The overall goals of this research were to identify the major human factors problems in the mass transit driver cockpit, to identify the operational activities, and vehicle components that are most likely to produce accidents and injuries and to investigate, through an in-depth study, the most hazardous human factors problems. A review of related literature set the stage for investigating potential hazards. The literature review included articles involving relevant design aspects of related vehicles such as trucks and automobiles along with research specifically focusing on transit buses. Discussions with transit agency officials and a one day workshop with several transit related groups were employed to provide an awareness of the most pressing problems. Observational research techniques including driver interviews were then used to clarify the problems, and workers' compensation files were analyzed to gather quantitative information on driver injuries. A thorough analysis of the data collected from driver interviews and
analysis of the data collected from driver interviews and workers' compensation reports pointed out two major classes of injuries - injuries related to the seat and injuries related to vehicle steering. The problems involved both the seat itself - its mechanical strength and durability, and the relationship of the seat to other vehicle controls - particularly the steering wheel and foot pedals. An anthropometric study of three transit bus cockpits indicated that some driver injuries could be reduced or eliminated by improving the relationship between the driver's seat and the vehicle controls. Specifically, the driver's seat could have a wider range of adjustments and the pedal controls could be moved further forward from the steering wheel.
A Human Factors Analysis of the Occupational Safety and Health of Public Transit Bus Drivers

by

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A HUMAN FACTORS ANALYSIS OF THE OCCUPATIONAL SAFETY AND HEALTH OF PUBLIC TRANSIT BUS DRIVERS

I. INTRODUCTION

In 1986 the Urban Mass Transportation Administration (UMTA) issued an RFP (request for proposal) on the problem area of human factors in mass transportation safety. The Transportation Research Institute at Oregon State University, with the combined effort of individuals from the Civil and Industrial Engineering Departments, prepared a proposal to address the problem. In 1987, UMTA awarded OSU a contract to finance the proposed work. The overall goal of this research is to "...use a systems approach to investigate the contribution of human factors to safety problems in public transportation." The project focuses on developing a methodology for identifying and analyzing the human factors elements that are most likely to produce accidents and injuries. The overall objective of the current research is to identify the components of mass transit systems and vehicles that are most likely to produce injuries or accidents, and to investigate the human factors elements that contribute to or mitigate the problems.

The present thesis work has been done in conjunction with the UMTA grant, and has focused specifically on the industrial safety and health of transit bus drivers and the human factors elements in the driver work place. The research conducted in Oregon was specifically directed to the problems of the fixed route bus segment of mass transit systems, and involved three fixed route bus companies within Oregon: Tri-Met in Portland, Lane Transit District in Eugene, and Cherriots in Salem. Corvallis Transit System was also involved in portions of the study. Quantitative data was collected from sources such as the Oregon Workers' Compensation Department (WCD) located in Salem, Oregon and the transit companies themselves. Data of a more qualitative nature was collected from discussions with transit officials and interviews of bus drivers. Their perceptions, ideas, and opinions regarding transit driver problem areas provided a background for the work as well as valuable insight on the most pressing human factors problems. The current research began with a several activities aimed at delineating the problems. These activities included a detailed literature review,
visits to transit agencies, and a transit group workshop (involving transit officials, drivers, transit users and government agency officials). Problem familiarization was followed by extensive data collection from three major sources: the Oregon Workers' Compensation files, interviews with bus drivers in each of the three cities, and demographic information acquired from the transit agencies. A statistical analysis of the quantitative data was completed and the qualitative data was sorted, summarized and combined to specifically identify the most hazardous problems and the human factors elements most likely to lead to those problems. The most hazardous problems were then investigated in detail with an in-depth human factors study, and potential solutions were put forward.

Driver Injury Problem

The magnitude of the driver injury problem can be clearly seen from a brief look at the workers' compensation statistics. Bus drivers in Oregon suffered a total of 402 work related injuries in 1986, costing the state a total of $2,877,540. Mass transit bus drivers in the three cities under study (Portland, Eugene, and Salem) accounted for almost 60% of these injuries and were responsible for over 60% of the cost. Comparing these costs to mass transit bus usage reveals that in the Portland area alone, driver injuries cost the state eight cents for every mile a passenger traveled.

These figures briefly identify transit driver injuries as a major financial problem in the state of Oregon; consideration of the pain suffered by injured drivers provides further impetus for a study of the problem. In order to identify the operational procedures or equipment design features that are primarily responsible for these injuries, data were collected and analyzed from all the sources previously described. Qualitative data included input and ideas from mass transit bus drivers, transit company officials, and other transit related individuals who participated in the workshop. Their perceptions of the problems and suggestions for potential solutions were collected and combined, and were used in directing an in-depth study of the most pressing human factors problems. The quantitative results of the
current research were used to develop a descriptive picture of the problem in a scenario of transit driver injuries.

While a detailed study was done on the human factors elements of the major problems, the research as a whole has a fairly broad scope. Numerous data sources were investigated and employed to develop a fairly comprehensive picture of the human factors issues related to driver injuries. Where possible, quantitative, objective data was used as a basis for study. However, the nature of human factors research involves working with the diverse and variable characteristics associated with multifarious human beings and, as a result, the research does not fit the mold of the standard, scientific, laboratory experiment. Nonetheless, valid research techniques for human factors investigation have been developed and were employed in the current study as described in the following section.

Research Techniques

Human factors engineering involves "...designing machines, operations, and work environments so that they match human capacities and limitations." This partial definition of the subject was given by Chapanis in his classic book, Research Techniques in Human Engineering. The study of man's interaction with machines does not typically lend itself to neat, compact, quantitative experiments as do many other branches of science. Instead, human factors studies may involve some subjective and qualitative data collection combined with quantitative data and experiments. Chapanis points out that "research" is difficult to characterize and define because methodologies in science are continually changing and research is not a repetitive production process (no two studies are exactly alike). However, in spite of the difficulty in defining exactly what constitutes research, some tactics and strategies of good research techniques can be put down in the form of general rules and principles which can be used as a guidepost "to study that most complicated of all machines - man" [Chapanis, 1959].

In his book, Chapanis describes the methods available for collecting reliable data on people and machines and the relationships between them. He also discusses principles and guidelines about ways
of doing dependable studies on people. One of the most direct ways of collecting data for human factors studies is direct observation or inquiry of the workers. The person who works with a piece of equipment every day will be very familiar with it and will probably be able to describe its potential problems in detail. Opinion data of workers, admittedly, has several limitations. Workers may adapt to shortcomings of the work place and therefore not recognize problems or, on the other side, workers may complain about machines or methods due to underlying discontent rather than actual problems with the equipment. The valid collection of opinion data is also difficult because of the potential biasing of the results by the questioner, and the failure of practiced workers to consider radically new ways of doing things. These limitations were taken into account and avoided as much as possible in the current research where opinion data was collected in the form of driver surveys. The driver interview form was carefully prepared to minimize biasing of the response. Individuals connected to the transit system, but not directly involved in driving, were spoken with to provide a different perspective and new ideas. Transit company officials and transit users were interviewed who were felt to be closely enough involved with the transit system to understand potential problems, but far enough removed from the bus driver's job to give a fresh new perspective on the problems.

Another limitation, according to Chapanis, is that "...observation techniques ... frequently cannot be generalized beyond a particular system." In one sense, Chapanis is correct in that all studies are specific to the particular situation used to make the observations. However, the extent to which the results can be generalized from one study to another may depend upon how closely the system studied is representative of the overall situation. The current research has focused upon transit bus drivers in three Oregon cities. To the extent that the same buses are used nationwide and to the extent that the transit bus driver population is anthropometrically similar in other cities, the results of this research may be generalized to other cities and states. Even in the case where different buses are being driven, the research approach used here may be applicable to other transit companies.
While opinions of drivers and others can provide a valuable perspective and focus on the current problems, opinion data by itself also has some serious limitations due to the subjective nature of the data, sample size limitations, and the difficulty of comprehensively identifying the significant relationships between the variables. Supplementing the subjective observations of transit officials and bus drivers, was the more quantitative data of the workers' compensation claims files. Chapanis listed several requirements of accident data for the useful application of the data in human factors research. Some of these requirements were an awareness of what constitutes an accident, an adequate system for reporting incidents and nearly complete coverage of incidents; these requirements were fulfilled by the Workers' Compensation data.
II. LITERATURE REVIEW

The Battelle Memorial Institute report [Cheaney et al., 1976] entitled, "Safety in Urban Mass Transportation" provided a useful departure point for a first summary of past work. This study was directed towards providing information to enable preparation of a safety guidelines manual. The study indicated that no "severe problems" exist in mass transit, but that cumulative accident rates are higher than they need to be. It pointed out that upcoming technology, in addition to providing new levels of service, will introduce new hazards and that safety requirements are becoming more stringent. The report also noted that while actual, physical safety is of prime importance, the perceived safety of a transit system is also relevant to the passengers and to the system itself. The study continues to give a concise summary of transportation safety activity:

"All effective transportation safety activity is directed ultimately to controlling the hazards originating in the interactions between the humans, machines, procedures, and environments comprising transportation systems. Hazards must be identified through analysis or accident experience and then controlled by 1) eliminating them by design 2) adding safety devices 3) adding warning devices, or 4) setting up special procedures."

The study of human factors has been defined as the study of the interaction between humans and machines. The human element of the current study is the bus driver or passenger; the machine element is the mass transit vehicle. The literature review will be divided into two parts: literature pertaining to drivers and literature related to vehicle design. The overall research will be aimed at identifying the hazards relevant to bus drivers. The Battelle study further helped to focus the current research by indicating that hazards leading to catastrophic accidents have been reasonably well controlled in conventional bus modes and that most of the costs in transit safety arise from the large number of minor accidents [Battelle Columbia Laboratories; Cheaney et al., 1976]. With respect to the driver, this study will focus on the actual driver work area, but will also include a discussion of the relevant elements of the vehicle as a whole.
A. DRIVERS

The human factors in the transit system include all elements affecting human performance. This may include the physical state and mental attitude of the driver as well as the previous preparation and training that a driver receives. Reports concerning driver performance have focused on numerous topics including driver selection and training, driver stress, alcohol and drug detriments to driving, driver fatigue, and effects of noise, vibration, heat and carbon monoxide on driver performance.

Driver Selection

A survey done by the National Safety Council's Transit Section [Pavilon, 1974] indicated that previous employer's records may be a very important factor in the driver selection process. Research done in Yugoslavia found that hypersensitivity and adaptability of the bus drivers were related to the number of accidents of the drivers and concluded that, "Adequate procedures when selecting persons for this profession could probably reduce the number of accidents..." [Stary and Jotanovic, 1981.] Swedish research directed at exploring the feasibility of "a selection procedure for the elimination of unsuitable drivers" found that drivers with more primitive psychological defense mechanisms and more primitive problem solving strategies were more likely to have accidents and that "predictions of which persons should have accidents, based on results from psychological tests, were highly successful." ["Personality and Driver Training," 1982.] Road tests also appear to assist supervisors in selecting employees better suited to the driving task [Pavilon, 1974].

Driver Training

Numerous studies have been done regarding training of school bus drivers, but less has been written on the recommended training of intercity mass transit drivers. A large degree of variation currently exists in transit bus driver training programs with training periods
ranging from 5 to 45 days and training methods including open road driving films, slides, classroom lectures, defensive driving courses, posters, in-service training and bulletins [Pavilon, 1974]. The three transit companies participating in the present research had training periods of three to three and a half weeks with classroom training including films, slides, video presentations and lectures and on the road training periods of 48 to 80 hours.

The Transportation Systems Center in Massachusetts investigated the use of a driving simulator as a means of teaching safe driving and other operating techniques in the training of bus operators [Wright and Forman, 1980]. After a thorough investigation of the various types of simulators available, the comprehensive costs of simulation, and the benefits for transit driver training, the study concluded that due to the high costs of simulators, simulation training was not cost effective and therefore not recommended.

A new approach to training mass transit bus drivers called Personalized System of Instruction (PSI) has been proposed by Robert Haynes and B.L. Hopkins [Haynes and Hopkins, 1983]. The new method differs from conventional teaching in using less of a lecture format and requiring students to study independently at their own pace. Results of the study showed that PSI trained students retained more of the training information and received fewer complaints from customers than students participating in a lecture/discussion training program.

Another suggested training method is to use a task analysis approach. Moe, Kelly and Farlow [1973] developed a report which describes the tasks involved in driving buses. The tasks were reviewed and ranked by expert bus drivers according to the criticality of a given task in the context of an operational situation. The authors of the task analysis report believe that it may be useful in the development of training programs. A second study, done in Sweden, also developed a comprehensive evaluation of various aspects of the driver task, "As a basis for the development of a new curriculum for the teaching of professional drivers..." [Spolander, 1980]. In this report, 211 composite tasks were grouped into nine categories and evaluated on the variables: frequency, safety, transportation efficiency and difficulty.
Driver Stress

Driver stress is becoming a topic of concern for many transit agencies. Transportation research in London found that "much sickness absence was from stress-related illness." [Forrester, Winterton, 1985]. Forrester continued that one person operations (as opposed to driver/conductor crews) "increase stress on train and bus drivers, which is not only bad for their health, but puts passengers at a risk as well." One report, Excess Risk of Sickness and Disease in Bus Drivers [Winkelbey et.al. 1985] reviewed 22 epidemiological studies that have examined health risks of bus driver in the past two decades. The epidemiologic studies, as a whole, have reported a consistent pattern of higher rates of absenteeism, illness, and death among drivers when compared to employees from other occupational groups. Winkelbey et. al. reviewed the epidemiological studies to determine if bias or, confounding of variables might be responsible for the results. They found that, on the whole, the studies were reliable. Several possible causes for the higher illness and absenteeism rate among bus drivers were proposed indicating that "...occupational stressors, including long working hours, time paced work, shift work, and high levels of job responsibility may directly contribute to increased health risks." A second study done by Ragland, Winkelbey et. al. [1987] noted the prevalence of hypertension in bus drivers and commented that "...the increased health risk associated with bus driving is of importance not only to the health and safety of the driver ... but to the vast public which interacts with these systems."

Another report, done in Berlin in 1980, examined the health and health risks of bus drivers and compared them to other occupational groups. This research employed two different selection processes to identify the subjects; one based on occupation (bus driver versus administrator) and one based on the physical fitness of the driver. The combined studies indicated that, "Severe occupational stress and the attendant effects on health among bus drivers caused the majority of them to leave their job prematurely."

Robert Spicher began a study in 1982 with the objective of developing training modules to help drivers deal with stress, help
supervisors recognize stress in drivers, and to develop an evaluative device to assist in the bus driver selection processes [Spicher, 1982]. Spicher points out that, "Some bus operators possessing the basic skills to operate the vehicle may still experience difficulties in performing their job satisfactorily because of an inability to cope effectively with the public." Spicher's search of the literature in this area revealed that occupational stress in drivers is interactive and results from both the personal characteristics of the driver and the conditions of the working environment. The literature also revealed that drivers can be trained to modify the characteristics which give them stress, that managers can learn how to modify a working environment to reduce stress, and finally, that training drivers and managers is a more cost effective way to deal with stress than screening out stress prone operators in the selection process.

Driver Fatigue

Driver fatigue is another factor that affects driving performance. Few studies have been done on fatigue effects specifically focusing on mass transit bus drivers, but the numerous studies done on truck and intercity bus drivers have relevant implications. Some disagreement exists on the degree to which driver performance deteriorates as drivers become fatigued. Some studies indicate that fatigue effects may be hazardous after six or seven hours of continuous driving while other studies claim that fatigue effects are not dangerous even after ten or eleven driving hours. One potential cause of the disagreement is the variety of measures that are used to indicate driver performance. These measures include mean time headway ("time it takes a following vehicle to reach a leading vehicle if the latter stops dead") [Miller and Mackie, 1980], critical tracking task sensitivity (a measure of the limit of operator frequency response) [O'Hanlon, 1980], biochemical tests [Milosevic et. al., 1981], subjective driver ratings of fatigue, and physiological measures.

In spite of the different performance measures, the majority of studies found that hazardous fatigue effects do exist and concluded that bus drivers with irregular schedules suffer more fatigue than
drivers with regular schedules [Miller and Mackie, 1980; Mackie and Miller, 1978]. Additional conclusions were that early morning hours cause more feelings of fatigue than daytime hours (regardless of previous hours worked), and that regular breaks seem to reduce feelings of fatigue. One theory behind the dissenting view that fatigue does not affect driving performance was that a driver who knows how long he must work will pace himself accordingly and therefore be able to work the required time [McDonald, 1980].

