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Invited Paper

A Statistical Analysis of Tree-Harvesting Worker Safety

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Abstract. Tree-harvesting worker data of 508 separate worker accidents are analyzed and an exploratory approach taken. The worker accident data cover a sample of five years. The scope of the study was the southeastern United States of America. As might be hypothesized, the chainsaw was the most hazardous type of tree-harvesting equipment. It accounted for 55% of the tree-harvesting accidents. Most chainsaw accidents resulted in injuries to the lower extremities and were more frequent among younger employees. The probability of one or more chainsaw accidents occurring in any 30-day period was approximately 0.856. Chainsaw accidents were more likely to occur in late morning and early afternoon. We used statistical tools such as Pareto charts, c-charts and Ishikawa diagrams. Such tools are useful in diagnosing the root-cause of tree-harvesting worker accidents and help in developing preventive safety programs. Recommendations to help improve the quality of information of accident data collected by insurance companies and others are briefly given. The strategy and culture of continuous process improvements are stressed.

Key Words : *tree-harvesting, worker accidents, chainsaw, Pareto charts, Ishikawa diagram and c-charts, information quality.*

1. INTRODUCTION

Safety can be a positive and unifying theme for any company. However, many safety programs fall short of intended goals and are unsuccessful. Many safety programs are reactive and dwell on problem solving (or blame) downstream after an accident occurs. Such an approach does not ensure preventive solutions for future accidents and does not develop a more effective safety program, which focuses on a culture of continuous process improvements.

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This paper focuses on two key aspects: (1.) better understanding tree-harvesting accident data and (2.) stressing a management strategy of continuous improvement and upstream thinking for prevention. Deming's (1986, 1993) Plan-Do-Check-Act Cycle for continuous improvement can readily be adapted to the tree-harvesting worker accident problem. See, also, the recent article of Johnson (2002) for some comments on this Cycle in general. If the Plan-Do-Check-Act Cycle is applied correctly it offers preventive solutions to problems and breaks a cycle of reactive management. The thrust of the paper is to go beyond just fixing problems to a focus on preventing future tree-harvesting worker accidents, i.e., to think upstream. Prevention of future accidents enhances the safety and quality of workers' lives, the lives of these workers' families, improves business performance and benefits society. This helps create a culture of continuous improvements where management and workers both have true win/win outcomes in cost savings and quality of life issues.

The application of statistical methods to diagnosing problems is crucial. It is the foundation of scientific reasoning and modern business practice (e.g., Mann 1989, Cook 1992, Young and Guess 1993, etc.). When applying statistical methods to production systems, the context of the statistical analysis often changes from enumerative methodology to methods that are more analytical, i.e., statistical process improvements and control (Sanders, Ranney and Leitnaker 1989, Parr 1992). Workers in the tree-harvesting industries have historically been at a higher risk of injury and fatality when compared to workers in other industries (OSHA 1989). Data on type of injury and frequency of occurrence are readily available (Wolf and Dempsey 1979, U.S. Dept. of Labor 1984, Leigh 1987, Williams 1988, NIOSH 1989, and Peters 1990). However, causal relationships for tree-harvesting worker accidents have not been as well documented (Burke and Godell 1985, Parker 1988, Kelly 1991, etc.) as many would like.

Part of the difficulty in documenting and defining causal relationships for tree-harvesting worker accidents has been incomplete or poor quality data collection by insurance companies. For those new to information quality and its process improvements, there are many very helpful papers and books available. We mention two excellent books in Redman (1997) and Huang, Lee, and Wang (1999) with their rich references. See, also, Redman (1995), Bowen, Fuhrer, and Guess (1998), Dobbins and Guess (1999) and Collins and Guess (2000) for further discussions, references, and examples on building better quality data.

Direct costs to the insurance industry from tree-harvesting worker accidents in southeastern states in the United States of America have been as high as $1.22 million for a week (APA 1991). Given the high cost of injuries and insurance claims, significant cost savings may be realized from even rather small reductions in the rate of occurrence of tree-harvesting worker accidents. This paper is a summary of a study funded by the American Pulpwood Association which had two goals: (1.) improve the understanding of the tree-harvesting worker accident process and (2.) assess causal relationships that lead to tree-harvesting worker accidents, which could then be used to prevent such accidents.

2. METHODS

Tree-harvesting worker accident data was sampled and analyzed from January 1987 to June 1992 for 508 separate accidents in nine states of the United States of America. The states were Alabama, Arkansas, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee and Virginia. For analyses the data were organized by "Vendor Group." A "Vendor Group" was a collection of tree-harvesting companies that supplied different firms (e.g., a "ACME" paper firm, etc.) with the processed trees for conversion to paper over a multiple state region . Each of the "Vendor Groups" had similarities within groups but different characteristics between groups. We had three groups. The data were naturally organized by these three "Vendor Groups."

The data were analyzed using helpful statistical process control (SPC) tools, i.e., c-chart, Pareto chart, etc. (Ryan 1989). The SPC tools were applied to this sample historical data. It is the hope that an illustration of the power of such SPC tools will enhance practitioners' better understanding of the tools and promote more use of such statistical tools. This will reveal the causal relationships that lead to tree-harvesting worker accidents. Additional analysis of the data attempted to estimate the probability of an occurrence of a chainsaw accident. Poisson distribution, commonly used in accident data, was used to estimate the chainsaw accident probabilities. Poisson processes involve observing discrete events in a continuous interval of time, length or space (Milton and Arnold 1990). Recall the Poisson density for the random variable X is:

$$f(x) = e^{-\lambda s}(\lambda s)^x / x!, \qquad x = 0, 1, 2, 3, \ldots,$$

where λ = the average number of occurrences of the event in question per month.
s = the time interval, e.g., 30 days.

The Poisson model provides helpful approximations for this data. Within each group the Poisson model is a very natural model. For the overall combined group data, however, the Poisson does not fit as closely as the three within group data, but still does provide a useful first order approximate model. A nonparametric approach could be used for the combined data to still estimate probabilities of accidents within 30 days, etc. Recall George Box's often used quote that "all models are wrong, but some models are useful."

An attempt was made directly with other data to document some of the causal relationships for tree-harvesting worker accidents. Intensive interviews in the spirit of quality circles were conducted with different groups of workers from a small sample of two tree-harvesting companies. The causal relationships suggested from these brainstorming sessions with tree-harvesting workers were summarized using the Fishbone or Ishikawa diagrams. This is a key part of Deming strategy with the front line workers being the key drivers of continuous process improvements.

3. RESULTS AND DISCUSSION

3.1 Organizing Tree-harvesting worker accident data using the Pareto Chart

The Pareto chart draws its name from an Italian economist, but J.M. Juran is typically cited with being the first to apply it to industrial problems (Juran 1988). The idea behind the Pareto chart is quite basic. The causes of whatever are being investigated (e.g. tree-harvesting accidents) are listed and a percentage is assigned to each one so the total is 100%. The percentages are then used to construct the diagram that is essentially a bar chart. The usefulness of the Pareto chart is that it summarizes data in a concise and descriptive fashion. It can be used to identify the vital causes of nonconformities.

