn[t1])/probn[i];
                }
        }
fprintf(f,"UNIT %d\n",j);
for(i=0;i<=k;i++)fprintf(f,"%f\t%f\t%f\t%f\n",P[i],probn[i],lemp1[i],lemn1[i]);
        for(i=0;i<=k;i++)
        {
        prob[i]=probn[i];
        lemp[i]=lemp1[i];
        lemn[i]=lemn1[i];
        }
}
getch();
}
```

PROGRAM FOR FINDING OUT EXPECTED ENERGY NOT SUPPLIED

```
#include<iostream.h>
#include<conio.h>
#include<math.h>
#include<stdio.h>
```

```
void main()
{

        FILE*f;
        int i,j,k,N;
        float pk[20],dk[20],lk[20],elc[20],eens[20],edlc[20];
        float prob[20],freq[20],cap[20];
        float d=10.982;
f=fopen("pp3.dat","r");
fscanf(f,"%d",&N);
for(i=1;i<=N;i++)
{
fscanf(f,"%f%f%f",&prob[i],&freq[i],&cap[i]);
}
fclose(f);

        clrscr();
        f=fopen("pp3.res","w");

        for (j=1;j<=N;j++)
        {
                if(cap[j]<d)
                pk[j]=1;
                else
                pk[j]=0;

                dk[j]=(prob[j]/freq[j])*8760;

                if(cap[j]>=d)
                {
                        lk[j]=0;
                        edlc[j]=0;
                }
                else
                {
                        lk[j]=d-cap[j];
            //          nlc[j]=freq[j];//
                        edlc[j]=prob[j]*8760;
                }
                        elc[j]=lk[j]*freq[j];
        //      }
                        eens[j]=lk[j]*dk[j]*freq[j];
        //              edlc[j]=dk[j]*freq[j];
                //}
//cout<<prob[j]<<" " <<freq[j]<<" " <<cap[j]<<" " <<pk[j]<<" "<<dk[j]<<" " << lk[j]<<" "<<elc[j]<< " " << nlc[j] <<"
" <<eens[j]<<" "<<edlc[j]<<endl;
//
        fprintf(f,"%f\t%f\t%f\t%f\t%f\t%f\t%f\t%f\t%f\t%f\n",prob[j],freq[j],cap[j],pk[j],dk[j],lk[j],elc[j],nlc[j],eens[j]
,edlc[j]);

        }

        fprintf(f,"prob\t\tfreq\t\tcapacity\tpk\t\tdk\n");
        fprintf(f,"*************************************************************************\n");
        for(j=1;j<=N;j++)
```

```
fprintf(f,"%f\t%f\t%f\t%f\t%f\n",prob[j],freq[j],cap[j],pk[j],dk[j]);

fprintf(f,"\nlk\t\telc\t\teens\t\tedlc\n");
fprintf(f,"****************************************************************************\n");
for(j=1;j<=N;j++)
fprintf(f,"%f\t%f\t%f\t%f\n",lk[j],elc[j],eens[j],edlc[j]);

getch();
}
```

PROGRAM FOR FUZZY LOAD MODEL

```
#include<stdio.h>
#include<math.h>
#include<conio.h>
void main()
{
FILE*f1,*f3,*f4,*f5,*f6,*f7;
int i,ii,N,z;
float a1,a2,c[30],x[20],m;
float mux[20],muy[100],muz[100],mumax;
float m1[10],m2[10],l1[50],n1[50];
float error,mm1,mm2,lf;
int l,k,hr;

clrscr();
f7=fopen("sun2.res","w");
f6=fopen("vivek.res","w");
f5=fopen("error.res","w");
/*triangle function*/
f1=fopen("triangle.dat","r");
//f2=fopen("triangle.res","w");
a1=2.0;
a2=235.0;
x[1]=2.0;
for(i=2;i<=11;i++)x[i]=x[i-1]+23.3;

f3=fopen("error.dat","r");

for(ii=1;ii<=24;ii++)
{
fscanf(f1,"%f",&c[ii]);
for(i=1;i<=11;i++)
        {
        if(x[i]<c[ii])        mux[i]=(x[i]-a1)/(c[ii]-a1);
        else
                              mux[i]=(x[i]-a2)/(c[ii]-a2);
        }



/*error program*/
f4=fopen("error1.dat","r");
```

```
for(i=1;i<=11;i++)fscanf(f4,"%f",&l1[i]);
fclose(f4);
m1[1]=0.05418;
m2[1]= -0.03271;
m1[2]=0.04668;
m2[2]=-0.02786;
m1[3]=0.01979;
m2[3]=-0.02115;
m1[4]=0.01488;
m2[4]=-0.01678;
m1[5]=0.01267;
m2[5]=-0.01425;
fscanf(f3,"%d%f%f",&hr,&error,&lf);

fprintf(f5,"*****************************\n");
fprintf(f5,"pattern for hour %d\n",hr);
fprintf(f5,"*****************************\n");

mm1=m1[error];
mm2=m2[error];

for (i=1;i<=11;i++)
{
        if (l1[i]>=0)
        {
        n1[i]= pow(((l1[i]*lf)/mm1),2);
        muy[i]=(lf*lf)/(lf*lf+2.33*n1[i]);
        }
        else
        {
        n1[i]= pow((l1[i]*lf/mm2),2);
        muy[i]=(lf*lf)/(lf*lf+2.33*n1[i]);
        }
fprintf(f5,"%f\n",muy[i]);
}


fprintf(f6,"for hour %d\n",hr);
for(i=1;i<=11;i++)fprintf(f6,"%f\t%f\n",mux[i],muy[i]);

/*final program*/

/*printf("input value of z\n");*/
/*scanf("%d",&z);*/

for(z=1;z<=11;z++) /*z loop start*/
{

for(i=1;i<z;i++)
{
        if(mux[i]<muy[z-i]) muz[i]=mux[i];
        else muz[i]=muy[z-i];
fprintf(f6,"z[%d] == %f\n",i,muz[i]);
}
mumax=muz[1];
for(i=2;i<z;i++) if(mumax<=muz[i])mumax=muz[i];
```

```
fprintf(f6,"maxmium value for %d\t%f\n",z,mumax);
fprintf(f7,"%f\n",mumax);
}/*z loop end*/

fprintf(f6,"*****************************\n");

}/*hourly loop end*/
getch();
}
```

PROGRAM FOR DEFUZZIFICATION

```
#include<conio.h>
#include<math.h>
#include<stdio.h>
void main()
{
FILE*f1,*f2,*f3;
int i,ii,j,k;
float ui[11],uout[11],s1,s2,us;
f3=fopen("newgen.res","w");
f1=fopen("sun1.res","r");
f2=fopen("sun2.res","r");

for(ii=1;ii<=24;ii++)/*hour start*/
{

for (i=0;i<11;i++)
 {
/* cout<<"enter "<<i <<" element of array U(i)";*/
/* cin>>ui[i];*/
fscanf(f1,"%f",&ui[i]);
 }
        for(i=0;i<11;i++)
         {
/*       cout<<"Enter the "<<i << " element of 2nd array mu out(i)";*/
/*       cin>>uout[i];*/
        fscanf(f2,"%f",&uout[i]);
         }
        s1=0;
        s2=0;

        for(j=0;j<11;j++)
         {
         s1=s1+ui[j]*uout[j];
         s2=s2+uout[j];
         }
  us=s1/s2;
/*  cout<<" The value of u(*)= "<<us<<endl;*/
printf("The value of u(*)= %f\n",us);
fprintf(f3,"The value of u(*) for hour %d = %f\n\n",ii,us);

}/*hour end*/
getch();
}
```

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