Another possible effect of the long hours is increased health risks due to prolonged sitting. Reports by Jennifer Kesley [1975] indicated that sedentary occupations increase the risk for herniated lumbar discs and that "people in occupations requiring prolonged driving of motor vehicles..." appear to be at particularly high risks.

Effects of Alcohol and Drugs

The effects of alcohol and/or drugs on a driver's mental state is another factor on the human side of the "human - machine" relationship. While it is a well known fact that high levels of blood alcohol cause deteriorated driving performance, the effects of drugs on driving performance was not studied until recently. It is now recognized that alcohol is just one of many psychoactive drugs in common use today [Wilson, 1980].

A study done by Arthur Solanz [1976] indicates that "...there seems to be a cause-effect connection between the taking of certain medicines in conjunction with driving and traffic accidents and therefore some medicine, as well as alcohol, should be considered as a risk factor in traffic."

A Dutch study also indicated that medicines can influence driving behavior and that physicians need to be aware of the effect of drugs on driving behavior [Nelemans, 1982]. This study concludes that some medicines cause more problems than others, that each driver should be treated as an individual case, and that it may be better to keep a driver off the road than risk the potential danger of a medicine related accident.
The most dangerous period in the use of therapeutic drugs is in the initial period; after this period, a tolerance for the drugs develops and the effects on driving behavior are reduced [Wilson, 1980]. The conclusions resulting from these studies indicate that many drugs affect driving ability and suggest that legislation be proposed to prevent drugged drivers from driving.

Noise Effects

Additional articles exist focusing on other elements of the drivers' working environment, such as noise and vibration. J. Williams and D.M. Jones [1980] studied the effects of noise on three aspects of driver performance: monitoring skills, motor skills and multicomponent skills. They found that when task demands are low, variable and intermittent noise may increase monitoring efficiency; whereas when task demands are high, variable noise appears to hinder motor skills and has no effect on multicomponent skills. Since most intercity bus driving involves relatively high task demands, loud variable noise may be a hindrance to mass transit drivers. Nonvarying noise may also hinder monitoring performance, impair motor skills, and hinder driving performance in general if the situation requires a broad attention span across many components. Finally, noise may also act as a masking agent, drowning out important cues and signals for the driver.

James Miller, in his comprehensive overview of truck and bus operator hazards [Miller, 1976] outlines the reasons why noise appears to be a hazardous stress factor. These include interference with communication and auditory signals, hearing loss, and psychophysiological effects on bodily functions. The current noise standards issued by OSHA are 90 dba for an eight hour exposure period. Unfortunately, a 1970 study showed that trucks and buses had noise levels ranging from 82 to 96 dba; in addition, noise from the environment may add to the noise from the bus itself. While bus designs have changed in the past years, many buses may still be in operation with unacceptably high noise levels.
Vibration, Heat and Carbon Monoxide Effects

Vibration is another factor relevant to driver performance. M. J. Clarke's report indicates that the reaction of human subjects to vibration is a widely debated topic due to contradictory evidence partly resulting from the wide variety of experimental techniques used to obtain evidence [Clarke, 1980]. Miller agrees that it will be several years before reliable, conclusive results can be obtained, but that vibration may have some effect on drivers' health [Miller, 1976].

Heat stress, ventilation and carbon monoxide levels also may affect driver performance. Air conditioning in truck and bus cabs is recommended by Miller to insure good overall driver comfort and attitude. A study of the thermal environment of bus drivers in Sweden also indicates "...that there are risks of a decrease in performance" due to uncomfortably high temperatures, but elevated temperatures cause very little health risk [Loevsund, 1980]. Several studies [Miller, 1976] have also been done concerning the effects of low levels of carbon monoxide on driving performance, but there is no consensus yet as to what those effects might be.

B. VEHICLES

Having looked at the first half of the "human - machine" relationship, involving the human element (drivers); the second half of the relationship involves the machine element i.e. the actual mass transit vehicle. Currently available anthropometric data will be reviewed first. Then, literature concerning vehicle controls and displays, and literature related to driver seat design will be examined. Literature related to bus design as a whole will also be reviewed because the driver is closely connected with and affected by the overall bus design.

Anthropometric Data

Most current anthropometric data originates from "groups within the population" (e.g. military) and as a result may not be entirely
applicable for use in designing vehicles for another specific group from the population (e.g. bus drivers). While the generally available anthropometric data is better than nothing, some studies have been done specifically concerning bus drivers [Guillien and Rebuffe, 1980; Sanders, 1977]. Where this data exists, it should be preferred over other data. The number of studies that have been done specifically concerning the anthropometric measurement of bus drivers is relatively small. In 1980, Guillien and Rebuffe (researchers of the Physiology Laboratory in France) measured 14 dimensional characteristics of 414 French bus drivers. These characteristics included such measurements as sitting height, forearm-hand length, knee height, shoulder breadth etc. While this data may be a useful reference for identifying relevant driver measurements, cultural body size variations may make the data irrelevant for use in designing bus cockpits for the American driver. A more useful study was done by Mark Sanders in 1977 who used a mobile laboratory to collect data for 50 bus and 227 truck drivers on static and dynamic anthropometry, reach envelope, and force production to steering wheel and brake-clutch pedals. This anthropometric data provides a valuable framework within which vehicle design and dimension choices can be made.

Vehicle Displays and Controls

Good background for the study of transit vehicle displays and controls is provided in an article written by Gordon Robinson [1979] describing the eye and head movements in going from one display to another when the displays are separated by a visual angle of 20 degrees or more. Robinson found that the movement pattern of the eyes appears to be related to three task variables including the angle of refixation, the new display’s visibility, and prior knowledge of the location of the new display.

In his study of bus and truck hazards, Miller points out, "...there has not been a consensus as to what priorities should be placed on the different type of locations of visual information that are available to the driver." [Miller, 1976]. As a result of this, several important design questions have been left unanswered concern-
ing how critical display visibility is, and what percentage of the population should be able to see a given display. Once these questions are answered, the task will be to use satisfactory design tools to "...establish display locations that will satisfy the agreed upon criteria."

A comprehensive study was done by the Essex corporation in 1972, "directed toward developing valid criteria for the standardization of control and display location, coding, and operations in passenger cars, trucks and buses." [Krumm et. al., 1972]. The report first determined that the time to locate a control or display was three seconds longer with unfamiliar panels than with familiar panels. This and other observations lead to the conclusion that control/display standardization is needed so that controls and displays are located in similar places in trucks, buses, and cars and that a standardized panel should be developed. The study also concluded that "...existing control display panels exhibit poor operability, i.e., that by virtue of their design they contribute to a greater likelihood of operator error and increased time to perform." In response to these problems a standardized "Essex panel" was developed based on the following guidelines:

- follow established conventions
- use the right hand rule (placing controls used when the vehicle is in motion on the right side of the steering wheel)
- group controls and displays by common function
- ensure quick response to higher priority controls and displays
- ensure minimum hand-off-wheel and eyes-off-road time
- locate and code controls to be identifiable without visual access

The lighting of displays and controls is another critical issue in driver safety. A report done by Catherine Stewart [1973] indicates that it is important that operator display lights be controlled so driver vision will not be degraded. The report suggests that panel lights be shaded so the light will be directed downward and interior surfaces be finished to reduce nighttime glare.
driver is not limited to his small work station, but also includes the bus as a whole. As the individual in control of the vehicle, passenger safety is of primary concern to the driver.

According to a report done by the Transport and Road Research Laboratory [Brooks et. al., 1980] involving a survey of the majority of the vehicles owned by stage carriage operators in Great Britain, "57% of passenger injuries were a result of falls and other incidents which occurred under normal conditions, not involving collisions and emergency action." Twenty nine percent of passenger injuries resulted from emergency stop procedures and 14% of passenger injuries were the result of vehicle collisions. Several elements of bus design are important contributors to these accidents such as acceleration and deceleration levels, design of seats, doorways, location of stanchions, handrails and assists, and the presence and location of the fare box. Of these factors, acceleration and deceleration levels and the presence and location of the fare box are the factors that most impact the driver as he/she works.

According to a study done by Booz Allen Applied Research [1976] drivers produce stopping rates of .3g (the equivalent of a sudden 30 lb force on a 100 lb person) at 8% of all stops. Part of the Leyland study, "Passenger Problems on Moving Buses" involved an investigation of the range of acceleration levels found in buses, a study of the amount of passenger discomfort caused by acceleration and jerk (jerk is defined as the rate of change of acceleration) and an analysis of the vehicle features that could be modified to produce a more comfortable ride [Brooks et. al., 1980]. They found that rapid changes in acceleration during a short time period cause the most discomfort and that gear changes, deceleration into bus stops, and acceleration caused by jerky power take-ups and braking for emergency stops are responsible for the most rapid changes in acceleration. They recommend installing automotive gear boxes and braking systems that give a driver more feedback on his acceleration levels to increase passenger comfort.

The presence and location of fare boxes is another factor related to passenger accidents and very relevant to the driver. Several studies have found that the currently most popular location of the fare box (beside the driver and in the lateral center of the bus) is
hazardous to passengers - particularly in on board falling accidents [Booz Allen, 1976; Brooks et. al., 1980]. Some studies call for padding the fare box and other potentially dangerous protrusions at the front of the bus. Another approach to the problem is to completely remove the fare box from the bus. With the fare collection process done at the bus stop rather than on board the bus, several radically different bus designs are possible and the workload of the driver is decreased [Daniels, Holcombe and Mateyka, 1978].
III. PROBLEM FAMILIARIZATION

Several sources of information were employed to become familiar with the general problems facing transit drivers. The literature review provided a broad overview of human factors considerations affecting drivers in general, as well as a solid foundation from which to approach transit bus driver problems. Visits to each of the transit companies provided an inside perspective from individuals directly involved with transit operations, but still somewhat removed from the driving task itself. Finally, a one day transit group workshop involving a wide variety of transit related individuals was held to provide a broad perspective on specific mass transit problems.

A. TRANSIT COMPANY VISITS

As stated earlier, visits to the three transit companies provided insight into the problems facing drivers as well as an opportunity to become familiar with the operational procedures of each company. The names and titles of the individuals spoken with during the visits are given in Table 1.

In the discussion that follows, the issues that were perceived as problems for each transit company will be discussed along with other operational activities that are relevant to how the company operates but were not identified as needing change or improvement. Different companies emphasized different issues as problems, so certain issues may be discussed as problems for one company and included with the operational activities of another company.

A checklist of desired information formed the initial basis for interaction with each transit group. Quantitative data was collected describing each company including the number of vehicles in the fleet, the annual passenger miles and trips, and amount of annual injury compensation to drivers. A free flowing discussion followed providing qualitative information concerning transit official's opinions on major work related driver injuries, factors causing injuries, and problems on board buses. Operational policy items including such things as designated seats for the handicapped, driver first-aid training, and
Table 1. Individuals Contacted During Transit Company Visits

<table>
<thead>
<tr>
<th>Company</th>
<th>Contacted Individuals</th>
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<tbody>
<tr>
<td>TRI-MET</td>
<td>Harry Saporta - Safety and Claims Manager</td>
</tr>
<tr>
<td></td>
<td>Lesley Dickensen - Health Rehabilitation Program Specialist</td>
</tr>
<tr>
<td></td>
<td>Keith Boos - Driver/Driver Trainer</td>
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<td></td>
<td>Cindy Callis Oberg - Bus and Rail Accessible Service Planner</td>
</tr>
<tr>
<td>LANE TRANSIT DISTRICT</td>
<td>Gary Deverell - Safety and Risk Manager</td>
</tr>
<tr>
<td></td>
<td>Micki Kaplan - Transit Planner</td>
</tr>
<tr>
<td>CHERRIOTS</td>
<td>Alan Puderbaugh - Transit Service Manager</td>
</tr>
<tr>
<td></td>
<td>John Wittington - Planning and Marketing Manager</td>
</tr>
</tbody>
</table>
fare collection procedures were also discussed. An example of the checklist is given in Appendix A.

Each transit company (except Salem) owned and operated several different models of buses. During the transit company visits, the bus lots were visited and the different models of buses were examined in detail. In Portland, the bus lot visit included an opportunity to drive the various models of buses. Driving the buses provided a first hand "feel" of a bus driver's job, and pointed out the distinct differences in the handling characteristics of different buses. It also provided a close-up look at several of the safety problems discussed during the transit visits.

Tri-Met

Tri-County Metropolitan Transportation District of Oregon (Tri-Met) serves Clackamas, Multnomah, and Washington counties. Tri-Met emerged out of the consolidation of the three separate bus companies serving the area prior to 1969 when Tri-Met was formed. Tri-Met is the largest transit district in the state, employing 943 drivers, 221 of whom are part-time.

According to Tri-Met officials, the major bus design features related to driver problems were the driver's seat, the steering wheel, inconsistent control layout, and lever type handbrakes. Problems with the driver's seat appear to be the major cause of back injuries and Tri-Met is in the process of implementing several programs aimed at reducing the problems. One third of the drivers currently use seat supports which are subsidized by the Workers' Compensation Department and are offered to the drivers at a reduced price. Seat supports are portable devises with seat back and seat bottom that are placed on the driver's seat and usually offer more support for the back, than the seat alone. The types of seat supports currently offered are "Acuback" and "Sacroease". Both of these products offer some support and each has advantages and disadvantages. The Sacroease support has a metal frame, offers very solid support, and is extremely durable. However several of the buses have seats which are shorter than the seat support and as a result, the legs of the driver are supported solely by
the edge of the seat support and circulation to the legs may be restricted. The Acuback model has the advantage of a soft and flexible seat bottom that will mold to any bus seat and also has an internal frame that can be adjusted to fit the back of the driver. The disadvantages of the Acuback are that the flexible seat bottom does not offer as much support and the model is not as durable as the Sacroease.

Along with the seat supports, Tri-Met is taking other measures to alleviate driver seat problems. A questionnaire distributed to drivers revealed that many drivers did not know how to adjust the seats and, as a result were experiencing problems. Many drivers have also experienced problems caused by the pneumatically supported seats loosing air pressure and dropping rapidly to the lowest position (commonly referred to as the seat "bottoming out"). Tri-Met is hoping to diminish both problems with a new seat which is to be included in the new buses being purchased this year. The new seat is a mechanical seat without the air pressure problems of the pneumatic seat and has double lumbar support.

Another problem related to the seat is that drivers tend to sit in the position that is initially most comfortable for them when starting their shift. This may not be the healthiest position. A static position for long time periods may also cause serious problems. To reduce these problems, drivers are encouraged to take stretch breaks in their seats; unfortunately, driver comments indicated that few drivers actually do the stretches. Finally, drivers are also involved in a back awareness class during training.

Steering was identified as the second major driving problem. The 1974 Flxible buses were manufactured with manual steering and have been the source of a number of problems. Changes are being made to help reduce the problem and several 1974 Flxible buses are being retrofitted with "air power assist" steering.

The third major vehicle-related hazard identified by Tri-Met officials was the lack of consistency in the layout of bus controls between the different types of Tri-Met buses. Most Tri-Met drivers do not drive a regular route where they may have the same type of bus each trip. Instead, each driver may drive a different bus each time he/she goes out and may even change buses in the middle of one shift. The
lack of consistency in the location of blinkers, flashers, gear shift, windshield wipers etc. may be especially hazardous in emergency situations when the driver must respond instinctively to a situation without the time to consider which bus is being driven.

The fourth problem relating to vehicles was identified as the lever type handbrake located at the left side of the driver in several buses. The levers on these handbrakes may be fairly stiff and can cause sprains and strains when they are pulled. Expectations concerning the degree to which the handbrake needs to be pulled to be set, as well as the expected stiffness, may be another cause of driver injuries.

Concerning drivers themselves, the three specific areas that were perceived as problems were driver stress, the physical condition of the drivers and a lack of breaks. The major source of driver stress was identified by Tri-Met officials as the continuous pressure of staying on schedule. Given the unpredictability of traffic conditions and spontaneous situations that take up the driver's time, drivers frequently seem to be fighting the clock to arrive at stops at the scheduled time. Other factors that potentially contribute to driver stress, could be the fear of being attacked (especially on certain routes), and simply dealing with angry or irate passengers.

The second major concern with respect to drivers was the physical condition of the driver. According to Tri-Met officials, sixty-eight percent of all Tri-Met drivers are clinically obese and studies have shown a correlation between obesity and back problems. Tri-Met offers several programs aimed at improving driver physique, such as fitness classes and weight loss incentive programs, but many drivers do not participate in these programs.