The chainsaw was clearly the most hazardous type of tree-harvesting equipment. Chainsaw accidents accounted for 55% of all tree-harvesting worker accidents (Figure 1). Other types of equipment that were frequently involved in accidents were the "skidder" (tree dragging heavy-lift equipment) and tree hauling truck.

When tree-harvesting worker accidents were organized by day-of-the-week, Monday had the highest number of accidents (Figure 2). The data did not list number of work hours per day. Therefore, it was not necessarily apparent if Monday had a higher number of worker hours when compared with other days of the week. It may have had fewer hours, but we can not tell from the current data. Recall our earlier comments on the great needs for additional improvements in information quality, which would help all parties.

Tree-harvesting worker accidents were more frequent among workers in the "21-30" age group (Figure 3). Great care should be taken with Figure 3, however, in that it might be possible that the higher percentage of accidents for the "21-30" age group was simply due to this age group having the largest number of workers. The data set in this study did not contain the total number of workers by age category. More data is clearly needed to improve understanding here. Regardless of the number in this age group, the total number of accidents could be reduced more by reductions there. This gives management and workers another starting place to develop further improvements in preventing accidents. It also teaches the importance of collecting higher quality information for managing better.

The distribution of tree-harvesting worker accidents by time of day suggested that accidents were more likely to occur in the late morning or early afternoon (Figure 4). The most frequent hours (EST) of tree-harvesting worker accidents were at 10:00 a.m., 11:00 a.m., 2:00 p.m., and 3:00 p.m. (Figure 4). This result may suggest that tree-harvesting worker accidents are more likely to occur near "break-times." It would be useful for future training of workers and supervisors to stress being more focused and safety active during these periods.

Lacerations accounted for the highest proportion (33%) of all logging injuries. Strains and fractures accounted for 18% and 16% of injuries, respectively. Injuries to the leg, knee or foot were the most common (78% of all injuries were to the extremities). The result of injuries to extremities coincides with the results of an OSHA study conducted in 1989 (OSHA 1989).

3.2 Chainsaw Accident Probabilities

The data suggest that the probability of at least one chainsaw accident occurring in a 30-day period is great. The probability of one or more chainsaw accidents for the nine-state study region in any 30-day period was 0.856 (Table 1). The probability of one or more chainsaw accidents occurring in any 30-day period for "Vendor Group A" was 0.769. For "Vendor Group B" the probability of one or more chainsaw accidents in any 30-day period was 0.706. For "Vendor Group C" the probability of one or more chainsaw accidents in any 30-day period was 0.950.

The probability of four or more chainsaw accidents in any 30-day period for "Vendor Group C" was .351, for "Vendor Group A" was .077, and for "Vendor Group B" was .036. It was not totally clear from the data as to why "Vendor Group C" was at a greater risk for chainsaw accidents. When compared to the other two "Vendor Groups", however, "Vendor Group C" supplied trees over a larger geographic area and seemed to have a higher proportion of workers in the "21-30" age group from other sources of information.

3.3 Diagnosing Chainsaw Accidents using the Ishikawa Diagram

The Ishikawa diagram has also been called the "Fishbone" chart. The cause-enumeration type of the Ishikawa diagram was used in this analysis. The cause-enumeration type is simply a listing of all of the possible causes without trying to establish any structure to the process (Ishikawa 1987).

Causes of chainsaw accidents identified from worker interviews were classified into four main categories: "Worker," "Methods," "Equipment," and "Environment" (Figure 5). Causes attributed to the "Worker" could be subclassified as: "inexperience," "attitude," "attentiveness," "chemical dependency," "haste" or "personal problems." "Equipment" related causes were subclassified as: "improper chain resistance (drag)," "lack of safety equipment," "poor chainsaw maintenance" and "undersized chainsaw." Causes of chainsaw accidents related to worker "Methods" were subclassified: "inadequate supervision," "improper training," "poor judgment," "improper tree-harvesting plan" (i.e., no pre-planned escape route for falling trees) and "dangerous tree cutting techniques." "Environmental" related causes of chainsaw accidents were subclassified as: "wet conditions," "steep slopes," "windy weather," "thick forest brush" and "dense timber."

A more detailed study of "Vendor Group C" as related to the information on the Ishikawa diagrams may reveal root causes of the reasons for that group's higher chainsaw accident rate. The probabilities and Ishikawa diagram as presented in this paper may be beneficial in establishing a chainsaw safety training and education program for all groups. Observational studies of worker habits may also be helpful in designing preventive chainsaw accident programs.

3.4 Monitoring Chainsaw Accidents using the c-Chart

The "c" in the c-chart is defined as the number of tree-harvesting worker accidents in a 30-day time period. Recall that the underlying assumption of the c-chart is that the data are derived from a Poisson process (or a process that is approximately Poisson). Chainsaw accidents were plotted for each "Vendor Group" (Figures 6, 7 and 8). The charts suggest a source of special-cause variation but also indicate that the common-cause variation has not been stable over time for each "Vendor Group." The c-charts indicated that several shifts in the chainsaw accident process have occurred. These shifts need further investigation. The reasons for such shifts should be identified and procedures to prevent future accidents developed in the spirit of Deming's (1993) Plan-Do-Check-Act cycle of continuous improvement. See, also, Johnson (2002).

Tree-harvesting worker accidents for "Vendor Group A" were in a state of statistical control prior to May 1988. This special-cause variation or event in May 1988 indicated that the number tree-harvesting worker accidents for that month were not part of the same process that led to previous tree-harvesting worker accidents. The reason for this higher number of tree-harvesting worker accidents should be investigated, e.g., rainy weather, steeper terrain, more hours worked, newer or younger workers needing more training, etc.

The c-chart also revealed that the chainsaw accident process had a shift from December 1988 where seven months of chainsaw accidents were lower than the historical average. The lower number of chainsaw accidents during this time period should also be investigated, e.g., additional safety equipment, less number of hours worked, change in type of worker, etc. Such additional analyses may be beneficial to the insurance industry for identifying reasons that produce a fewer number of chainsaw accidents.

The c-chart also revealed a possible problem with the reporting of chainsaw accidents. It seemed highly improbable that exactly one chainsaw accident occurred in the six consecutive months following November 1991. Such a run of consecutive points may be a flag to the insurance industry to assess the measurement system for tracking chainsaw accidents. This gives a practical way of managing and continuously improving information quality.

The "out-of-control" signals, process shift indicators, and improbable runs of consecutive chainsaw accidents illustrate the value of the c-chart as a long-term monitoring, analysis and prevention tool. The c-chart may also be a valuable statistical tool for improving and evaluating the success of any new chainsaw safety programs.