The third major concern was a lack of scheduled breaks. Driver schedules are tight and Portland traffic unpredictable with the result that breaks for the drivers are not consistent and are frequently missed. Scheduled lunch breaks are also rare and drivers may frequently eat a hurried lunch while driving.

Operational activities at Tri-Met that were not perceived as problems included driver selection and training, driver hours and extraboard policies. Drivers are selected based upon their driving
record for the past five years, a personality and public relation test, past employer references, an interview and a physical. Once hired, drivers are given three weeks of training including classroom lectures, video presentations, and on the road training; topics covered include public relations training and back awareness training. Advanced Driver Development sessions are then given throughout the year focusing on additional relevant topics such as dealing with stress, helping the handicapped, etc.

Fatigue due to long working hours was not perceived as a major problem at Tri-Met. The average number of hours worked consecutively for a full-time driver at Tri-Met is nine hours. Currently, there is no restriction on the number of hours any operator may drive. This situation is unique to Tri-Met among most transit agencies because Tri-Met is not under Public Utilities Commission (P.U.C.) restrictions of hours.

Extraboard refers to the drivers who stand by at the transit office and are available to drive should any scheduled operator call in sick or be unable to do their scheduled run. Many drivers prefer to be extraboard drivers since the position can be quite lucrative and the drivers receive pay while they wait at the driver’s lounge for the next call. Extraboard drivers may work very long hours if several routes need drivers and the extraboard driver is asked to work consecutive shifts. While drivers are allowed to refuse work after a certain number of hours, most drivers accept additional hours because of the additional money earned. One driver/trainer for Tri-Met, gave examples of extraboard drivers sometimes working 18-20 hours/day for four days in a row and indicated that he himself had worked as much as 170 hours in a two week period.

Lane Transit District

Lane Transit District (LTD) serves the Eugene-Springfield area (population approximately 275,500) with a fleet of 69 buses. LTD employs 108 full-time and 17 part time drivers. The major driver problems perceived by officials at Lane Transit included back and shoulder problems, the physical condition of the drivers and stress.
The driver selection policy was noted as having been an important factor in reducing driver injuries in recent years.

LTD officials identified the major vehicle related problem as the driver's seat. As at Tri-Met, the driver's seat was cited as a major source of the back and shoulder injuries. To combat back injuries, drivers are given tips on how to avoid back problems. No formal training on back care is provided and several drivers have been sent to the Eugene back clinic.

The physical condition of the drivers was another concern. Again, obesity was noted as being prevalent among drivers and as potentially mitigating driver injuries. Weight loss incentive programs have been initiated and a physical is given to each driver every three years with checklist surveys which show changes in driver health.

The third perceived problem was driver stress with the major source of stress being associated with staying on schedule. Routes are scheduled so that drivers can get a five minute break between runs, but breaks are not consistently taken by drivers because of the tight schedule. Drivers may often not have time to take a lunch break, but they are not allowed to eat on the bus.

LTD's Safety and Risk Manager cited a major reduction in claims costs from 1976 to the present and attributed a major portion of that reduction to modification of the driver selection process. (Workers' Compensation Department records later confirmed the general downward trend in yearly claims.) In 1972, the selection of drivers was relatively indiscriminate, while today drivers are hired on the basis of a video test, a series of interviews, a road test, a physical and a drug test. Interpersonal skills are also considered and the selection committee looks for drivers who will relate well to the public.

Several additional reasons for the claims cost reduction were also cited including better buses in the current fleet, a preventative maintenance program for the buses, the physical, and the Take Care health program for the drivers. The Take Care health program is basically an incentive program to encourage drivers to stay physically fit and healthy. The program involves LTD paying a major part of the tuition for various health programs and classes such as weight loss, and exercise programs, stress management classes etc. Finally, the
modified work program helps to reduce claims costs by reducing the number of days an injured driver stays at home. Drivers are encouraged to work in the office answering phones and doing other office jobs; drivers who participate tend to return to their regular driver job more quickly than drivers who recover at home.

Operational activities that were not perceived as problems at Lane Transit District included driver hours and driver training. The Lane Transit District system offers 4:30 a.m. to 11:30 p.m. service. Extraboard drivers may refuse work after 10 hours of driving, and LTD officials perceived no problems with driver fatigue. The three and a half weeks of training received in Lane County include five days of off route training, two days of classroom training, eight days of on route training (consisting of two hours in the classroom and six hours behind the wheel), and one day of defensive driving.

Lane County Transit is insured by SAIF Corporation (State Accident Insurance Fund) and is one of the leaders in the nation for per capita handicapped riding. All buses are equipped with front door wheelchair lifts which can be operated from the drivers seat. Front door lifts are important because many courtesy stops in Eugene do not prohibit parking near the bus stops, and a bus would be unable to maneuver the rear door close enough to the curb to allow wheelchair operation.

Cherriots

Cherriots Salem Area Transit is one of the smallest transit companies being studied with roughly 2.4 million passenger trips/year and eight million passenger miles. All forty-three Cherriot buses were manufactured by General Motors Corporation according to UMTA's transbus guidelines; they are known as Advanced Design Buses (GM ADBs). The Transbus Program was implemented by UMTA in 1971; the primary objective of the program was to design and develop prototypes of a new generation of coaches according to specific guidelines. These buses are equipped with a "kneeling" mechanism which allows the right front corner of the bus to be lowered to curb height; "kneeling" the bus makes boarding easier by decreasing the height of the first step. Buses are scheduled from 5:45 a.m. to 7:45 p.m. and Cherriots is insured by SAIF.
The perceived problems in Salem were of a different nature than the perceived problems in Portland and Eugene. Back and shoulder injuries were still the major driver complaints, but steering, seating, and the physical condition of the drivers were not perceived as problem areas. The main problems concerning the buses were poor ventilation and a lack of heat.

Operational activities in Salem included driver hours, driver selection and training, and health programs. Salem's Cherriots does not have extraboard drivers; instead, part-time drivers are called in when they are needed. Drivers are assigned to regular routes three times a year, and may do one particular run in the morning and a different run in the afternoon. Drivers are selected on the basis of interviews, a driving test, and a medical test. In the past, only candidates with prior bus driving experience were considered, but the pool of potential drivers has recently been reduced and this policy may be revised. The three week driver training period includes eighty hours of on-the-road training along with films and slide presentations. In past years, back stretching classes were also included in the training, but these are no longer offered.

According to officials, obesity is not a problem among Cherriots drivers. Schedules are relatively loose so stress is also not a major problem. Drivers usually have a five to seven minute breaks between runs and a half hour lunch break. None of the routes are notably stressful due to crime. Minor stress is caused by the question of whether a driver should kneel the bus for elderly passengers or not. Apparently, some older transit riders are offended when a bus driver kneels the bus, feeling that it implies they are old and not able to board a bus by themselves. Other passengers are angry when the driver does not kneel the bus. Branches hanging into the streets have also caused some problems - damaging buses that are driven too close to the curb.

Summary of Transit Company Visits

Transit officials in each of the three companies had well defined ideas and opinions on the major problems facing their drivers. Company
officials unanimously cited back and shoulder problems as the major types of driver injuries; the driver's seat and steering wheel were considered to be the major causes of these problems. A lack of consistency in vehicle controls and problems with handbrakes were other vehicle related problems mentioned. Transit officials perceived stress to be the major driver related problem due to tight scheduling, a lack of breaks and poor physical condition of the drivers. Driver selection and training, extraboard policies, and driver fatigue were generally not perceived as problems. Visits to each of the transit companies under study provided a framework for understanding and approaching the human factors problems faced by transit drivers. Information gathered during these visits combined with both the literature review and the transit group workshop provided an overview of the occupational safety and health problems of transit bus drivers. The human factors problems and potential hazards were then studied in detail using observation research techniques and accident data.

B. TRANSIT GROUP WORKSHOP

The transit group workshop provided a broad perspective on transit problems because of the wide variety of transit related groups participating. The workshop involved bringing together several transit related groups that do not frequently have the opportunity to interact including transit officials, representative drivers and trainers, transit users and state and federal agency officials. The purpose of the workshop was twofold. First, it provided familiarization with the transit groups and insight on their perspective of the human factors problems affecting bus drivers. Secondly, it provided a forum for the transit groups to exchange information on safety problems and identify available data and expertise. Of the twenty one participants, nine represented the transit agencies located in Portland, Eugene, Salem, and Corvallis; nine represented users who were visually impaired, wheelchair users, elderly or had limited mobility; and three represented Oregon and Washington state government agencies. The one day workshop was held on Thursday, November 12, 1987 in Salem, Oregon.
The workshop was structured to provide the maximum input from the participants on potential problems and solutions within the transit system. It also provided participants with an opportunity to exchange ideas and learn how other groups are approaching mutual concerns. A list of participants is shown in Table 2 and Figure 1 shows the agenda for the day.

A brainstorming session provided an opportunity for participants to input their ideas on transit system operational areas that are likely to produce accidents and injuries. The goal of the brainstorming session was to stimulate the group to generate numerous ideas on transit problems quickly. Participants were asked to relax and throw out any idea without fear of criticism. Various topics concerning driver safety such as check out and maintenance procedures and on board problems were introduced and participants were asked to write down four to six words indicating their feelings about the topic. Later, the brainstorming ideas were grouped into five categories: environment, operations, equipment, driver, and passengers. Environmental concerns were related to street design and maintenance, weather, traffic and bus stop locations; while operational considerations included items such as schedule time frames and breaks, driver stress or boredom, driver training and overly long shifts. The equipment category involved the driver’s seat and seat belt, fare box, control location, cab layout and step configuration. Driver concerns included the physical conditioning and health of the driver, drug/alcohol procedures, and stress management skills. Finally, the passenger category concerns were: driver harassment and assault, wheel chair considerations, and passenger awareness. A complete list of the ideas generated during the brainstorming session is included in Appendix B.

Following a discussion of passenger issues, transit safety problems were looked at from the perspective of the transit agencies. The discussion focused on several issues including time and budget constraints, education for both transit system employees and the public, and other topics. Each topic was briefly considered and discussed and participants were asked to consider the degree of effort required to improve the problem. The problems that were considered most difficult to improve are listed below in ranked order:
<table>
<thead>
<tr>
<th>Workshop Participants</th>
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<tbody>
<tr>
<td>Mr. Michael L. Allen</td>
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<tr>
<td>Transit User</td>
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<tr>
<td>Mr. Keith Boos</td>
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<tr>
<td>Driver Trainer</td>
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<tr>
<td>Tri-Met</td>
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<tr>
<td>Mrs. Cindy Callis Oberg</td>
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<td>Bus &amp; Rail Accessible Service Planner</td>
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<td>Tri-Met</td>
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<tr>
<td>Chris Christian</td>
</tr>
<tr>
<td>Transit User</td>
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<tr>
<td>Mr. Gary Deverell</td>
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<tr>
<td>Safety and Risk Manager</td>
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<tr>
<td>Lane Transit District</td>
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<tr>
<td>Mr. Louis Grimmer</td>
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<tr>
<td>Transit User</td>
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<tr>
<td>Mr. Barry Hartford</td>
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<tr>
<td>Transit User</td>
</tr>
<tr>
<td>Mrs. Kate Hunter-Zaworski</td>
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<tr>
<td>UMPTA Project</td>
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<tr>
<td>Miss Lorell Jabs</td>
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<tr>
<td>UMPTA Project</td>
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<tr>
<td>Ms. Micki Kaplan</td>
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<tr>
<td>Planner</td>
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<tr>
<td>Lane Transit District</td>
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<td>Mr. Dave Kleger</td>
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<td>Transit User</td>
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<tr>
<td>Mrs. Connie Kramer</td>
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<tr>
<td>Transit User</td>
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<tr>
<td>Mr. Lee LaFontaine</td>
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<tr>
<td>Transportation Planner</td>
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<tr>
<td>Public Transit Division</td>
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<tr>
<td>Dr. Robert D. Layton</td>
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<tr>
<td>Professor</td>
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<tr>
<td>Transportation Research Institute</td>
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<tr>
<td>UMPTA Project</td>
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<td>Mrs. Joanne Lucas</td>
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<td>Transit User</td>
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<tr>
<td>Ms. Evelyn Marker</td>
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<td>Transit User</td>
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<tr>
<td>Mrs. Carolyn Nelson</td>
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<tr>
<td>Director of Personnel</td>
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<tr>
<td>Division of Finance &amp; Administrative Services</td>
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<tr>
<td>Tri-Met</td>
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<td>Mr. Alan Puderbaugh</td>
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<td>Transit Services Manager</td>
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<tr>
<td>Cherriots Salem Area Transit</td>
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<tr>
<td>Dr. Robert S. Safford</td>
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<tr>
<td>Associate Professor</td>
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<td>Industrial Engineering Department</td>
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<td>UMPTA Project</td>
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<td>Safety and Claims</td>
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<td>Ms. Santha Still</td>
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<td>Department of Industry and Finance</td>
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<tr>
<td>Mr. Doug Van Dyke</td>
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<tr>
<td>Director of Transportation</td>
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<tr>
<td>Corvallis Transit System</td>
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<tr>
<td>Mr. John Whittington</td>
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<tr>
<td>Planning &amp; Marketing Manager</td>
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<td>Cherriots Salem Area Transit</td>
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<td>Ms. Ethyl Young</td>
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<td>Transit User</td>
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WORKSHOP ON HUMAN FACTORS IN THE TRANSIT INDUSTRY

Salem Convention Hotel
5301 Market St N E, Salem

Thursday, November 12, 1987

WORKSHOP AGENDA

9:00-9:15  Registration
9:15-9:45  Introduction
9:45-10:15 Project Background
10:15-10:30 Brainstorming Procedures
10:30-10:45 BREAK
10:45-12:00 Brainstorming
11:00-11:30 On Board
11:30-11:35 minIBREAK
11:35-12:00 Driver Safety
12:00-1:00 LUNCH BREAK Washington Room
1:00-1:30 Discussion of Brainstorming Ideas
1:30-2:00 Summary of Literature Review
2:00-3:00 Discussion of Transit Safety by Participants
3:00-3:15 BREAK
3:15-3:45 Setting Priorities to Transit Safety Issues
3:45-4:30 Discussion of Project
4:30 Closure

Figure 1. Transit Group Workshop Agenda
The ranking numbers were calculated by having each participant rank the concern on a scale of one to five (five being the most important). The scores were averaged over the number of participants voting and an average rank for each concern was determined.

Potential improvements were discussed and participants identified the items they would most like to change in a wish list of transit safety improvements. Ideas were ranked according to the previously described system and the ranked list is given below:

- Change in schedule - adequate time for breaks 5.0
- Change in schedule - adequate time for routes 4.8
- Reroute to eliminate narrow streets 2.9
- Reassignment of vehicles 2.5

The transit group workshop provided some new inputs into transit driver problems along with confirming some of the problems identified by the literature review and transit company visits. New considerations brought out by the workshop included the idea that education of the public concerning bus routes, driver responsibilities and driver authority are important for the driver as well as for the public. Communication between drivers and management also came out as an important concern, and a change in driver behavior to reduce stress was also mentioned. Scheduling problems were confirmed as a major driver concern and the distinction between scheduling enough time to complete the route and scheduling enough time for both the route and breaks was made. The workshop completed the general problem identification phase of the study. Several of the problems identified were investigated more fully with the opinion data of driver and the quantitative data from workers' compensation claims.
A general overview of the problems facing transit drivers was provided by the literature review, transit visits and workshop. Once the general problems were understood, more detailed information was collected on specific problems through observational research techniques and accident data. Observational data were collected using personal interviews of almost 100 drivers. Accident data involved the study of summary tables of Workers' Compensation claims in the past eight years along with in-depth examinations of numerous Workers' Compensation files.

A. OBSERVATIONAL DATA - DRIVER SURVEYS

Survey Research Principles

The drivers themselves provided the first source of data for a more detailed look at some of the human factors problems previously identified. A personal interview format was chosen as the means of gathering information from drivers. The advantages of this method are fairly rapid data collection, immediate feedback and the opportunity to clarify or expand on drivers suggestions with interviewer questions. The main disadvantages of personal interviews as a survey research method are sampling problems and relatively high costs.

The most accurate estimates of true population figures are provided by simple random or stratified random sampling plans [Tull and Donald, 1973]. However, these sample methods require careful planning and additional expenses that were not justified given the purpose of the driver interviews. The purpose of the interviews was to gain the insight of transit drivers on the potential human factors problems and occupational safety hazards facing transit bus drivers. Concerning the format of interviews, closed-ended questions have the advantages of being easy to tabulate and unambiguous; however they also have the corresponding disadvantages of possible biasing of responses and of limiting the study to what is expected by the survey designer. Open-ended questions on the other hand, have the disadvantages of being more
difficult to tabulate and possibly more difficult for interviewees to answer; but they also allow for unexpected and unique responses, and go beyond specific answers to fully explore the entire spectrum of potential problems and solutions. A combination of both closed and open ended questions was used in the driver survey with the goals of gathering feedback on specific problems identified in the literature along with providing opportunity for drivers to freely add their own individual insights on human factors problems in transit bus driving.

Driver Survey Development

The driver survey was drafted based upon potential problems identified in the literature. This draft was further revised with the input generated at the transit group workshop and transit company visits. The revised interview was reviewed by each transit company and returned with their comments, objections and suggestions. A final copy of the driver survey was developed for each of the four cities studied: Corvallis, Salem, Eugene, and Portland. The form of the survey was slightly different for each city depending on the number of different types of buses in the fleet, but the basic content and questions remained consistent for all four cities.

The survey was designed to collect feedback on a wide variety of topics. An example of the final survey given at Tri-Met is shown in Figure 2. The first question explored the make of bus that is most preferred among bus drivers and the reasons why it is preferred; the second question concerned the make of bus that is least preferred with the corresponding reasons. Feedback was then collected on the vehicle components which cause most problems and driver input was requested on what could be done to correct the problems. Question four focused on potential driver concerns, such as concerns about accidents, assaults, staying on schedule etc. and driver opinions on how these concerns could be reduced were solicited. Occupational safety issues were addressed in the fifth question concerning the types of work related injuries experienced by the drivers and the causes of these injuries. Differences in control location from one bus to another precipitated question six; feedback on the problems associated with location
DRIVER SURVEY

Date ________________________  # of yrs driving___________
Time ________________________  avg hrs/day _______________
Agency TRI-MET ____________  avg hrs/week ____________
M____ F____  a.m. ______ split ____ mat ______ ngt ______
age________  # of yrs this shift ______
  part____ full____ extra____  # of yrs this schedule____

1. What make bus do you most prefer to drive?
   100 series _____  400 series _____  1000 series _______  other _____
   300 series_____  900 series______  articulated_______  other_____

1a. Why do you prefer this bus?

2. What make bus do you least prefer to drive?
   100 series_____  400 series_____  1000 series________
   300 series______  900 series_______ articulated_______ other______

2a. Why do you not prefer this bus?

3. Which of the following causes you the most difficulty in operating the bus? e.g.
   controls _____ steering wheel_____ seat____ brake/accelerator pedals____
   fare box____ blinker buttons____ steps____ emergency brake____
   other________

3a. What type of problem do you experience related to this aspect of the vehicle?

3b. What do you think could be done to correct this problem?

3c. Do you encounter any problems with the wheelchair lift? If yes, what problems?

Figure 2. Tri-Met Driver Survey
4. Which of the following concerns you most?

vehicle accident    shoulder/arm problems    assault
back problems     road conditions    traffic    schedules
other

4a. What could be changed to reduce these concerns?

5. Have you experienced any work related injuries? Yes    No    

5a. What was the injury?

5b. What was the cause?

6. Do the differences from bus to bus of the following controls and displays cause any problem in the operation of the bus?

wipers    heater    panel light switch    horn
blinders    parking brake    headlight switch    fuel gage
gear shift    speedometer    high beam switch    door controls
ignition    wheelchair lift    interior light switch
defroster    other

7. What is the most difficult or demanding part of your job?

8. What is the maximum number of hours you have ever driven in a week?

8a. Did driving this much cause you any health or other problems?

9. In your opinion, what is the biggest concern for passenger safety?

10. If you had a wish list for changes in the equipment or operational procedures of your job, what would be your first three wishes?

    1.
    2.
    3.

Figure 2. (Continued).
differences of specific controls was collected. The seventh question was included to collect data on what drivers perceive to be the most difficult part of their job; while the eighth question was directed primarily to extraboard drivers and their perceptions of the effects of long hours on their health and their driving performance. Question nine, keeping with the holistic view that factors beyond the drivers immediate work station may affect the driver, explored driver's concerns for passenger safety. Finally, question ten was an open ended question encouraging drivers to express their wish list of potential changes in the equipment and operational procedures of their job; this question gave the driver an opportunity to bring up any potential hazards, problems, or suggestions.

A total of 96 drivers were interviewed, with the number of drivers spoken with at each company being somewhat proportional to the size of the company. Interviews took place in the driver lounge area of the participating transit companies; drivers were "randomly" chosen among those drivers who were present, with most of the drivers who were present during the interview periods being interviewed. Interviewing times were arranged so that a cross section of all drivers regardless of shift might be spoken with. Demographic data concerning the age, sex, shift driven, number of years driving and the average number of hours per day and per week were collected to enable assurance later on that a representative group of drivers had been surveyed. The number of men and women interviewed at each company are given in Table 3 and summaries of the survey results for each company are given in Appendix C.

Pilot Study - Corvallis Transit System

The Corvallis Transit System was used for a pilot study of the driver surveys because of its close proximity to Oregon State University. Five Corvallis drivers were interviewed on December 14, 1987 after the company payroll meeting. The pilot study provided an opportunity to try out the survey questions and make certain that there were no serious problems. It also provided some interesting insights into some of the differences between relatively small (ten drivers) and
Table 3. Number of Drivers Interviewed at Each Transit Company

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corvallis Transit System</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Lane Transit District</td>
<td>17</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Salem Cherriots</td>
<td>25</td>
<td>4</td>
<td>29</td>
</tr>
<tr>
<td>Tri-Met</td>
<td>36</td>
<td>7</td>
<td>43</td>
</tr>
<tr>
<td>Totals</td>
<td>82</td>
<td>14</td>
<td>96</td>
</tr>
</tbody>
</table>
much larger (60-900 drivers) transit companies. The Corvallis fleet consists of five buses: three "New Look" buses manufactured by the General Motors Corporation of Canada (GMC), one ROHR Flexette bus and one Argosy. Service hours are from 6 a.m. to 6 p.m. daily.

In regards to driving concerns, the most difficult part of their job, and passenger safety concerns, Corvallis drivers gave answers somewhat similar to larger company drivers as shown in Table 4. Schedules, vehicle accidents, and bicyclists were concerns. Dealing with passengers, rush hour traffic, and careless pedestrians were stated as being the most difficult parts of the job, and passengers standing up while the bus is in motion was the biggest concern for passenger safety.

Problems in bus operation, work related injuries, the maximum number of hours driven, and wish list questions all received very different answers from the answers of drivers in larger companies. While drivers of larger companies expressed problems with the seat, fare box, and brake pedals, Corvallis drivers mentioned only the poor location of the windshield wiper control as a potential problem. None of the Corvallis drivers spoken with had experienced a work related injury. Some of these small company differences may potentially be explained by the number of hours worked. While larger company drivers averaged around sixty hour/week, few Corvallis drivers had driven over forty hours per week and most drivers worked less than forty hours per week. Overall, Corvallis drivers had few complaints about the transit system, with the one exception that they unanimously disliked the design of the 1980 Flexette - a bus that was recently purchased by CTS. The poor design of the Flexette cab was fairly obvious upon its arrival and it is currently used only when the GMCs are being serviced. Corvallis drivers unanimously wished the Flexette would be removed from the fleet.

Survey Results

As mentioned earlier, slightly different forms of the survey were given at each transit company depending upon the number of different bus models in the company's fleet. The first two questions in the
Table 4. CTS Concerns as Compared to Larger Transit Systems Concerns

<table>
<thead>
<tr>
<th>Similar Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Safety Concerns</td>
</tr>
<tr>
<td>Passengers standing while vehicle in motion</td>
</tr>
<tr>
<td>Driver Concerns</td>
</tr>
<tr>
<td>Schedules</td>
</tr>
<tr>
<td>Vehicle accidents</td>
</tr>
<tr>
<td>Bicyclists</td>
</tr>
<tr>
<td>Most Difficult Part of Job</td>
</tr>
<tr>
<td>Dealing with passengers</td>
</tr>
<tr>
<td>Rush hour traffic</td>
</tr>
<tr>
<td>Careless pedestrians</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Different Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Component Complaints</td>
</tr>
<tr>
<td>Poor location of windshield wiper control</td>
</tr>
<tr>
<td>Work Related Injuries</td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td>Maximum Number of Hours/Week</td>
</tr>
<tr>
<td>Average less than 40 hrs/wk</td>
</tr>
</tbody>
</table>
survey, focusing on the most and least preferred buses, indicated that bus preference is relative - depending upon the available bus models. The 1980 Canadian GMC was unanimously preferred in Corvallis, while the same bus was least preferred in Eugene. Corvallis drivers described the bus as the most comfortable and well made among the vehicles in the Corvallis fleet, while Eugene drivers disliked the bus mainly because it was less comfortable than other buses in the Eugene fleet, gave a rough ride, had poor steering, and was noisy.

The main reasons any particular bus was preferred was because it was comfortable (or had a comfortable seat), was easy to handle and easy to turn, or was reliable. The converse of several of these items were some of the main reasons to least prefer a bus, i.e. buses were least preferred because they had an uncomfortable seat, were difficult to handle, were difficult to steer and were not reliable. Additional complaints concerning buses that were least preferred were that they were noisy and rattled or were too big for city streets.

Preferred Bus Models - Cherriots

In 1980, Cherriots started buying General Motors Corporation Advanced Design Buses (GM ADBs) - changing from one of the oldest fleets in the country to one of the newest fleets in a relatively short period of time. Table 5 shows the composition of the Salem fleet in 1983, at the beginning of the change over. The majority of buses in 1983 were manufactured in 1967 or earlier. This is a distinct contrast to the current fleet where all buses were built in 1980 or later. All of the buses currently being driven are GM ADBs. The GM ADB buses do not differ much from year to year and the first two questions regarding bus make preferences were deleted from the driver surveys done in Salem. The remainder of the driver survey provided input on drivers opinions of these buses, indicating that, like most buses, the major problems involve the driver's seat and seat adjustments. Other comments revealed that the fare box may be in an inappropriate place, that glare on the windshield from the ceiling lights may be a hazard, that mirrors could be located to provide more visibility, and that, in
<table>
<thead>
<tr>
<th>Number of Vehicles</th>
<th>Year Manufactured</th>
<th>Manufacturer</th>
<th>Seated Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>1960</td>
<td>GM*</td>
<td>44</td>
</tr>
<tr>
<td>1</td>
<td>1962</td>
<td>GM</td>
<td>44</td>
</tr>
<tr>
<td>4</td>
<td>1963</td>
<td>GM</td>
<td>44</td>
</tr>
<tr>
<td>16</td>
<td>1966</td>
<td>GM</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>1966</td>
<td>GM</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>1966</td>
<td>GM</td>
<td>49</td>
</tr>
<tr>
<td>2</td>
<td>1967</td>
<td>GM</td>
<td>35</td>
</tr>
<tr>
<td>9</td>
<td>1980**</td>
<td>GM</td>
<td>44</td>
</tr>
</tbody>
</table>

*GM = General Motors Corporation
**Advanced Design Buses
spite of the uniformity of the buses, the braking pressure required to stop the vehicle differs from one bus to another.

Preferred Bus Models - Lane Transit District

The Lane Transit District fleet consists of three bus models: thirty one 1984 Gillig Phantoms (Gilligs), eighteen 1980 Canadian GMCs (identified as the most preferred Corvallis bus) and twenty 1976 Flxibles (FLXs). A large amount of diversity was noted among drivers concerning their most and least preferred buses and none of the models were clearly cited as being preferred by a large majority of drivers. It is interesting to note that similar reasons for preferring and not preferring a particular bus were given for each bus make. For instance, different drivers made similar comments about each of the three bus models; one driver preferred the 1984 Gilligs because they had the "best visibility" or "most comfortable seats" while another driver preferred the 1980 Canadian GMC or the 1976 FLX for the same reasons. This implies that bus model preference may be partially related to the physical characteristics or preferences of a particular driver and may not be entirely dependant upon bus design.

Even though none of the buses were preferred by a large majority, the 1976 FLX and the 1984 Gillig were preferred most frequently and disliked least frequently. As mentioned earlier, the 1980 Canadian GMC was the least preferred bus for the majority of Eugene drivers. Half of the drivers who least preferred this bus cited an uncomfortable seat as the cause of the dislike; several other drivers mentioned a rough ride, rattles, and difficult steering as additional causes of dislike. Yet, even while the majority of drivers disliked the bus, four drivers most preferred this bus and considered it easiest to handle.

Drivers were equally split in terms of preferring the 1976 FLX and the 1984 Gillig. While each bus model received similar positive comments, it was also clear that drivers held varying priorities concerning the most important bus characteristics. Drivers who valued easy bus handling, and were more or less indifferent to vehicle size, preferred the nine foot seven inch wide Gillig, viewing it as the "easiest to drive." Drivers who placed a high priority on small
vehicle size preferred the eight foot five inch wide Flxible, stating that it was "designed for all streets" and disliking the Gillig Phantom because it was "too big for streets" (quotes from driver surveys). The overall consensus of the LTD drivers spoken with, was that the 1976 FLX and the 1980 Gillig were preferred over the 1980 Canadian GMC. A table of most and least preferred buses for LTD drivers, along with corresponding reasons is shown in Table 6.

Preferred Bus Models - Tri-Met

Tri-Met, owns and operates several "fleets" of buses. Five hundred and thirty four buses are currently in service with ages ranging from five to sixteen years and vehicle capacities ranging from 42 to 64 seated passengers per vehicle. Five different manufacturers are represented in the Tri-Met fleet, with different manufacturing years distinguishing vehicles of the same manufacturer. Every bus in each Tri-Met fleet receives a bus number with the same first digit indicating what fleet the bus belongs to. For example, all 1974 Flxible buses have "1--" coach numbers and are commonly referred to as 100 series buses among Tri-Met personnel. The year, manufacturer, series number and dimensions for each Tri-Met bus are given in Table 7.

While almost every bus make was preferred by at least a few Tri-Met drivers, a strong majority (47%) preferred the 1982 General Motors Corporation Advanced Design Bus (GM ADB) buses. These are the newest buses in the Tri-Met fleet and are identical to the buses of the Cherriot fleet in Salem. The GM ADB buses are equipped with power steering and a "kneeling" mechanism which works by lowering the right front corner of the bus. Sixty five percent of the drivers preferring the GM ADBs liked them because of the "better power steering" and the "easier turning." Thirty-five percent of the drivers found the GM ADBs more comfortable than other bus makes; a few of the drivers specifically referred to the bus seat as being more comfortable.