4. CONCLUSIONS

We have explored and analyzed a sample of 508 separate tree-harvesting worker accidents in a nine-state region in the southeastern United States of America. As expected tree-harvesting is a high-risk profession that can result in injury to the workers. The analysis indicated that the most hazardous type of tree-harvesting equipment was the chainsaw. The probability of one or more chainsaw accidents occurring in a 30-day period was approximately 0.856. Chainsaw accidents resulted in injuries primarily to the lower extremities. Workers between the ages of 21 and 30 may be at a higher risk of accidents. Lacerations, strains and fractures were the most frequent type of logging injury. Tree-harvesting worker accidents were most likely to occur in the late morning and early afternoon. This suggests implementing more training of younger workers and, also, stressing timeframe warnings to all workers for preventing future accidents.

The use of Ishikawa diagrams here for tree-harvesting worker accidents may provide addition insight into the root-cause of accidents (e.g., poorer maintenance of equipment/chainsaws was a factor workers observed). The use of control charts, primarily the c-chart may provide important statistical monitoring tools for early warning/detection of shifts in tree-harvesting worker accidents or atypical events in tree-harvesting accidents. This would help in prevention of problems.

The statistical techniques employed in this study represent only a small subset of the statistical tools available for more detailed analysis. The statistical tools used in this study were the most appropriate given the limited tree-harvesting accident data provided by the insurance industry. However, the study revealed potential root-causes for chainsaw accidents that can be estimated. Factors such as poor maintenance, lack of safety equipment and improper chainsaw usage are causes for chainsaw accidents that have straightforward, implementable preventive solutions. This moves the culture toward more upstream thinking.

It is strongly recommended that the insurance industry continuously improve information quality and the level of detail of tree-harvesting data. Also, additional data in more standard electronic formats (e.g., number of workers by age group, number of hours worked per day, weather conditions in specific working areas, maintenance records on different equipment, etc.) are still needed by many companies.

We encourage tree-using companies and insurance corporations to aggressively implement an upstream preventive strategy and continuous improvement culture. This approach can improve the safety and quality of workers' lives, the lives of the workers' families, improve business performance and benefit society. Such a culture of continuous improvements would help both management and workers realize true win/win outcomes in real cost savings and higher quality of life issues.

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REFERENCES

Agresti, A. (1990). *Categorical Data Analysis,* Wiley, New York.

APA - American Pulpwood Association. (1991). Recent logging injury data, *American Pulpwood Association Report* 91-A-4, (March), Washington, D.C.

Bowen, P., Fuhrer, D., and Guess, F. (1998). Continuously improving data quality in persistent databases, *Data Quality* @ http://www.dataquality.com/998bowen.htm. (See www.dataquality.com/ in general.)

Burke, P.J. and Godell, L. (1985). Statistical process control in woodlands, *TAPPI Proceedings of 1985 Pulpwood Conference.*

Collins, M. and Guess, F. (2000). Improving information quality in loan approval processes for fair lending and fair pricing, *Information Quality Conference in 2000 at Massachusetts Institute of Technology's Sloan School of Management Proceedings* 45-53.

Cook, D. F. (1992). Statistical process control for continuous forest products manufacturing operations, *Forest Product Journal*, **42** (7/8): 47-53.

Deming, W. E. (1986). *Out of the Crisis,* Massachusetts Institute of Technology, Center for Advanced Engineering Study, Cambridge, MA.

Deming, W. E. (1993). *The New Economics for Industry, Government and Education,* Massachusetts Institute of Technology, Center for Advanced Engineering Study, Cambridge, MA.

Dobbins, J. G. and Guess, F. (1999). Developing a data quality strategy in a provider of Web based health information systems, *Information Quality Conference in 1999 at Massachusetts Institute of Technology's Sloan School of Management Proceedings,* 176-184.

Huang, K-T., Lee, Y. L. and Wang, R. Y. (1999). *Quality Information and Knowledge,* Prentice Hall, New York.

Ishikawa, K. (1987). *Guide to Quality Control,* Kraus International Publications, White Plains, NY.

Johnson, C. N. (2002). The Benefits of PDCA, *Quality Progress,* American Society for Quality, Milwaukee May: 4.

Juran, J. M. (1988). *Juran's Quality Control Handbook,* Fourth Edition, McGraw-Hill Book Company, New York.

Kelly, K. (1991). Managing for quality - a bean-counter's best friend, *Business Week* (October 25), 42-43.

Leigh, J. P. (1987). Estimates of the probability of job-related death in 347 occupations, *Journal of Occupational Medicine*, **29** (6): 510-519.

Lindgren, B.W. (1976). *Statistical Theory*, Macmillan Publishing Co., New York.

Mann, N. R. (1989). *The Keys to Excellence - The Story of the Deming Philosophy*, Prestwick Books, Los Angeles.

Milton, J. S. and Arnold, J. C. (1990). *Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences*, McGraw-Hill Publishing Company, New York.

National Institute of Occupational Safety and Health (NIOSH). (1989). National traumatic occupational fatalities: 1980-1985, *Department of Health and Human Safety Publication* No. 89-116, Morgantown, WV.

OSHA - Occupational Safety and Health Administration (OSHA). (1989). Logging operations notice of proposed rule-making, *Federal Register*, **54** (83): 18798-18817.

Parker, H.V. (1988). Purchased chip quality control provides improved pulp quality and yield, *TAPPI Journal*, (December), 79-82.

Parr, W. (1992). A new paradigm for management, *Survey of Business*, **28** (l): 18-21.

Peters, P.A. (1990). Logging fatalities and injuries due to felling trees, *American Society of Agricultural Engineers Presentation Paper No.* 907536.

Redman, T. C. (1995). Improve data quality for competitive advantage, *Sloan Management Review* **36** (2), 99-107.

Redman, T. C. (1997). *Data Quality for the Information Age*, Artech House Computer Science Library, New York.

Ryan, T. P. (1989). *Statistical Methods for Quality Improvement*, Wiley, New York.

Sanders, R.D., Ranney, G. B. and Leitnaker, M. G. (1989). Continual improvement: a paradigm for organization effectiveness, *Survey of Business*, **25** (l): 12-20.

U.S. Department of Labor, Bureau of Labor Statistics. (1984). Injuries in the logging industry, Department *of Labor Bulletin 2203*, GPO: Washington, D.C.

Williams, J.C., (1988). Logger's concerns for safety, *Proceedings of Forestry and the Environment-Engineering Solutions*, B.J Stokes and C. L. Rawlins (Eds.), New Orleans, 203-206.

Wolf, C. H. and Dempsey, D. P. (1979). Logging work injuries in Appalachia, *Southern Lumberman*, (December 15), 75-

Young, T. and Guess, F. (1994). Reliability processes and structures, *Microelectronics Reliability*, **34**,.1107-1119.

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Timothy Young is Assistant Research Professor in the Forest Product Center at the University of Tennessee. He earned a M.S. in Forest Science from the University of Wisconsin and a M.S. in Statistics from the University of Tennessee. He has numerous articles in academic and trade journals for the forest products industry and other areas, such as reliability and management. He has conducted research and consulted for a wide variety of groups, both private and public. He has worked for the U.S Forest Service, Champion International, Georgia Pacific, etc. He has had extensive grants from the U.S. Agriculture Departments and others. His current areas of research include forest products, engineered wood products, statistical process improvements, and reliability.

Frank Guess is Full Professor and PhD Director in the Department of Statistics at the University of Tennessee. He earned the Frank Wilcoxon's Best First Year Student in Applied Statistics Award in 1979 and the Ralph Bradley PhD Student Award for outstanding achievement in 1984, both at Florida State University's Department of Statistics. Dr. Guess has had grants from IBM, Air Force Office of Scientific Research, and the Army Office of Research. He has been an Invited Program Committee Member and speaker in the Fourth International Reliability Research Conference held at the University of Missouri, Columbia, June, 1991. He spent January-July, 1993 on sabbatical at Oak Ridge National Laboratory. Also, he served as an Invited Program Committee Member of the First International Research Conference on Lifetime Data Models held at Harvard University, co-sponsored by the Statistics Department at Harvard University, June, 1994. Dr. Guess has spoken at the Massachusetts Institute of Technology's Sloan School of Management Information Quality Conference in 1999 & 2000. He has written over 25 papers in reliability and statistics *in Annals of Statistics, Journal of Statistical Planning & Inference, Quality and Reliability Engineering: International, IE News: Quality Control & Reliability Engineering, IEEE Transactions on Reliability, Biometrics, Biometrika. Reliability Review, Journal of Royal Statistical Society*, etc. He serves on the Editorial Board the *International Journal of Reliability and Applications*.

Table 1. Probability estimates for chainsaw accidents by vendor group assuming the Poisson distribution

Number of chainsaw accidents per month	All vendor groups		Vendor group A		Vendor group B		Vendor group C	
	P[X = t]	P[X ≤ t]	P[X = t]	P[X ≤ t]	P[X = t]	P[X ≤ t]	P[X = t]	P[X ≤ t]
0	0.1440	0.1440	0.2037	0.2037	0.2946	0.2946	0.0500	0.0500
1	0.2791	0.4231	0.3242	0.5279	0.3600	0.6546	0.1499	0.1999
2	0.2704	0.6935	0.2579	0.7858	0.2200	0.8746	0.2244	0.4243
3	0.1747	0.8682	0.1368	0.9226	0.0896	0.9642	0.2244	0.6487
4	0.0328	0.9856	0.0544	0.9796	0.0274	0.9916	0.1677	0.8164
5	0.0106	0.9962	0.0173	0.9943	0.0067	0.9983	0.1011	0.9175

Note: The probability of four or more chainsaw accidents = P (four or more chainsaw accidents) = $P[X \geq 4] = 1 - P[X < 4] = 1 - P[X \leq 3]$. For all vendor groups, $P[X \geq 4] = 0.1318$, for vendor group A, $P[X \geq 4] = 0.0774$, for vendor group B, $P[X \geq 4] = 0.0358$, for vendor group C, $P[X \geq 4] = 0.3513$. Data accumulated from 508 tree-harvesting accidents in nine southeastern United States from January 1987 to June 1992.