The next most frequently preferred bus was the 1972 Flexible bus (300 series). These buses are thirty-five feet long and eight and a half feet wide with eight cylinder engines. Drivers prefer these buses
Table 6. Bus Preferences with Reasons
Lane Transit District

<table>
<thead>
<tr>
<th>Most Preferred</th>
<th>Least Preferred</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gillig Phantom - 8</strong></td>
<td><strong>Gillig Phantom - 5</strong></td>
</tr>
<tr>
<td>most comfortable - 2</td>
<td>too big for streets - 5</td>
</tr>
<tr>
<td>easiest to drive - 6</td>
<td>difficult to steer</td>
</tr>
<tr>
<td>best visibility</td>
<td>poor visibility</td>
</tr>
<tr>
<td>best seat</td>
<td>seat not comfortable</td>
</tr>
<tr>
<td><strong>Flxible - 7</strong></td>
<td><strong>Flxible - 4</strong></td>
</tr>
<tr>
<td>most comfortable seat - 2</td>
<td>floats - 2</td>
</tr>
<tr>
<td>better quality - 2</td>
<td>seat hurts back</td>
</tr>
<tr>
<td>designed for all streets</td>
<td>rattles</td>
</tr>
<tr>
<td>easiest handling</td>
<td></td>
</tr>
<tr>
<td>best visibility</td>
<td></td>
</tr>
<tr>
<td>wheel chair lifts are best</td>
<td></td>
</tr>
<tr>
<td>compartment for driver</td>
<td></td>
</tr>
<tr>
<td>belongings</td>
<td></td>
</tr>
<tr>
<td><strong>Canadian GMC - 4</strong></td>
<td><strong>Canadian GMC - 10</strong></td>
</tr>
<tr>
<td>easiest to negotiate - 3</td>
<td>less comfortable seats - 5</td>
</tr>
<tr>
<td>like location of controls</td>
<td>noisy/rattles - 3</td>
</tr>
<tr>
<td>best visibility</td>
<td>rough ride - 2</td>
</tr>
<tr>
<td></td>
<td>poor steering - 2</td>
</tr>
<tr>
<td></td>
<td>floats</td>
</tr>
<tr>
<td></td>
<td>breaks down</td>
</tr>
<tr>
<td></td>
<td>poor location of windshield wiper</td>
</tr>
</tbody>
</table>
Table 7. Composition of Tri-Met Fleet, 1987

<table>
<thead>
<tr>
<th>Number of Vehicles</th>
<th>Year Manufactured</th>
<th>Manufacturer*</th>
<th>Series Number</th>
<th>Vehicle Length (ft)</th>
<th>Vehicle Width (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>1963</td>
<td>FLX</td>
<td>1120-1139</td>
<td>40</td>
<td>8.5</td>
</tr>
<tr>
<td>3</td>
<td>1970</td>
<td>GM</td>
<td>1200-1202</td>
<td>35</td>
<td>8</td>
</tr>
<tr>
<td>31</td>
<td>1971</td>
<td>FLX</td>
<td>455-600</td>
<td>35</td>
<td>8</td>
</tr>
<tr>
<td>127</td>
<td>1972</td>
<td>FLX</td>
<td>301-434</td>
<td>35</td>
<td>8.5</td>
</tr>
<tr>
<td>20</td>
<td>1973</td>
<td>FLX</td>
<td>435-454</td>
<td>35</td>
<td>8.5</td>
</tr>
<tr>
<td>75</td>
<td>1974</td>
<td>FLX</td>
<td>100-179</td>
<td>40</td>
<td>8.5</td>
</tr>
<tr>
<td>98</td>
<td>1976</td>
<td>AMG</td>
<td>1000-1099</td>
<td>40</td>
<td>8.5</td>
</tr>
<tr>
<td>11</td>
<td>1980</td>
<td>GMC</td>
<td>200-210</td>
<td>35</td>
<td>8</td>
</tr>
<tr>
<td>87</td>
<td>1981</td>
<td>CI</td>
<td>700-786</td>
<td>60</td>
<td>8.5</td>
</tr>
<tr>
<td>75</td>
<td>1982</td>
<td>GM</td>
<td>900-974</td>
<td>40</td>
<td>8.5</td>
</tr>
</tbody>
</table>

*Manufacturers Key:
FLX = Flxible Corporation
GM = General Motors Corporation
AMG = American General Corporation
GMC = General Motors Corporation of Canada
CI = Ikarus Coach and Body Works (Crown/Ikarus)
because they are small, easy to handle, easy to maneuver in tight situations, and dependable.

The last two bus makes most preferred by a number of drivers (9% each) were also, ironically, the least preferred buses for the majority of drivers. A few drivers found the Crown/Ikarus articulated buses and the 1974 FLX (100 series) buses to be the most comfortable and easiest to handle, but the majority of drivers considered these buses along with the 1976 AMG (1000 series) buses to be their least preferred buses.

The unique feature of the Crown/Ikarus articulated bus is the accordion-like partition in the middle of the bus, making it "bendable." The front section and the trailer (back section) combine to make this bus sixty feet long with a capacity of 64 seated passengers and a capacity of 100 passengers if both seated and standing individuals are counted. These buses were manufactured with power steering and "kneel" by lowering the entire front end of the bus to curb height. The articulated bus was least preferred by 30% of the drivers; the most frequent reason given was that the bus was unreliable and broke down frequently. Other complaints were that the bus was too big for city streets, that the trailer could swing out and hit objects and that the bus was noisy. Some drivers went so far as to claim that the bus was unsafe and dangerous to the public because of blind spots and poor maneuverability.

The 1976 American General Corporation (AMG) buses were least preferred by 26% of the drivers spoken with. These vehicles were purchased without power steering and "air power assist" steering was added later. The fact that the major complaint concerning these buses involved oversteering and a lack of steering control indicates that the "air power assist" addition is less effective than manufacturer installed power steering. Additional complaints were that the buses were noisy, bulky (too big), and had uncomfortable seats.

Similar to the 1976 AMGs, the 1974 FLXs were manufactured with manual steering and "air power assist" steering is currently being installed in the buses. These buses have the same dimensions as the 1976 AMGs (40 feet long, 8.5 feet wide), but the wheel base of 21 inches makes the bus a little harder to steer. Sixteen percent of the
Tri-Met drivers least preferred the 1974 FLX and, not surprisingly, pointed to steering difficulty as the primary reason for disliking the bus.

Equipment Related Driver Problems

As expected from talks with transit officials, the driver's seat was the vehicle component that caused the most problems for drivers. Forty-two percent of the drivers interviewed had some complaint about the driver's seat. The most frequent comment was that the seats do not have enough adjustments to fit different drivers comfortably. Other comments related to seat adjustments were that vertical adjustments are a problem due to the short straps holding some seats (straps are sometimes tied to the seat frame and the seat itself to keep the seat from bouncing up and down) and the likelihood, on several buses, of bottoming out if the seat is not adjusted to its highest or lowest position. Some drivers indicated that the seat in some buses is not directly aligned with the steering wheel, making steering somewhat awkward and uncomfortable. Worn out seats, broken cushions and vinyl covers add to the discomfort. Several drivers indicated that the driver's seats become less comfortable over long periods of time and that leg and back pains are the results of uncomfortable seats. Drivers also commented that seats differ greatly from one bus to another. Driver's suggestions for reducing seat problems ranged from simply "buying better seats" or "not cutting costs on driver's seats" to designing new seats with more adjustments, and having seat design engineers drive a bus and letting experienced drivers (instead of first year drivers) test potential seats. Cloth covers for the seats and a "seven-way chiropractic" seat were also suggested.

The next most frequent complaint concerning the operation of the bus was with brake and accelerator pedals. The most frequent complaint was that the brake pressure required to stop the bus varies greatly from bus to bus and it can be difficult to adjust to the correct pressure on a new bus. Also the difference in the slant of brake pedals may cause problems. The only potential solution that drivers could offer was to manufacture all the brake pads alike.
The fare box and its use caused drivers some difficulty with a wide variety of problems cited, ranging from being difficult to see at night and being distracting while driving, to having slots that are too small and simply being in the way. Windshield glare from coach ceiling lights was a major complaint of Salem and a few Tri-Met drivers, all of whom drove GM ADBs. Their suggestions were to install footlights instead of ceiling lights or to have ceiling lights only at the rear of the bus where they would not cause windshield glare. Other complaints included emergency lights being difficult to locate, company two-way radios being distracting, mirrors being in the wrong position within the bus, and blinker buttons on the floor being difficult to operate.

Question 3c on the survey concerned wheelchair lifts and their ease of operation. While most drivers stated that they had no problems in operating the wheelchair lifts, many drivers mentioned that the lifts were unreliable and frequently did not work. The articulated bus in particular was cited as having an especially unreliable wheelchair lift; the lift was manufactured by Vapor Corporation and later installed on the Crown/Ikarus articulated bus. Other concerns about the wheelchair lifts were that they were slow and interfered with a driver staying on schedule.

Driver Concerns

The most frequently mentioned concern of drivers in all three cities was vehicle accidents. This concern may be related to fear of administrative hassles or the possible loss of a job more than it is related to fear of physical injury caused by the accidents. While vehicle accidents were of concern to 30% of the drivers interviewed, most drivers felt that accidents were inevitable and that part of the driver's job involves dealing with potential accident situations. A few drivers suggested that better on-the-road training might help to reduce accident concerns, and several drivers pointed to alert transit drivers as the best defense against vehicle accidents.

The next major concern appeared to be traffic. It is initially surprising that Salem and Eugene drivers (city populations 90,300 and 101,300 respectively) found traffic to be more of a concern than
Portland drivers (population of 365,900). Thirty four percent of Salem drivers and 58% of Eugene drivers indicated that traffic was a concern while only 8% of Portland drivers mentioned traffic as a concern. Perhaps Portland drivers expect to drive in heavy traffic and therefore do not consider it a concern while Salem and Eugene drivers have more of a problem due to a lack of heavy traffic driving experience. Eugene drivers mentioned the problem of narrow lanes and Salem drivers referred to problems with branches in the road; both of these problems might make traffic more of a concern. The major suggestions to reduce traffic concerns involved increasing law enforcement and insuring that other drivers, bicyclists and pedestrians obey traffic rules. Other suggestions included making bus lanes wider in downtown Eugene, increasing flexibility in routes (with longer layovers in non-peak hours), and adjusting the bus schedule for heavy traffic (i.e. following a different schedule during rush and non rush periods).

Back problems concerned 24% of all driver interviewed. While traffic was a major concern of LTD and Cherriots drivers, back problems were a major concern of Tri-Met drivers. Forty-two percent of Tri-Met drivers were concerned about back problems, compared to approximately 20% of Cherriots and LTD drivers. The greater concern in Portland may be partially due to a "Hawthorne Effect" - whereby people express more concern for whatever has been brought to their attention. Tri-Met has tested several driver's seat designs, and has initiated the distribution of various seat supports to reduce back problems, thus making drivers aware that a problem may exist. The most frequent suggestion to reduce back problem concerns was to improve driver seats by adding lumbar support and air cushioning. Several drivers felt that starting a general exercise program would help to alleviate back concerns, and some extraboard drivers felt that driving fewer hours would also reduce back problems.

Schedules were a major concern of Portland drivers (35%), a moderate concern of Eugene drivers (26%), and a minor concern of Salem drivers (14%). Portland and Eugene drivers proposed loosening the schedules as the primary solution for scheduling problems with several drivers suggesting that the schedules be adjusted to fit the routes, for example, factors such as heavy traffic or poor road conditions
should be considered in making the schedule, not merely route distance. Other suggestions included laying out bus schedules with a bus instead of with a car, adjusting schedules for the time of day (so more time is allotted for a route when there is more traffic) and having layovers at the end of routes. At one company, drivers mentioned that a tight schedule, coupled with a driver's desire to stay on schedule, contradicts the "Safety First" motto advocated by signs posted around the drivers lounge. Finally, a few drivers mentioned that stopping for handicapped passengers can be time consuming and may be stressful because of the desire to stay on schedule.

Shoulder and arm problems concerned about 13% of all drivers interviewed. The majority of shoulder concerns were related to manual steering buses; a few shoulder concerns were related to stress, the driver's seat, and a lack of exercise. One concern, that was unique to Tri-Met drivers, was assault. Thirty eight percent of the Tri-Met drivers interviewed mentioned assault as a major concern. Several drivers qualified their statements with the additional information that assault was not a serious problem on all routes, but was a major concern for certain specific routes. The most frequent suggestions for reducing assaults were to increase the number of individuals enforcing laws - both city police and Tri-Met security agents. Other suggestions included community programs to reduce the overall crime rate in certain areas and an emergency button on board the bus that would activate the transmit channel of the radio, enabling dispatchers to hear any problems or conflicts that occurred.

Work Related Injuries

Forty percent of all drivers spoken with had experienced some sort of work related injury. Less than half of the drivers spoken with in Salem and Eugene were injured while over half of the Portland drivers interviewed had experienced an injury. These findings are consistent with data from workers' compensation claims which indicate that the percentage of drivers injured at Tri-Met is greater than the percentage of drivers injured at Cherriot or LTD. Salem and Eugene drivers had injury rates (number of injuries occurring in one year divided by the
number of drivers employed by the company during that year) of between 3% and 16% over the eight year study period. Portland injury rates, on the other hand, varied from 16% to 35%. There are several possible explanations for the difference in injury rates between Tri-Met and the other two companies. One possible explanation is the age of the company fleets - the average age of the Tri-Met fleet is 12.5 years; the average age of the LTD fleet is 7.4 years; and the average of the Cherriot fleet is around three years. Older buses are more likely to have manual steering and may have worn out seats or other problems making a higher injury rate more likely for an older fleet. Additional research is needed to determine if the age of the buses has a significant effect on driver injury rates. Another possible explanation is that Tri-Met drivers are more willing to make WCD claims than drivers in the other two cities. WCD claims at Tri-Met almost doubled during contract negotiations in 1983, and Tri-Met officials attributed the high number of claims to the job loss threat that the negotiations posed. This situation indicates a general attitude towards making WCD claims that may account for the higher injury rate at Tri-Met.

Certain types of injuries appear to be more prevalent in certain cities. Sixty four percent of Salem injuries were shoulder and arm injuries; 70% of these injuries were caused by buses in Cherriot's old fleet that did not have power steering. Back injuries in Salem were caused by being rear ended or by falling, but none of the drivers interviewed in Salem were injured directly because of the driver's seat.

Portland drivers on the other hand, expressed the opinion that many injuries were directly related to the driver's seat. Almost all of the back injuries were attributed to some problem with the driver's seat. The remaining injuries had a wide variety of causes including stress, assault, manual steering, and fatigue. The Eugene drivers spoken with had experienced back, shoulder and neck injuries and attributed them to several causes including the drivers seat, manual steering, assault, a malfunctioning wheelchair lift, and vehicle accidents.

Taking all three companies together, 21% of the work related injuries (of the drivers interviewed) were caused by a problem related
Many of these injuries were due to the seat bottoming out, others were due to miscellaneous seat problems such as broken seats or problems with seat adjustments. Another 20% of the injuries were related to steering problems with the majority of these accidents occurring on buses without power steering. Finally, 16% of the driver injuries were due to assault (all of these occurred in Portland) and 13% were due to vehicle accidents.

Variations in Control Location

The sixth question on the driver interview was designed to explore driver's perceptions concerning the problems caused by different control locations in the various buses. Originally, the question focused on the location differences of specific controls, but during the course of interviewing numerous drivers, it became clear that most drivers do not feel that different control locations are a problem. Since most drivers seemed to have few problems with differing control locations, listing the various possible controls as problems seemed superfluous. Drivers also seemed more inclined to talk about the problems with the various controls listed, instead of answering the question concerning the difference in control location between buses. As a result, the general question was revised to, "Do the differences from bus to bus of the locations of the controls and displays cause any problem in the operation of the bus?"

In general drivers expressed the idea that it takes some time to get used to the various buses, but once a driver becomes familiar with all the different buses and drives each bus type fairly frequently, the different control locations are no longer a problem. One notable exception to this idea was the location of the four way hazard lights. Hazard lights are not used frequently, but when they are needed, it is usually important to be able to locate them quickly; several drivers noted that locating the hazard lights on different buses was a problem. Estimates on how long it takes drivers to become familiar with the various controls ranged from two weeks to three months depending on the number of different bus makes the driver is becoming familiar with. A few drivers mentioned other minor problems such as confusing blinker
buttons (located on the floor) with headlight high beam controls or reaching for a control that is not in the expected location.

Most Difficult Elements of Transit Driving

Question seven was originally worded to explore the amount of stress that bus drivers perceived that they experienced as a result of their job. However, some transit company officials objected to the suggestion to the drivers that bus driving might be a highly stressful occupation and the question was reworded to collect data on what the drivers perceived to be the most difficult part of their job. With the reworded question, the topic of stress was not mentioned frequently indicating that many drivers may not be particularly concerned about the potentially stressful nature of the transit driver's job.

The job element that drivers in all cities found most difficult was dealing with passengers; dealing with irate or angry passengers was considered especially difficult, but just being patient with all the people that a driver comes in contact with was also difficult. Staying on schedule was the next most difficult job aspect (for all drivers together), followed by dealing with unsupportive management in Eugene and Portland and dealing with traffic in Salem. Working split shifts, not having two days off in a row, and getting up for early shifts were also difficult job aspects for several drivers.

Effects of Long Hours

Most drivers agreed that driving sixty or more hours per week causes fatigue - both mental and physical. Drivers were equally split on whether driving over 60 hours in one week causes health problems. Of the drivers who had driven more than 40 hours in one week, 50% of the drivers indicated their longest driving week had caused them no health problems; the other 50% of the drivers claimed that driving long hours did cause health problems. Differences in the maximum number of hours driven did not account for the differing opinions; drivers who claimed no problems averaged 63 hours per week while drivers who claimed that health problems did result from long hours averaged 67.5
hours on their longest week. Some drivers may have been reluctant to admit fatigue problems because the extra hours make the driver's job very lucrative. Drivers who did express health concerns cited the problems of long hours as stress, weak vision, poor judgement, poor attitude and exhaustion. A few drivers commented that these conditions could result in safety hazards both for the driver and the public. Additional health problems that were cited as resulting from long hours were muscle spasms and back problems; several drivers also indicated that family time is cut short by long hours.