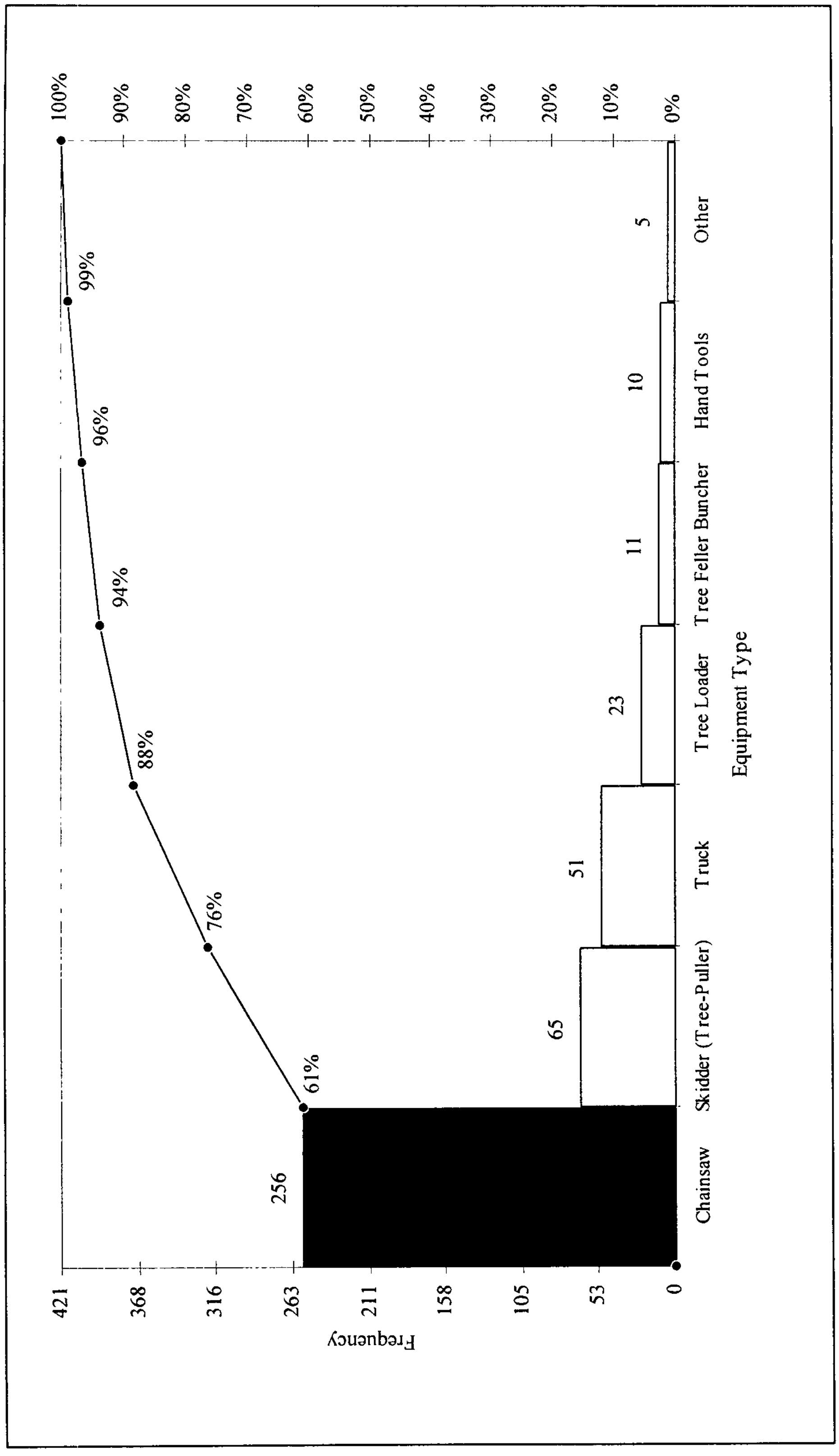

Figure 1. Pareto chart of equipment being used by worker at time of accident

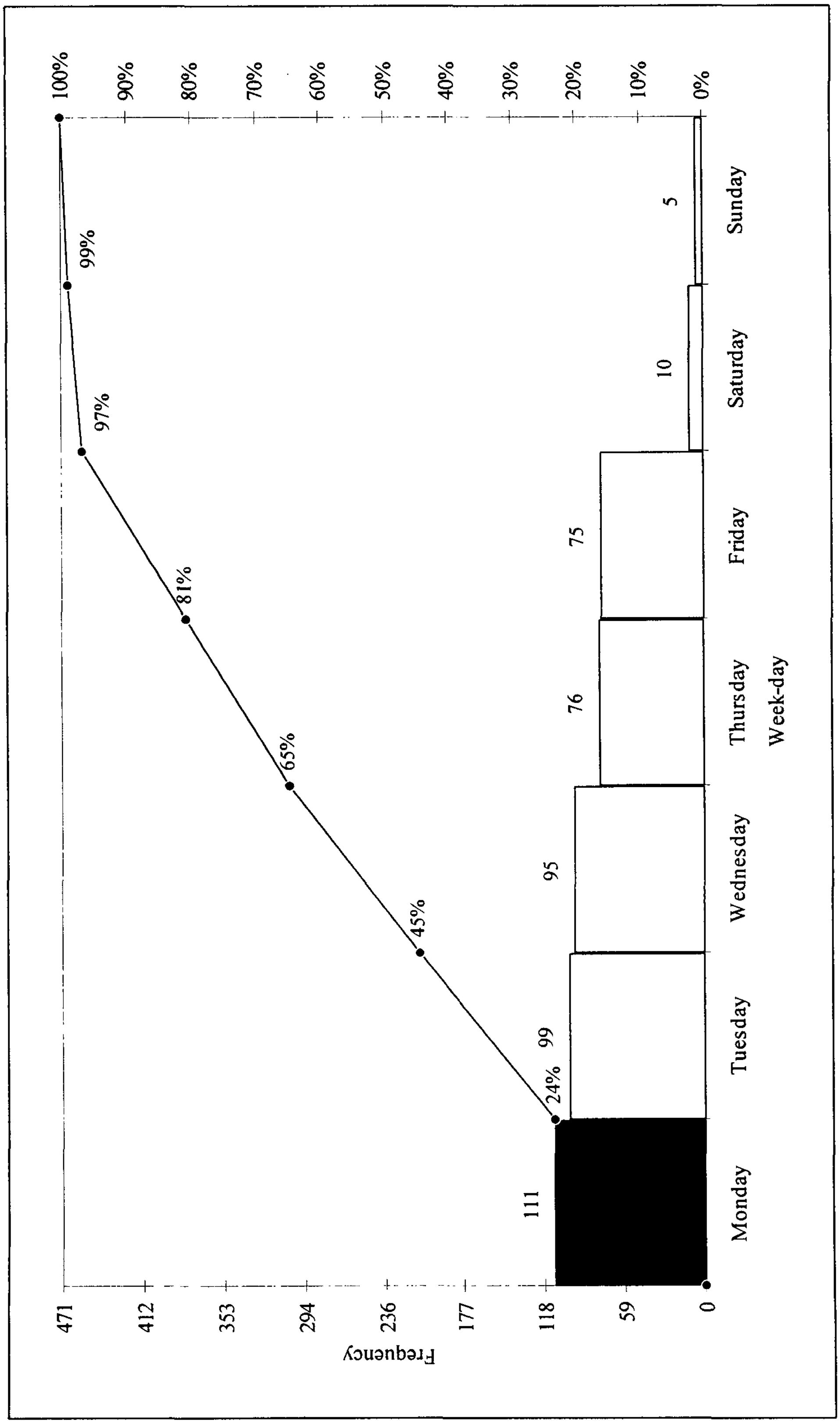

Figure 2. Number of tree harvesting accidents by week-day

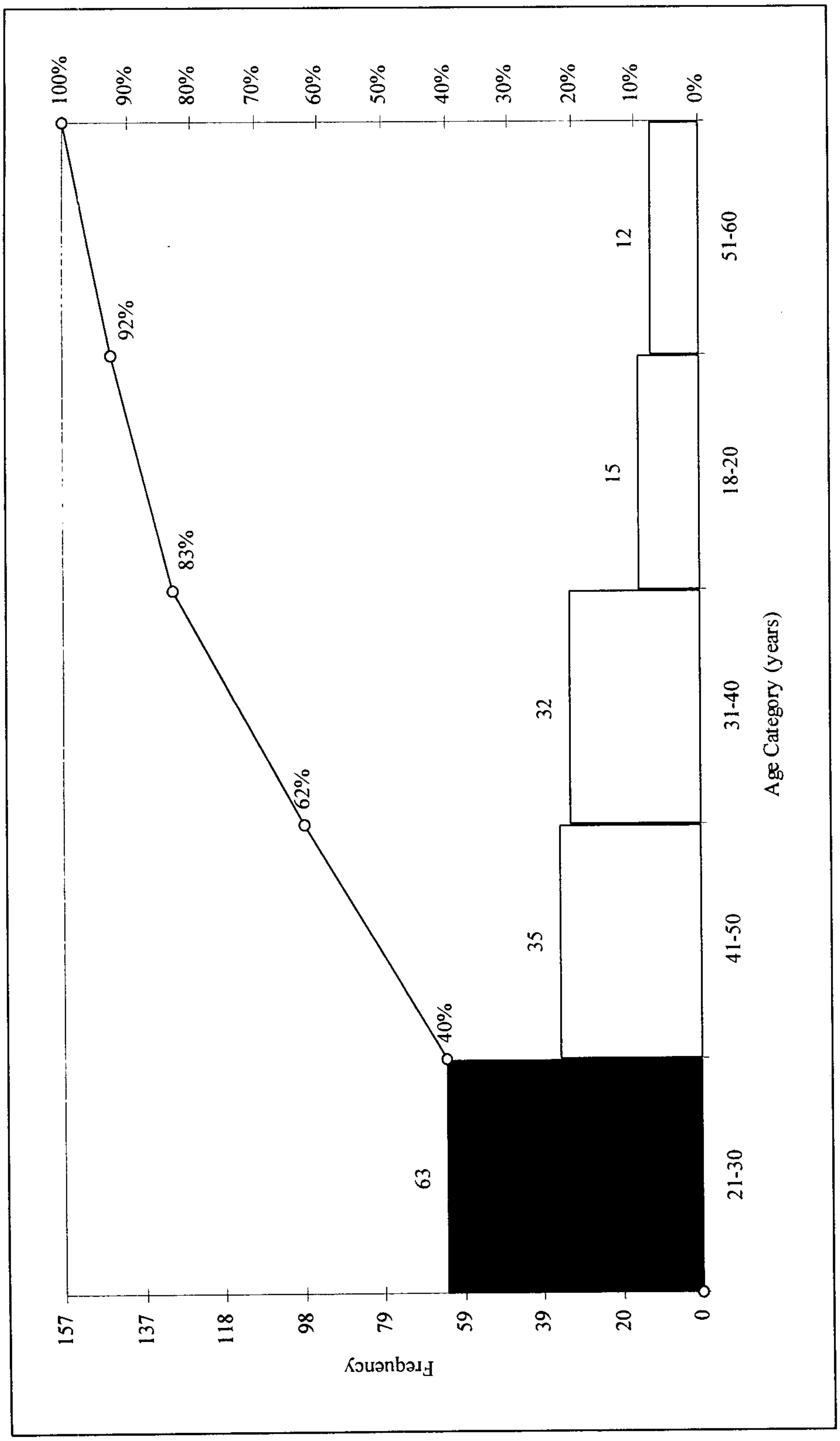

Figure 3. Pareto chart of tree harvesting accidents by age of worker

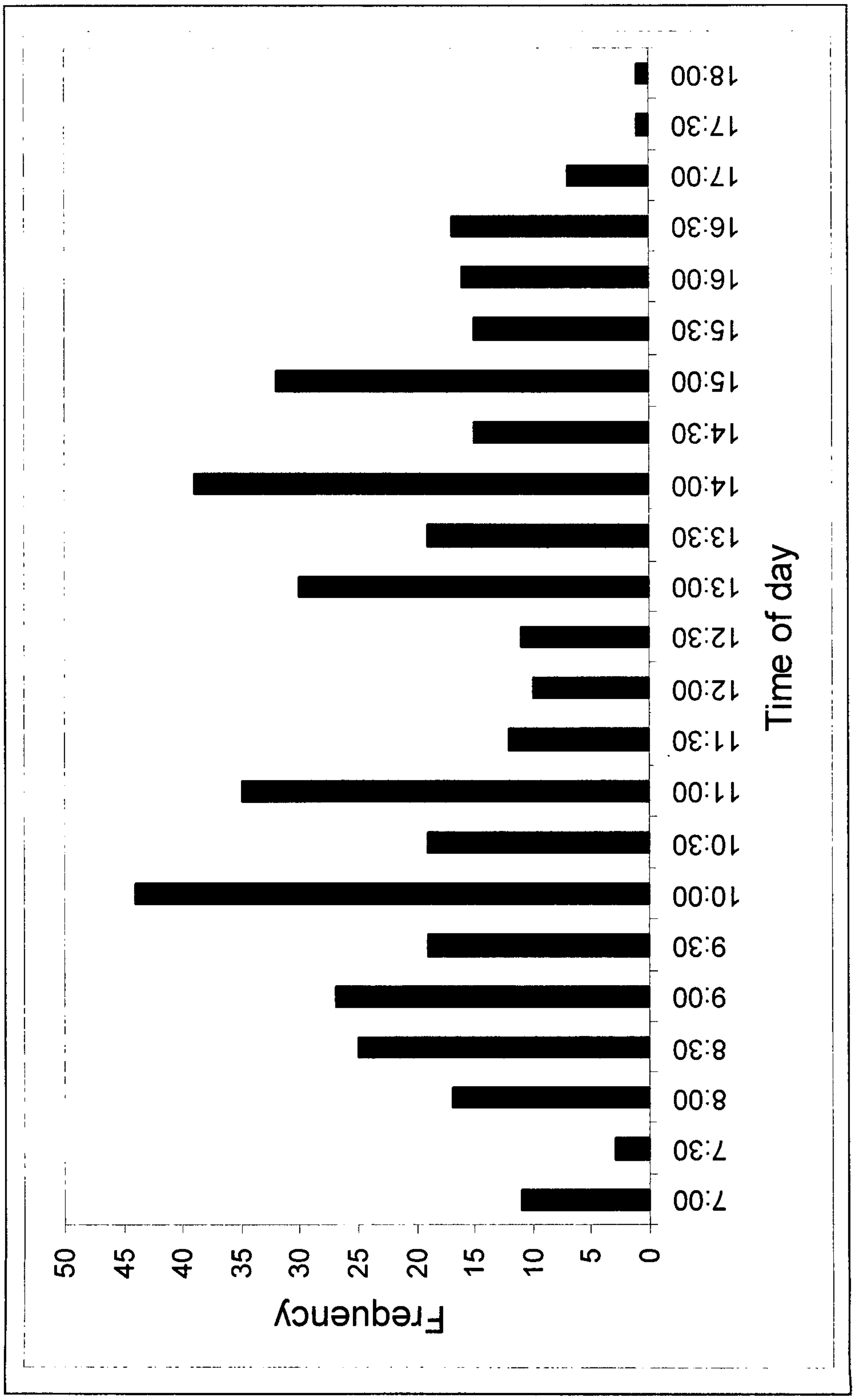