Driver Concerns about Passenger Safety

Drivers in all cities cited the major concern for passenger safety as passengers standing up while the bus was in motion. Several drivers mentioned that passengers who get out of their seats before the bus comes to a complete halt could be thrown forward and injured should the driver have to make a sudden stop. Passengers who cross the street in front of traffic, or run out into traffic when trying to catch a bus, are the next major passenger safety concern. Boarding and exiting problems with slippery steps, loose handrails or steps that are too steep are the third major concern - especially for elderly and handicapped passengers. Slippery floors and unsupervised children concerned some drivers and assault was a major concern of Portland drivers.

Driver Wish lists

The final question on the driver survey gave drivers the opportunity to bring up any potential hazards, problems, or suggestions concerning the bus or operational procedures. As expected, the responses were broad and varied. The one wish that was mentioned several times, and was common to all companies, was a request for better driver seats. Reducing glare on the windshields was a wish common to Eugene and Salem drivers, and more consistent scheduling was a wish common to Portland and Salem drivers. Eliminating split shifts
and improving management relations were wishes common to Portland and Eugene drivers.

Other than the above mentioned common wishes, each transit company seemed to have their own unique equipment elements and operational procedures that drivers would like to change. Salem drivers focused on work schedules with several drivers (21%) wishing for a schedule of four ten-hour days, and low seniority drivers wishing for two days off in a row. Many Salem drivers (17%) would like to have designated stops instead of the pick-up-anyone-who's-waiting policy of the present, and another 17% of the drivers wished that the bus routes would be rerouted to insure safe routes (e.g. eliminate the current hazards of making left turns across heavy traffic). All Cherriots buses currently return to a central location between each run - some drivers wished to eliminate this end-of-the-line island in the central city area because they felt that it was unsafe due to the high congestion of people and vehicles and pedestrian "horseplay" occurring on the island. Other wishes common to more than one driver included better placement of mirrors within the bus (so drivers could see the whole bus), air conditioning for the buses, buses being dispatched according to schedule (instead of waiting for late buses with potential transfers) and the development of a policy book which would support the driver's position when there was a conflict with passengers.

The most frequent wish of Eugene drivers (32%) was that schedules would be loosened. After that, several drivers wished for eliminating split shifts, reducing the noise level on the bus (by not requiring the radio to be left on), and changing the policy that part-timers are penalized for absences (which encourages part-time drivers to drive when they are ill). To support the wish to eliminate split shifts, one driver pointed out that since most accidents occur within the first hour of driving, split shifts may double the potential for accidents.

The most frequent wish of Tri-Met drivers was a wish for better seats. This was followed closely by a wish for more support from management - especially in conflicts with passengers. Several drivers wished for more protection for operators (concern about assault), more layover time and breaks, and more reliable buses. Another general desire was that schedules would be changed to fit the routes (e.g.
routes with more traffic would be given more time), and fewer breakdowns would occur on the articulated buses. New buses, better maintenance of current buses and moving the wheelchair lifts to the front door were also wishes mentioned by several drivers. The most frequent wishes for each company are shown in Table 8.

Summary of Driver Surveys

The aim of interviewing almost one hundred transit bus drivers was to collect information on what drivers perceive to be the most hazardous parts of their job and to gather their suggestions for potential solutions to the problems. As expected from the talks with transit officials, the driver's seat was cited as the vehicle component causing most problems. Almost all of the back injuries of surveyed drivers were caused by problems with the driver's seat and close to half of all the drivers interviewed had some complaint about the driver's seat. The major problems cited included a lack of seat adjustments and poor maintenance of the seats. The most frequent suggestions for improving seats were redesigning seats to be more adjustable so they would comfortably fit all drivers, and spending more money to buy better seats.

Unexpectedly, considering transit officials comments, drivers did not note the steering wheel as a vehicle component causing major problems. While several drivers mentioned steering problems in the past and drivers frequently cited difficult steering as a reason for least preferring certain bus models, vehicle steering was not cited as a specific problem. Likewise, stress was not mentioned as a specific concern of drivers, but the concept was implied in other driver comments such as the frequent wishes to improve driver-management relations and major concerns about scheduling. Scheduling changes were the second most frequent wish of all drivers interviewed. While some drivers proposed loosening schedules to reduce scheduling pressure, most drivers suggested that schedules simply be refigured so that they are appropriate for the given route. The drivers surveys provided insight on the most hazardous problems perceived by drivers. This data was then used as a basis for comparison to the more quantitative
Table 8. Most Frequent Driver Wishes

<table>
<thead>
<tr>
<th>Tri-Met</th>
<th>Lane Transit</th>
<th>Cherriots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a) Vehicles</td>
</tr>
<tr>
<td>Better seats (26%)</td>
<td>Reduce window glare (10%)</td>
<td>Air conditioned buses (10%)</td>
</tr>
<tr>
<td>Better maintenance (9%)</td>
<td>Better seats (5%)</td>
<td>Better mirrors (to see whole bus) (7%)</td>
</tr>
<tr>
<td>Newer buses (7%)</td>
<td></td>
<td>Reduce windshield glare (especially at night) (7%)</td>
</tr>
<tr>
<td>Better visibility (7%)</td>
<td></td>
<td>Better seats (7%)</td>
</tr>
<tr>
<td>Heat on the buses (5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Schedules</td>
</tr>
<tr>
<td>More layover time and breaks (16%)</td>
<td>Loosen schedules (32%)</td>
<td>Change schedules to fit routes (10%)</td>
</tr>
<tr>
<td>Change schedules to fit routes (12%)</td>
<td></td>
<td>Dispatch according to schedule (don't hold for later buses) (7%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Policy</td>
</tr>
<tr>
<td>Eliminate split shifts (5%)</td>
<td>Eliminate split shifts (10%)</td>
<td>Four 10-hour days (21%)</td>
</tr>
<tr>
<td></td>
<td>Don't penalize part-timers for absence (10%)</td>
<td>Two days off in a row (17%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) Other</td>
</tr>
<tr>
<td>More supportive management (23%)</td>
<td>Reduce noise level on bus (10%)</td>
<td>Designated stops (17%)</td>
</tr>
<tr>
<td>More protection for operators (assault) (12%)</td>
<td>Improve management relations (5%)</td>
<td>Safer bus routes (14%)</td>
</tr>
<tr>
<td>Eliminate no-pay zone downtown (7%)</td>
<td></td>
<td>Eliminate end-of-line island (7%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Policy book to improve driver/passenger relations (7%)</td>
</tr>
</tbody>
</table>
information collected from the workers' compensation files on bus
driver injuries and accidents.

B. ACCIDENT DATA - WORKERS' COMPENSATION FILES

The Oregon Workers' Compensation Department (WCD) has as its goal
the provision of "...safe and healthful working conditions for every
working man and woman in Oregon." To assist in the accomplishment of
this goal, the department has developed a safety and health program;
one of the functions of this program is "...to describe accurately the
nature of Oregon's work-related injury and illness experience."
Beginning in 1971, the Oregon Workers Compensation Department has
maintained extensive files of all workers' compensation claims filed
in Oregon (Oregon Work Injuries and Illnesses, 1985).

The injury data collection process starts with the employer's
First Report of Injury form (WCD Form 801). This form is filled out by
the employer soon after the employee reports the accident. It contains
a brief description of the accident along with other information on the
employee and the injury. Information taken from WCD Form 801 is coded
according to the Federal Supplementary Data System (SDS) Program
according to the type, source and nature of the injury, and the part
of the body affected. SDS is an information record system which
supplements general information on incidence rates and establishment
size by providing data on the specific characteristics of each work
related injury. (A similar record system is used by 24 other states
which may enable the techniques developed in the current research to be
applied to other states as well.) Much of the information from the 801
form is entered into an extensive computer database. This data base
contains pertinent information about each claim including the name,
age and sex of the employee; the date of the incident; and whether the
incident occurred on company premises. It also includes the WCD file
number which can be used to locate specific files at the WCD in Salem.
The cost of the claim is included in three categories - permanent
partial disability costs, total temporary disability costs, and
medical costs. The total number of days lost from work and whether the
claim was accepted or denied is also included.
The SDS coded data contains information on the specific characteristics of each incident providing a brief description of each incident. The type of injury identifies the event or situation which directly resulted in the injury; overexertion, falls, and "struck by" are examples of incident types. The nature identifies the principle characteristics of an injury (examples of incident natures are bruise, sprain, or fracture), and the source refers to the object or exposure which directly produced the injury - such as boxes, machines or vehicles. The body part affected by the injury is also included. An example of the content and format of the output from the WCD database is given in Table 9 and a list of variables is given in Table 10.

An interpretation of the first claim listed in Table 9 indicates that a 45 year old female bus driver fractured her fingers by pinning them on the bus she was driving. The incident occurred on transit property (the bus) and information concerning the incident can be found in WCD file 102-3040. The driver lost one day from work as a result of the injury and incurred $81.65 in medical costs. The claims board accepted the claim and awarded a total of $178.33 for the injury.

The WCD files were employed in two different ways. First, several summary tables were generated, which provided an overall picture of the most frequently occurring transit driver incidents, along with the most frequently occurring characteristics related to the injuries. Secondly, the most frequent types of accidents were looked at in much greater detail by examining numerous WCD files. The physical files of all WCD claims are maintained by the Workers' Compensation Department in the Labor and Industries building in Salem, Oregon. Each WCD file contains detailed information concerning the injury; the Employer's First Report of Injury form (WCD form 801), medical reports and records, WCD correspondence and other pertinent information is kept in the files. Direct examination of these physical files provided more details on the specific causes and characteristics of bus driver injuries and accidents.

The WCD has the computer capabilities to organize the information from the data base into tables comparing two to four variables. These summary tables show the number of injuries with the various characteristics - for example a table of body parts versus type of injury.
Table 9. Example of Summary Information Available from Oregon Workers’ Compensation Department

<table>
<thead>
<tr>
<th>Report</th>
<th>Employer</th>
<th>Location</th>
<th>SIC</th>
<th>Occupation</th>
<th>Source</th>
<th>Accident Type</th>
<th>Claim Status</th>
<th>Award Type</th>
<th>Part(s)</th>
<th>TD Days</th>
<th>Medical Cost</th>
<th>TTD Cost</th>
<th>TTD Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/04/80</td>
<td>Hull Virginia M</td>
<td>TRI-COUNTY METROPOLITAN</td>
<td>4111</td>
<td>Bus Driver</td>
<td>VeH. at Rest</td>
<td>Pinned by claims</td>
<td>Accepted</td>
<td>TTD</td>
<td>Fracture</td>
<td>1</td>
<td>0.00</td>
<td>96.68</td>
<td>1</td>
</tr>
<tr>
<td>3/04/80</td>
<td>Candelaria Carmen L</td>
<td>TRI-COUNTY METROPOLITAN</td>
<td>4111</td>
<td>Janitor</td>
<td>Bodily Motion</td>
<td>Free</td>
<td>Accepted</td>
<td>TTD</td>
<td>Sprain/Strain</td>
<td>1</td>
<td>1,920.00</td>
<td>8,248.03</td>
<td>154</td>
</tr>
<tr>
<td>3/24/80</td>
<td>Garcia Cecilee A</td>
<td>TRI-COUNTY METROPOLITAN</td>
<td>4111</td>
<td>Bus Driver</td>
<td>Bus</td>
<td>Accident</td>
<td>Accepted</td>
<td>TTD</td>
<td>Sprain/Strain</td>
<td>1</td>
<td>4,862.26</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>3/24/80</td>
<td>Donald Elfie L</td>
<td>TRI-COUNTY METROPOLITAN</td>
<td>4111</td>
<td>Vehicle Washer</td>
<td>Floor</td>
<td>Fall on Premises</td>
<td>Accepted</td>
<td>TTD</td>
<td>Bruise</td>
<td>1</td>
<td>0.00</td>
<td>359.15</td>
<td>77</td>
</tr>
</tbody>
</table>

* Non-driver accidents were excluded from summary statistics presented elsewhere.
Table 10. Partial List of Variables in Workers Compensation Database

a) the employee's name  
b) the employee's age  
c) the employee's sex  
d) the employee's occupation  
e) an indication of whether or not the accident occurred on the premises of the employer  
f) the WCD file number indicating the file location of complete information concerning the incident  
g) the type of incident  
h) the source of the injury  
i) the nature of the injury  
j) the part or parts of the body affected by the injury  
k) an indication of whether the claim associated with the incident was accepted or denied  
l) the current status of the claim  
m) the type of claim award  
n) the amount of money to compensate the employee for permanent partial disabilities  
o) the amount of money to compensate the employee for total temporary disability  
p) the amount of money to compensate the employee for medical expenses  
q) the number of days of work affected by the incident
will indicated the number of back injuries that have occurred as the result of a fall. Tables including only bus drivers instead of all occupations were generated for the current research; the specific variables requested for each table to be generated are listed below:

1. body Part vs. injury Type
2. driver Age vs. injury Type vs. driver Sex
3. driver Age vs. injury Nature vs. driver Sex
4. body Part vs. injury Nature vs. driver Age
5. injury Source vs. injury Type
6. injury Source vs. injury Nature

These tables were used to identify the characteristics of the most frequently occurring incidents; later, specific incident groups were identified and examined in greater detail with the WCD files.

The initial tables received from the Worker's Compensation Department presented a picture of all Oregon bus drivers, including school bus and intercity drivers and including all cities. Later, the same tables were generated for the specific cities of Portland, Salem, and Eugene. This data was based on the transit companies and therefore included only transit bus drivers. The summary tables were used to develop an overall picture of bus driver injuries and point out the major concerns related to the occupation. The most frequently occurring types of accidents were then examined in detail by looking at the physical WCD files in Salem. The data involving all drivers also provided a basis for comparison to point out and highlight the specific concerns of transit bus drivers and to illustrate how transit bus driving concerns may differ from concerns of all bus drivers in general.

Comparison of Transit Companies

During the five year study period, (1982 through 1986), a total of 938 Workers' Compensation claims were accepted and paid for transit drivers in the state of Oregon. Tri-Met, the largest transit company under study, accounted for 92% of all transit driver claims; LTD and Cherriots each accounted for 4%. Transit drivers in the three companies under study accounted for almost 60% of all bus driver claims.
in the state. Yearly claims for each transit company are given in Table 11.

The general trend in the number of claims per year differed from one company to another. LTD claims followed a decreasing trend that Gary Deverell (Lane Transit Safety and Risk Manager) attributed to a recent change in the driver selection procedure. Cherriots claims followed an increasing trend and Tri-Met exhibited a relatively consistent number of claims each year with the exception of 1984 when yearly claims almost doubled. According to Tri-Met officials, the abrupt increase in 1984 claims may be explained in part by the contract negotiation occurring during the same year. Oregon bus driver (not including the three transit companies being studied) exhibited a slowly increasing trend of WCD claims per year. Due to the small number of yearly claims involving Lane Transit and Cherriot drivers, Tri-Met data was used in the table breakdowns for comparisons of all drivers to transit drivers.

Accident Type versus Body Part

The first summary table generated by the WCD was used to identify the most frequently occurring types of accidents. As mentioned earlier, the accident type classification identifies the situation or event which directly produced the injury or illness. Ninety specific types of accidents are included in the SDS program; these were combined into several descriptive categories, and the categories were included in the tables involving the type classification. The remaining accident types were grouped together under the "all others" category.

The data involving all bus drivers in Oregon indicated that overexertion accidents occur most frequently followed by non-collision accidents, bodily reaction accidents, falls, and "struck by or against" type accidents. All other incident types involved less than 7% of the driver WCD claims. Data involving only transit drivers indicated that non-collision accidents occurred most frequently followed by bodily reaction incidents, "struck by or against" type incidents, overexertion and falls. Non-collision and bodily reaction type incidents were consistently the most frequently occurring categories and overexertion
Table 11. WCD Claims per Year by Transit Company.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cherriots</th>
<th>Lane Transit District</th>
<th>Tri-Met</th>
<th>Total Transit Bus Drivers</th>
<th>Other* Drivers</th>
<th>All Bus Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>2</td>
<td>8</td>
<td>166</td>
<td>176</td>
<td>129</td>
<td>305</td>
</tr>
<tr>
<td>1983</td>
<td>7</td>
<td>13</td>
<td>155</td>
<td>175</td>
<td>119</td>
<td>294</td>
</tr>
<tr>
<td>1984</td>
<td>4</td>
<td>6</td>
<td>250</td>
<td>260</td>
<td>124</td>
<td>384</td>
</tr>
<tr>
<td>1985</td>
<td>11</td>
<td>8</td>
<td>157</td>
<td>176</td>
<td>146</td>
<td>322</td>
</tr>
<tr>
<td>1986</td>
<td>11</td>
<td>4</td>
<td>136</td>
<td>151</td>
<td>156</td>
<td>307</td>
</tr>
<tr>
<td>Totals</td>
<td>35</td>
<td>39</td>
<td>864</td>
<td>938</td>
<td>674</td>
<td>1,612</td>
</tr>
</tbody>
</table>

*Includes school bus drivers, intercity bus drivers
was also a frequently occurring category for all three transit companies. "Struck by or against" type incidents and falls occurred frequently at Tri-Met, but did not occur frequently at either of the smaller companies. This may suggest some differing problems for larger versus smaller transit companies. Incident type percentages for each transit company are shown in Table 12.