Figure 4. Histogram by time of tree harvesting accident

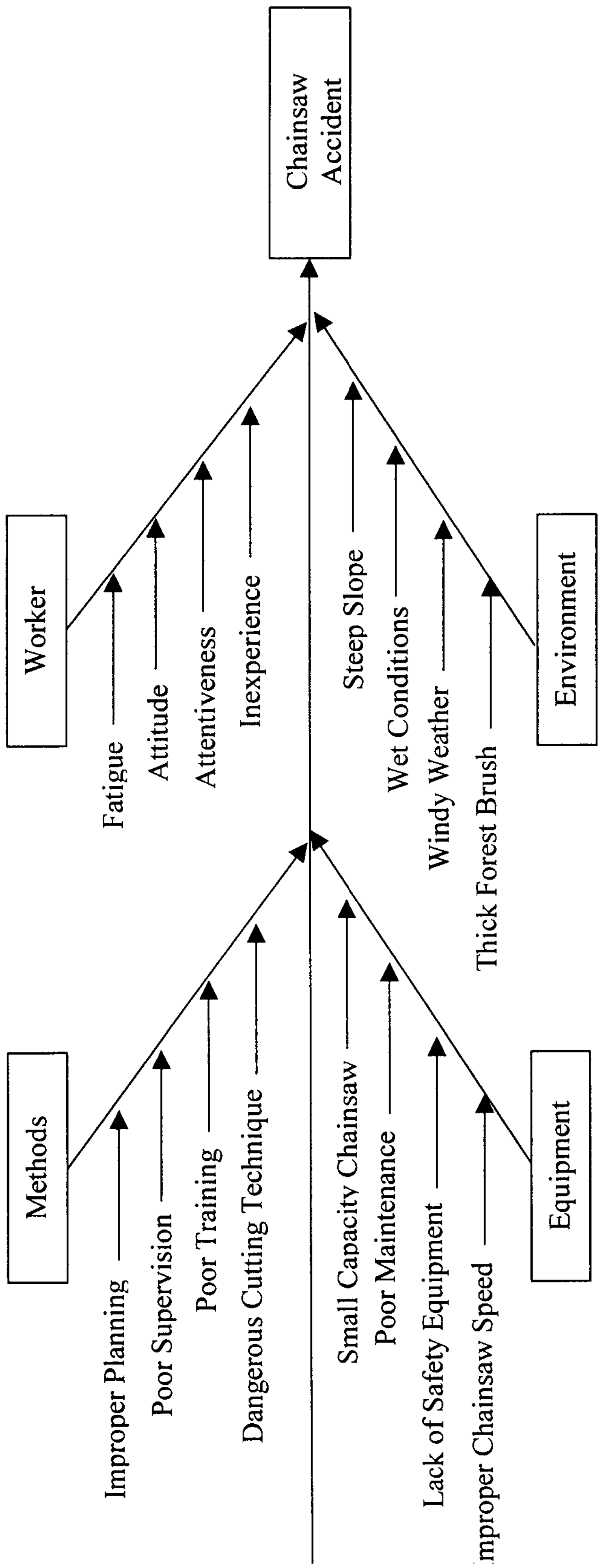

Figure 5. Ishikawa diagram of causes that may lead to chainsaw accidents.

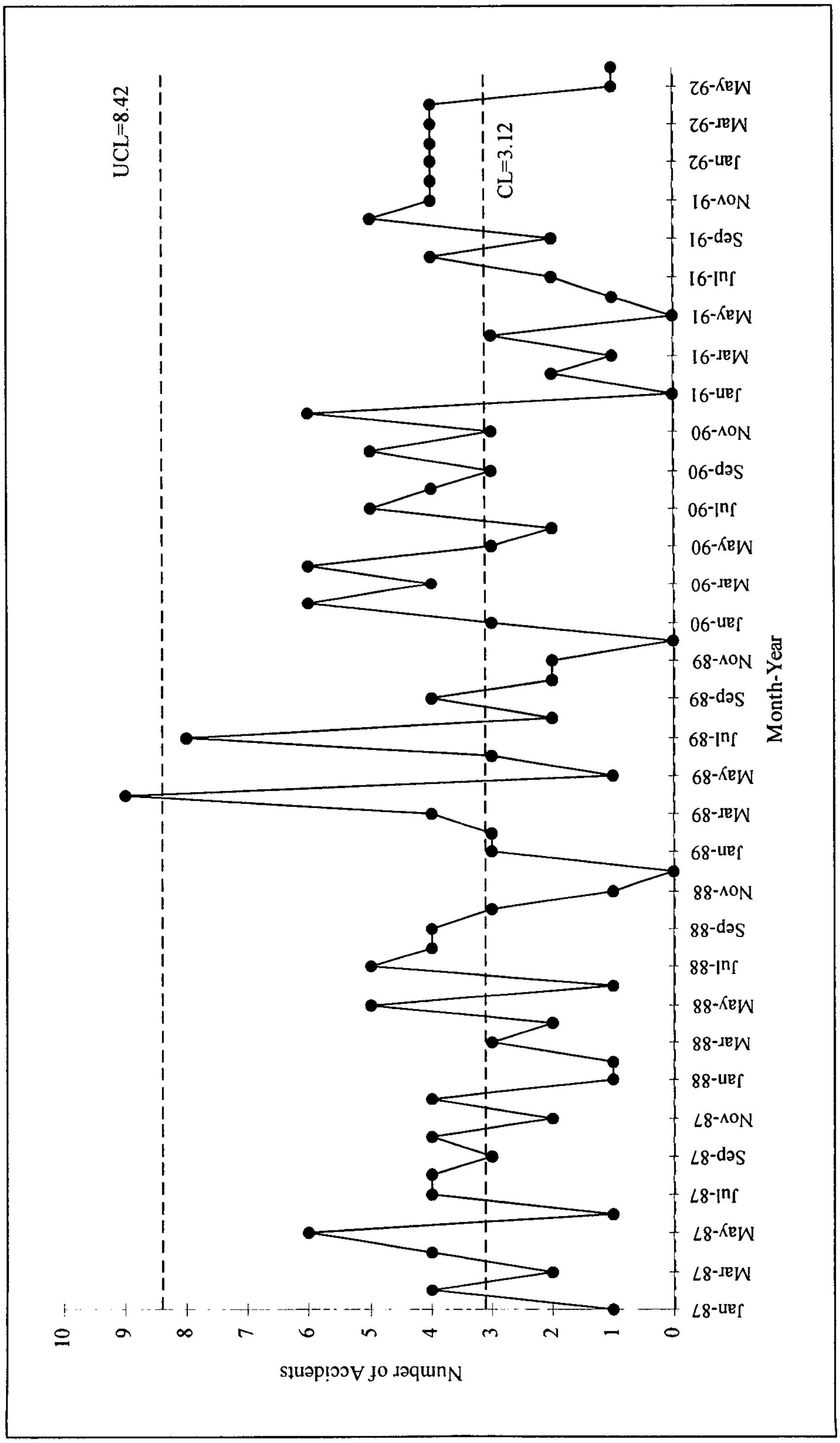

Figure 6. C-chart of tree harvesting worker accidents for Vendor Group A

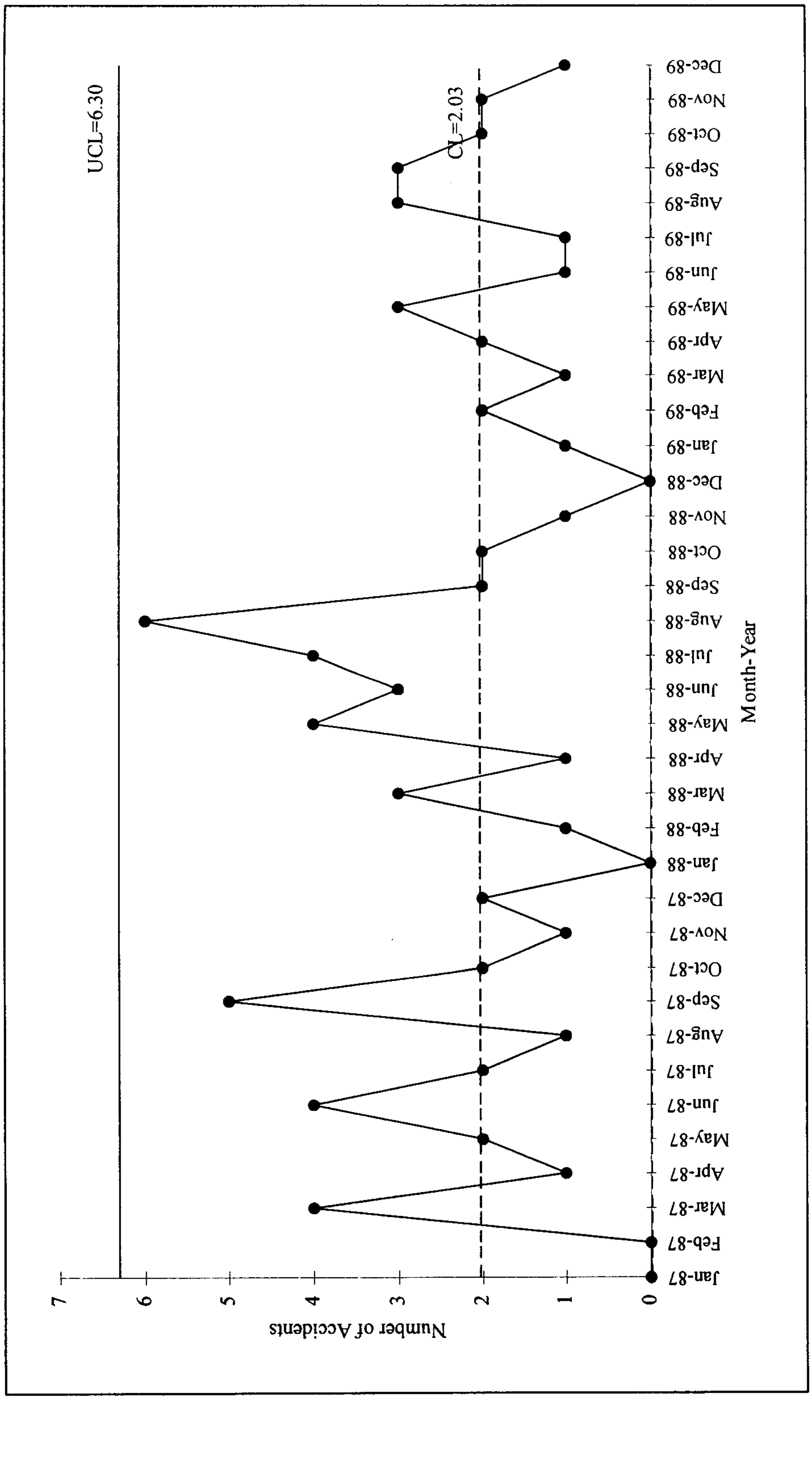

Figure 7. C-chart of tree-harvesting worker accidents for Vendor Group B

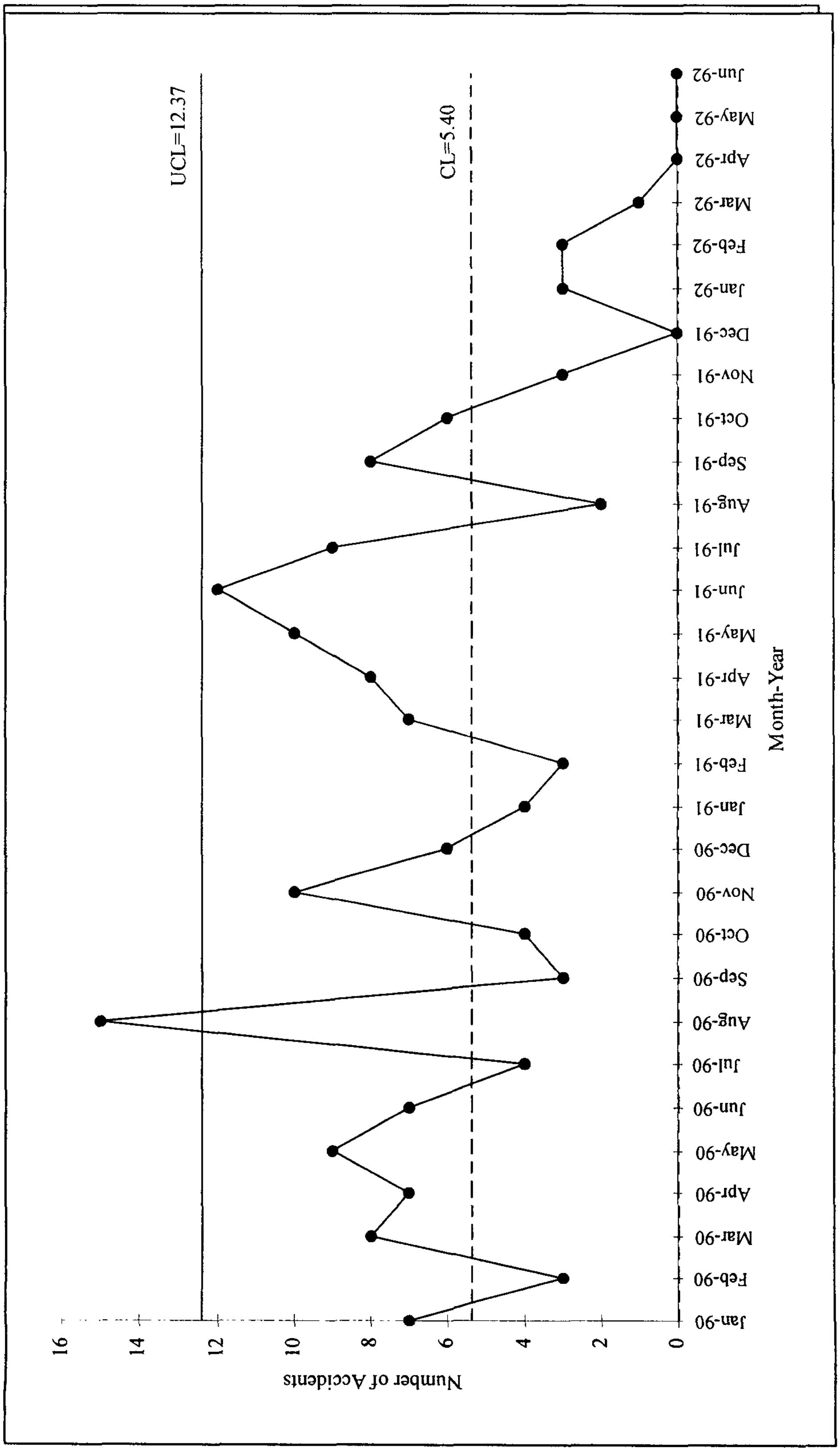

Figure 8. C-chart of tree-harvesting worker accidents for Vendor Group C