The most frequently occurring types of accidents were studied in greater detail by identifying the specific parts of the body that were most frequently injured. The back and shoulder were frequently injured in all types of accidents for both transit drivers and all drivers, and multiple parts was another frequently occurring part category. (An injury is classified as involving multiple parts when more than one major body part has been affected such as an arm and a leg. This classification indicates the severity of the injury rather than providing information on the specific part of the body that is most frequently injured.) Other parts of the body that were injured frequently in specific types of accidents include the neck, ankle, and knees. A breakdown of the major types of accidents and the most frequently injured parts of the body for each type of accident is shown in Table 13. Tables 14 and 15 show a summary of the major accident types with the corresponding percentages of body parts injured for all drivers and transit drivers respectively.

Nature versus Part versus Age versus Sex

Another summary table generated by the WCD identified the most frequently occurring incident "natures". (The "nature" classification identifies the principle characteristics of an injury.) The major nature of injuries for WCD claims in all occupations has consistently been sprains and strains and bus driving is no exception. Sixty seven percent of all work related injuries for Oregon bus drivers suffered some sort of sprain or strain. In the sub-category of transit drivers, results were almost identical with 67% of Tri-Met drivers and 69% of Salem and Eugene drivers suffering sprains or strains. Bruises were the next most frequent nature category accounting for merely 10% of the
### Table 12. Major Types of Accidents by Transit Company

<table>
<thead>
<tr>
<th>Type</th>
<th>Tri-Met</th>
<th>Lane Transit</th>
<th>Cherriots</th>
<th>All* Bus Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncollision Accident</td>
<td>25%</td>
<td>21%</td>
<td>23%</td>
<td>17%</td>
</tr>
<tr>
<td>Bodily Reaction</td>
<td>15%</td>
<td>28%</td>
<td>17%</td>
<td>16%</td>
</tr>
<tr>
<td>Struck By or Against</td>
<td>15%</td>
<td></td>
<td></td>
<td>11%</td>
</tr>
<tr>
<td>Overexertion</td>
<td>14%</td>
<td>13%</td>
<td>23%</td>
<td>22%</td>
</tr>
<tr>
<td>Falls</td>
<td>11%</td>
<td></td>
<td></td>
<td>14%</td>
</tr>
<tr>
<td>Both Vehicles Moving</td>
<td>8%</td>
<td>15%</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Standing Vehicle or Object</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Includes school bus drivers and intercity bus drivers*
Table 13. Most Frequent Claim Types by Most Frequent Body Parts Injured

<table>
<thead>
<tr>
<th>Incident Type</th>
<th>Tri-Met</th>
<th>All Bus Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overexertion Incidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>24%</td>
<td>39%</td>
</tr>
<tr>
<td>Shoulder</td>
<td>25%</td>
<td>15%</td>
</tr>
<tr>
<td>Multiple Parts</td>
<td>36%</td>
<td>14%</td>
</tr>
<tr>
<td>Noncollision Accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>37%</td>
<td>35%</td>
</tr>
<tr>
<td>Multiple Parts</td>
<td>19%</td>
<td>20%</td>
</tr>
<tr>
<td>Shoulder</td>
<td>16%</td>
<td>15%</td>
</tr>
<tr>
<td>Neck</td>
<td>8%</td>
<td>7%</td>
</tr>
<tr>
<td>Bodily Reaction Incidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>26%</td>
<td>25%</td>
</tr>
<tr>
<td>Ankle</td>
<td>14%</td>
<td>17%</td>
</tr>
<tr>
<td>Multiple Parts</td>
<td>16%</td>
<td>10%</td>
</tr>
<tr>
<td>Shoulder</td>
<td>11%</td>
<td>9%</td>
</tr>
<tr>
<td>Knee</td>
<td>9%</td>
<td></td>
</tr>
</tbody>
</table>

Note: Body parts not listed are injured in less than 5% of all incidents.
Table 14. Percentage of Incidents Affecting Each Body Part for Major Incident Types - All Bus Drivers*

<table>
<thead>
<tr>
<th>Type of Incident</th>
<th>Relative % of Incident Types</th>
<th>Back</th>
<th>Shoulder</th>
<th>Multiple Parts</th>
<th>Neck</th>
<th>Ankle</th>
<th>Knee</th>
<th>Head</th>
<th>Hand</th>
<th>Wrist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncollision</td>
<td>17</td>
<td>35</td>
<td>15</td>
<td>20</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bodily Reaction</td>
<td>16</td>
<td>25</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Struck By or Against</td>
<td>11</td>
<td></td>
<td></td>
<td>17</td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overexertion</td>
<td>22</td>
<td>39</td>
<td>15</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Falls</td>
<td>14</td>
<td>23</td>
<td></td>
<td>19</td>
<td></td>
<td>15</td>
<td>10</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both Vehicles Moving</td>
<td>7</td>
<td>12</td>
<td>60</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Injured for All Incident Types Combined</td>
<td>25</td>
<td>9</td>
<td>21</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

*Includes school bus drivers and intercity drivers
Table 15. Percentage of Incidents Affecting Each Body Part for Major Incident Types - Transit Bus Drivers

<table>
<thead>
<tr>
<th>Type of Incident</th>
<th>Relative % of Incident Types</th>
<th>Back</th>
<th>Shoulder</th>
<th>Multiple Parts</th>
<th>Neck</th>
<th>Ankle</th>
<th>Knee</th>
<th>Head</th>
<th>Hand</th>
<th>Wrist</th>
<th>Finger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncollision</td>
<td>24</td>
<td>36</td>
<td>15</td>
<td>19</td>
<td>8</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Bodily Reaction</td>
<td>16</td>
<td>26</td>
<td>12</td>
<td>15</td>
<td>9</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Struck By or Against</td>
<td>14</td>
<td>23</td>
<td></td>
<td>18</td>
<td>17</td>
<td>7</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overexertion</td>
<td>14</td>
<td>25</td>
<td>24</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Falls</td>
<td>11</td>
<td>22</td>
<td></td>
<td>18</td>
<td>11</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both Vehicles Moving</td>
<td>9</td>
<td>13</td>
<td></td>
<td>60</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Injured for All Incident</td>
<td>23</td>
<td>11</td>
<td>24</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Types Combined</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
transit driver injuries. Table 16 shows the breakdown of strain and sprain nature injuries according to body part and driver sex.

Non-collision Accidents

As shown in Table 12, non-collision accidents were the most frequently occurring incidents for transit drivers and the body parts that were most frequently injured were back, shoulder and multiple parts. Specific incidents with these characteristics (non-collision accidents affecting back, shoulder or multiple parts) were identified using the summary information computer printout of WCD claims (shown in Table 9) and the specific files were examined in detail at the Workers Compensation Department in Salem.

Non-collision accidents include injuries caused by the motions of the vehicle, but not resulting from a two vehicle collision. Injuries resulting from bodily motion during sudden starts or stops, falling objects or falls from a vehicle (caused by vehicle motion) are all classified as non-collision type incidents. Bodily conditions incurred by vehicle movement, such as a shoulder injury resulting from the jerk of a steering wheel when a vehicle hits a hole, are also classified as non-collision accidents.

Nineteen non-collision accidents were studied in detail with the WCD files. The claims were chosen randomly from the WCD computer printout and contained a wide spectrum of driver characteristics. The sample included 15 men and 4 women; ages ranged from 25 to 58 years; claim amounts ranged from $133 to $16,810. All of the claims were made by Tri-Met drivers in 1986 or 1987. Bus makes were identified in 74% of the incidents revealing that seven 1976 AMG buses, four 1974 FLX buses, and two 1981 Crown/Ikarus (C/I) articulated buses were being driven when the incidents occurred. These statistics are more striking with the realization that only 18% of the 534 Tri-Met buses are 1976 AMGs, 14% are 1974 FLXs and 16% of the fleet are 1981 C/Is.

Forty two percent of the non-collision accidents involved some problem with the driver's seat and another 42% were related to vehicle steering. The remaining 16% were not specifically related to the drivers' seat or steering problems, but resulted from a jar to the
Table 16. Breakdown of Incident Natures by Body Part.*

<table>
<thead>
<tr>
<th>Nature of Incident</th>
<th>Relative % of Incident Natures</th>
<th>Multiple Parts</th>
<th>Shoulder</th>
<th>Neck</th>
<th>Ankle</th>
<th>Knee</th>
<th>Head</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative % of Incident Natures</td>
<td>Back M F</td>
<td>M F</td>
<td>M F</td>
<td>M F</td>
<td>M F</td>
<td>M F</td>
</tr>
<tr>
<td>All Drivers</td>
<td></td>
<td>67 219 138</td>
<td>115 111</td>
<td>60 51</td>
<td>40 37</td>
<td>27 50</td>
<td>**</td>
</tr>
<tr>
<td>Sprain</td>
<td></td>
<td>33 21</td>
<td>10 7</td>
<td>7</td>
<td>7</td>
<td>67 136</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>18</td>
<td>12</td>
<td>8</td>
<td>9</td>
<td>12 6</td>
<td>12</td>
</tr>
<tr>
<td>Bruise</td>
<td></td>
<td>8 21</td>
<td>10 9</td>
<td>9</td>
<td>14 10</td>
<td>15 11</td>
<td>6</td>
</tr>
<tr>
<td>Transit Drivers</td>
<td></td>
<td>66 136 55</td>
<td>91 51</td>
<td>27 34</td>
<td>14 10</td>
<td>11 9</td>
<td>12</td>
</tr>
<tr>
<td>Sprain</td>
<td></td>
<td>30 23</td>
<td>12 9</td>
<td>4</td>
<td>3</td>
<td>66 136</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>18 23</td>
<td>8</td>
<td>4</td>
<td>13 4</td>
<td>7 2</td>
<td>12</td>
</tr>
<tr>
<td>Bruise</td>
<td></td>
<td>9 21</td>
<td>28</td>
<td>14 10</td>
<td>14 9</td>
<td>5 8</td>
<td>**</td>
</tr>
</tbody>
</table>

*Upper Cells - % of incidents affecting specified body part
Lower Cells - number of men and women injured
**Cells are empty for percentages of less than 3%
driver caused by rough roads, the force of the road being transferred to the driver via the seat or controls.

All of the seat related incidents were strikingly similar. Each one occurred when the driver hit some rough spot in the road, the bus was jolted, and the seat gave way - suddenly dropping to its lowest position (an occurrence known as "bottoming out" among drivers). The body build of the drivers ranged from an "obese woman" to a "slight man" (physician's descriptions in the WCD files) with five of the drivers being considerably overweight (two unknown). The incidents involved six men and two women and occurred on four different bus models. The majority of incidents occurred on 1976 AMG buses, two occurred on C/I articulated buses and one claim involved a 1974 FLX. Three fourths of the injuries involved a sprain or bruise to the back of the driver.

Some of the driver's comments concerning the claims were of special interest. One driver reported that he "has bottomed out a lot of the time without hurting" indicating that the event may be a fairly common experience and that it does not always result in an injury. Another driver indicated that, in his experience as a charter bus driver, driver seats were more comfortable and did not frequently cause injury to the driver. He stated that the more expensive charter seats were of much higher quality than current transit driver seats and that cutting costs on seats was the source of drivers seat problems. One fact that this driver may not have considered relating to charter driver seats is that charter drivers do not usually change buses as frequently as transit drivers, enabling charter drivers to adjust the seat to their body build and leave it that way. Charter drivers may also do more "open road" driving and experience less "stop and go" situations.

Another 42% of the non-collision accidents were related to steering the bus. All of these incidents involved male Tri-Met drivers and occurred in 1986 or 1987. Three of the incidents involved 1974 FLX buses, two occurred on 1976 AMG buses (1000 series), one on an articulated bus, and two on buses of an unknown model. These steering related incidents could be attributed to several different situations. Several of the incidents took place when the driver "took severe
evasive action" (driver's words) to avoid a collision. The bus hitting a hole and jerking the wheel was responsible for another two injuries. One back injury, involving a driver with previous back problems, had no specific cause, but occurred while the driver was making a right turn. Finally, in two cases, the steering wheel "froze" or stuck, in one case causing a serious accident involving other vehicles, and in another case causing a severe wrenching of the driver's arm and shoulder. Four of the incidents involved shoulder injuries; the others involved multiple parts, neck or back.

The remaining non-collision accidents involved the bus hitting a bump or chuck hole and an injury resulting to the back or shoulder of the driver. Two of these three drivers were men; the bus models were unavailable in the WCD files. In summary, fully 58% of the non-collision accidents resulted from the bus going over some bump in the road and the steering wheel or seat, being unable to withstand the force of the jolt, jerking or giving way - resulting in an injury to the driver.

Bodily Reaction Accidents

The next most frequently occurring type of transit driver injury was the bodily reaction type injury. Fifteen percent of transit drivers and 16% of all drivers suffered this type of incident. The bodily reaction type category applies to, "...non-impact cases in which the injury resulted solely from a free bodily motion which imposed stress or strain upon some part of the body." (WCD Code definitions of incident types). The bodily reaction category includes the sub-category of free bodily motion which applies to internal injuries resulting from involuntary motion or unnatural body positions due to efforts to recover from lost balance or slips, fright, or sudden noise. It also includes muscular or internal injuries resulting from reaching, turning or bending when the motion resulted in the injury. The bodily reaction category also includes a misstepping sub-category which involves injuries due to unsure footing on a cluttered, uneven or clear surface.
Of the 26 WCD bodily reaction files examined, 18 involved free bodily motion, six involved misstepping and two were attributed to bodily reaction type incidents in general. Driver ages ranged from 23 to 59 and claim costs ranged from $229 to $16,689. The files included twenty men and six women drivers and the incidents occurred in 1986 or 1987. Several bus models were represented in the injuries, but the 1974 FLX bus was by far the most frequently appearing bus model, being responsible for almost half of the injuries where the bus model was known. 1972 and 1973 FLX buses were being driven during three of the incidents, 1982 General Motors (GM) buses were driven during two incidents and a 1980 GMC accounted for one incident.

Bodily reaction type incidents occurred in a wide variety of situations. The most frequent situation involved the driver simply experiencing pain in some part of his/her body while he/she was driving without a directly apparent cause. The WCD file reports indicated that several of the drivers had been driving 13-16 hours per day for several days; some of these drivers suggested prolonged sitting might be partially responsible for the injury. Some drivers had experienced previous injuries which may also have contributed to the injury. Other drivers specifically pointed to the 1974 FLX bus and claimed that the difficult steering on 1974 FLX buses was largely responsible for the injury. (As mentioned earlier, the 1974 FLX buses are currently being retrofitted with "air power assist" steering.)

The next most frequent situation involved the driver slipping or tripping while walking to, from, or around their bus. These incidents seemed to occur at all times during a driver’s shift - before the shift began, at a break, and after the shift was completed. Problems with the seat caused three of the bodily reaction injuries. Two of these incidents involved the driver’s seat coming loose and rocking or bouncing through the remainder of the route causing back strain. The third incident was similar to the non-collision seat injuries; it involved the drivers seat bottoming out after a bump - causing a serious back injury.

The remaining bodily reaction incidents covered a wide range of situations and circumstances. Two injuries involved drivers bending over from their seats to pick up transfers from the floor and straining
their back. (This type of injury might be avoided by a properly placed transfer holder in convenient reach of the driver.) Two more incidents involved two drivers slipping on the top step of their bus while trying to adjust the mirror or get off the bus. Similar to the non-collision turning incidents, two drivers injured their back and shoulder as a result of making sharp turns (one on a 1974 FLX bus, the other bus model unknown) and one driver jerked her neck and back in a quick turn to avoid a car. The remaining drivers experiencing bodily reaction injuries were injured by several additional causes; one driver injured her back in stepping over the console to deboard the bus, another driver straightened up after checking the fare box and injured his back, and another injured her back after turning suddenly in her seat.

Overexertion Incidents

Overexertion type incidents were the most frequently occurring injury type for all bus drivers; they also accounted for 14% of transit bus driver injuries. Overexertion injuries occur in non-impact situations where an injury results from extreme physical effort, as in lifting, pulling, pushing, wielding or throwing the source of the injury (WCD Code definitions of accident types). Of the 26 overexertion files examined, four involved pushing or pulling, five involved wielding (handling the bus) and one involved lifting. The remaining 17 incidents were in the general overexertion category. Fifty percent of the overexertion incidents involved women. This is a higher percentage of women than the previously studied type categories where usually 35% of the incidents involved women. Driver ages ranged from 26 to 53 and claim amounts ranged from $369 to $14,282. All incidents occurred in 1986 or 1987 and all drivers worked for Tri-Met.

Over half (57%) of the overexertion incidents involved turning or steering a bus. Forty percent of the turning injuries involved women and 60% involved men (proportions slightly higher than the overall men versus women injury rates for 1986). The situations surrounding the turning injuries ranged from wrenching the wheel to avoid a collision to simply turning the bus. Almost half of the drivers reported that the hard steering of the bus they were driving precipitated the injury
- all of these injuries occurred on 1974 FLX buses. Considering all overexertion injuries, over half occurred on 1974 FLX buses and several drivers pointed to the difficult steering on 1974 FLXs as the cause of their injury. Other bus models that were represented in the turning injuries included 1976 AMG buses and 1972 FLX buses; bus models could not be identified in four of the turning injuries.

Several drivers were injured when making sharp turns and some drivers indicated that turning in a narrow space resulted in the injury. Other drivers commented that buses that were already difficult to steer became even more difficult after they were loaded and this precipitated the injury. One driver had difficulty in adjusting the seat and reported that turning the bus caused an injury because the seat was not at the proper height. Another injury occurred when the bus hit a curb causing the steering wheel to jerk the driver's shoulders and upper body.

The remainder of the overexertion incidents had a wide variety of causes. Two injuries resulted from trying to adjust a mirror and slipping on the steps, or straining a shoulder against a mirror that would not move. One injury resulted from pulling on the handbrake and another from adjusting the vertical height of the seat. One injury was the outcome of slipping on the pavement on the way to the bus, and another occurred after a driver bent over to move a trash can. Two injuries were related to passengers; one driver was injured in trying to break up a fight on board the bus and another was injured when she threw out her arm to keep a passenger from falling after a sudden stop. Finally, one injury was related to a malfunctioning wheelchair lift and occurred when the driver and another passenger lifted the wheelchair over the four inch barrier of the lift that would not retract properly.

In summary, the majority of the overexertion accidents were related to steering problems with the majority of steering problems occurring on 1974 FLX buses. Women drivers were more highly represented in this type of incident than in the other types of incidents. The higher proportion of women injured in overexertion incidents may be due to the typically smaller stature of women combined with the
unusually large forces required to turn certain buses - especially loaded buses without power steering.

Multiple Claims

A detailed look at specific WCD files in Salem also answered questions concerning the number of claims made by one driver. A statistical software package helped to organize claims over the seven year study period by driver initials. Calculations of the number of claims per driver during the period pointed out some surprising results.

Out of the 1250 transit drivers claims examined, only 31% of those claims were one-time driver claims, 45% were made by driver with two to four claims apiece, and 24% were made by drivers who initiated 5-12 claims apiece during the seven year period. In terms of drivers, these figures indicated that 20% of the drivers making WCD claims have initiated three or more claims each, while 19% have initiated two claims apiece and 58% have initiated one claim in the seven years.

Another way of looking at this data is that 40% of the drivers making WCD claims during the period accounted for almost 70% of the claims. Breaking this down further revealed that 5% of the drivers (with seven or more claims each) accounted for 16% of all driver claims. Table 17 shows the breakdown of multiple claims per driver with cumulative percentages of claims and drivers.

These results are more striking in light of the number of drivers who did not initiate any claims during the study period. For example, in 1986, Tri-Met and Cherriots together employed a total of 910 drivers. A total of 147 workers compensation claims involving bus drivers were accepted during the year. Only 48 of those claims (33%) were first time driver claims, the remaining two thirds were made by drivers who had made one or more previous claims. Over the entire period, a total of 654 drivers were injured with an average of two claims apiece while over 300 drivers made no injury claims at all.

The questions raised concerning the multiple claims per driver centered around the associations involved between two or more claims made by one driver. Were the claims independent or were they related
### Table 17. Breakdown of Multiple Claims per Driver

<table>
<thead>
<tr>
<th>Claims/Driver</th>
<th>Number of Drivers</th>
<th>Total Claims</th>
<th>Cumulative Frequency of Claims</th>
<th>Cumulative Frequency of Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>384</td>
<td>384</td>
<td>31%</td>
<td>59%</td>
</tr>
<tr>
<td>2</td>
<td>126</td>
<td>252</td>
<td>51%</td>
<td>77%</td>
</tr>
<tr>
<td>3</td>
<td>69</td>
<td>207</td>
<td>68%</td>
<td>88%</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>104</td>
<td>76%</td>
<td>92%</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>95</td>
<td>84%</td>
<td>95%</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>108</td>
<td>93%</td>
<td>98%</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>35</td>
<td>96%</td>
<td>99%</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>24</td>
<td>97%</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>18</td>
<td>98%</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>11</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>12</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>654</td>
<td>1250</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
to each other? Are certain drivers more prone to accidents than other drivers? Are some drivers more willing to make claims for injuries than other drivers?

To answer these questions, sixteen drivers with three or more claims each were chosen randomly from the WCD computer printout and three to five specific WCD file numbers were identified for each driver. These files were located and examined more closely at the WCD in Salem.

Just under half of the drivers studied had several claims affecting the same body part. In these cases, usually two, of the three or four claims looked at, involved the same body part being affected in both claims. For instance one claim might involve a strained shoulder and another might involve neck and shoulder pain. Half of the claims affecting the same body part occurred consecutively; the other half had claims affecting different body parts in between the same body part claims. Even when the same body part was injured in consecutive claims, the cause of the injuries appeared to be unrelated.

For the majority of drivers, each different claim had a unique cause. Frequently, the various origins of the injuries seemed to be quite distinctly independent indicating that multiple claims for one driver are not necessarily related. Assuming that each claim is a unique case with a distinct origin, and considering that 23% of the transit drivers are making almost 50% of the WCD claims, the question arises as to whether certain drivers are more prone to injuries or whether some drivers are more willing to report claims.

The multiple claims data indicates that some drivers may feel quite free to report any and all minor injuries to the WCD. The specific files of several drivers with multiple claims indicated that many of the claims were disputed. Frequently, the claims were of a somewhat nebulous nature. For example, one driver claimed that a lack of support from the management caused anxiety - shaking, sweating and sleepless nights; another driver claimed mental stress due to a threat from a passenger. Several claims were attributed by the claimants to very general and broad causes such as simply driving the bus. One woman, making five claims in the seven year period, reported injury
causes ranging from "turning the bus" to getting a finger caught in a restroom stall door.

In summary, multiple claims for one driver do not appear to be directly related to one another. It does appear likely that certain drivers are more willing than other drivers to make WCD claims and that these drivers may make claims for somewhat nebulous or disputable causes. This information could provide a basis for further research concerning several claims made by one driver or it might be useful for better quantifying the problem of illegitimate claims. The realization that claims are being made for somewhat nebulous causes may point out some potential activities to reduce costs at the WCD.

C. CLAIM AMOUNT DATA

The WCD was also able to supply information concerning the dollar amount and total costs of the claims made by transit drivers in the three cities under study. Claim amount information was available for the four year period from 1983 through 1986. In analyzing the descriptive data from the summary tables, the acceptance date (the date the WCD agrees to pay the expenses of the injury) is used as a reference date for the claim. In working with claim amounts, the closing date of the claim (the day the injury is healed and will require no further expenses) is the reference point. There may be a considerable time lag between the time a claim is accepted and the time it is closed and, as a result, the number of claims attributed to each year may differ between the summary table data and the claim amount data. Claims may also be closed and then reopened and closed again, leading to a higher number of claims per year in the claim amount data.

The purpose of studying claim costs was twofold. First, using the dollar amounts as an indication of the magnitude of the problem, an analysis of claim amounts could assist in directing study towards the most pressing problems. Secondly, an investigation of claim amounts could point out unexpected problems or situations that were not identified by other measures. For instance, a study of driver ages and injury amounts pointed out that injuries to drivers over 61 years old cost more than injuries to drivers of all other ages. Unfortunately,
the small sample size of drivers over 61 made statistically significant results unobtainable. The average claim amounts for driver ages in ten year increments are shown in Table 18.

Injury type versus claim cost tables revealed that the average cost of the five most frequently occurring types of injuries varied greatly from year to year and that no specific accident type was consistently more costly than another. Table 19 displays the average claim costs for the five most frequently occurring types of accidents over the past four years. Due to the slightly different recording techniques, claim cost data was broken down into slightly different categories than the summary table data. The moving vehicle accident category includes non-collision accidents combined with three other accident categories. Table 19 also indicates an upward trend in claim costs over the past four years. The overall average claim amount has risen from $5,203 (1986 dollars using an inflation rate of 10%) in 1983 to $7,544 in 1986.

Average claim amounts, as related to body parts, also varied greatly from year to year and disclosed no unusual or unexpected results. The average claim amounts for the most frequently injured body parts are shown in the top half of Table 20. The bottom half of Table 20 shows the total costs associated with each body part as well as the number of injuries associated with each body part. This table indicates that back and multiple parts are the most costly body parts injured due to the number of injuries affecting these parts along with the high average cost.

As an indication of the magnitude of the driver injury problem, total claim costs are useful figures. Table 21 shows the total costs per year for all types of accidents. The moving vehicle accident category is considerably larger than the other categories because it combines several subcategories of accidents (non-collision, both vehicles moving, and "standing vehicle or object" incidents as well as "unspecified" highway motor vehicle accidents). The total cost for driver injuries drops off rapidly after the fall type incident indicating that the five most frequently occurring accidents account for the bulk (96% in 1986) of WCD claims costs. The types of accidents studied in detail in this research included three of the five major
Table 18. Claim Amounts by Driver's Age (Actual Dollars)

<table>
<thead>
<tr>
<th>Age</th>
<th>1983</th>
<th>1984</th>
<th>1985</th>
<th>1986</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-30</td>
<td>3,110*</td>
<td>3,243</td>
<td>6,831</td>
<td>7,516</td>
<td>5,175</td>
</tr>
<tr>
<td></td>
<td>37†</td>
<td>45</td>
<td>31</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>31-40</td>
<td>4,495</td>
<td>3,650</td>
<td>5,456</td>
<td>8,360</td>
<td>5,490</td>
</tr>
<tr>
<td></td>
<td>61</td>
<td>99</td>
<td>111</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>41-50</td>
<td>3,317</td>
<td>3,825</td>
<td>6,535</td>
<td>5,774</td>
<td>4,863</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>51-60</td>
<td>3,533</td>
<td>5,553</td>
<td>8,480</td>
<td>7,543</td>
<td>6,277</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>15</td>
<td>13</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>61+</td>
<td>16,172</td>
<td>10,600</td>
<td>9,599</td>
<td>21,224</td>
<td>14,399</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

*Average claim amount

†Number of injuries
Table 19. Average Claim Costs for the Most Frequent Accident Types

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th></th>
<th></th>
<th>Average Cost Over 4 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving Vehicle Accidents</td>
<td>3,973</td>
<td>5,150</td>
<td>8,299</td>
<td>9,302</td>
</tr>
<tr>
<td>Bodily Reaction Accidents</td>
<td>5,112</td>
<td>3,121</td>
<td>5,305</td>
<td>6,239</td>
</tr>
<tr>
<td>Struck by or Struck Against Accidents</td>
<td>4,354</td>
<td>3,010</td>
<td>1,918</td>
<td>5,095</td>
</tr>
<tr>
<td>Overexertion Accidents</td>
<td>2,679</td>
<td>3,067</td>
<td>3,909</td>
<td>8,197</td>
</tr>
<tr>
<td>Fall</td>
<td>2,438</td>
<td>2,178</td>
<td>8,399</td>
<td>4,931</td>
</tr>
</tbody>
</table>

Overall Average Cost Per Year

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Dollars</td>
<td>3,909</td>
<td>3,867</td>
<td>6,223</td>
<td>7,544</td>
</tr>
<tr>
<td>1986 Dollars*</td>
<td>5,203</td>
<td>4,679</td>
<td>6,845</td>
<td>7,544</td>
</tr>
</tbody>
</table>

*Using an inflation rate of i = 10

**± one standard deviation
Table 20. Average Claim Amounts for Most Frequently Injured Body Parts (Actual Dollars)

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1983</td>
<td>1984</td>
<td>1985</td>
<td>1986</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cost Over</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 Years</td>
</tr>
<tr>
<td>Back</td>
<td>4,142</td>
<td>4,493</td>
<td>7,668</td>
<td>8,674</td>
<td>6,2447</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>±2,267</td>
</tr>
<tr>
<td>Multiple Parts</td>
<td>5,027</td>
<td>5,500</td>
<td>7,195</td>
<td>9,564</td>
<td>6,822</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>±2,052</td>
</tr>
<tr>
<td>Shoulder</td>
<td>1,645</td>
<td>4,344</td>
<td>6,639</td>
<td>6,176</td>
<td>4,701</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>±2,266</td>
</tr>
<tr>
<td>Neck</td>
<td>3,293</td>
<td>2,137</td>
<td>9,862</td>
<td>6,455</td>
<td>5,437</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>±3,469</td>
</tr>
<tr>
<td>Knee</td>
<td>8,303</td>
<td>3,109</td>
<td>8,148</td>
<td>7,301</td>
<td>6,715</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>±2,444</td>
</tr>
<tr>
<td>Ankle</td>
<td>4,000</td>
<td>573</td>
<td>3,633</td>
<td>1,371</td>
<td>2,394</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>±1,681</td>
</tr>
</tbody>
</table>

Total Cost/Number

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Parts</td>
<td>145,775/29</td>
<td>280,493/51</td>
<td>453,291/63</td>
<td>612,114/64</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>173,970/42</td>
<td>273,858/55</td>
<td>383,381/50</td>
<td>477,071/55</td>
<td></td>
</tr>
<tr>
<td>Multiple Parts</td>
<td>145,775/29</td>
<td>280,493/51</td>
<td>453,291/636</td>
<td>12,114/64</td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td>26,318/16</td>
<td>125,984/29</td>
<td>159,347/24</td>
<td>142,043/23</td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>46,114/14</td>
<td>55,559/26</td>
<td>167,653/17</td>
<td>90,375/14</td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td>99,631/12</td>
<td>27,978/9</td>
<td>97,779/12</td>
<td>94,908/13</td>
<td></td>
</tr>
<tr>
<td>Ankle</td>
<td>16,002/4</td>
<td>6,303/11</td>
<td>32,695/9</td>
<td>6,854/5</td>
<td></td>
</tr>
<tr>
<td>Accident Type</td>
<td>1983</td>
<td>1984</td>
<td>1985</td>
<td>1986</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>Moving Vehicle Accidents</td>
<td>254,258</td>
<td>484,067</td>
<td>804,993</td>
<td>809,292</td>
<td></td>
</tr>
<tr>
<td>Bodily Reaction Accidents</td>
<td>132,913</td>
<td>109,228</td>
<td>159,136</td>
<td>224,618</td>
<td></td>
</tr>
<tr>
<td>Struck by or Struck Against Accidents</td>
<td>104,499</td>
<td>108,370</td>
<td>57,542</td>
<td>107,003</td>
<td></td>
</tr>
<tr>
<td>Overexertion Accidents</td>
<td>132,913</td>
<td>88,934</td>
<td>113,351</td>
<td>286,895</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>36,576</td>
<td>50,091</td>
<td>209,975</td>
<td>128,201</td>
<td></td>
</tr>
<tr>
<td>Rubbed or Abraded Accidents</td>
<td>2,486</td>
<td>23,401</td>
<td>10,839</td>
<td>26,844</td>
<td></td>
</tr>
<tr>
<td>Mental Stress</td>
<td>704</td>
<td>10,086</td>
<td>2,517</td>
<td>990</td>
<td></td>
</tr>
<tr>
<td>Caught in</td>
<td>23,618</td>
<td>389</td>
<td>117</td>
<td>20,551</td>
<td></td>
</tr>
<tr>
<td>All Others</td>
<td>7,765</td>
<td>3,205</td>
<td>35,398</td>
<td>17,524</td>
<td></td>
</tr>
</tbody>
</table>
claims categories: non-collision accidents (making up the major portion of "Moving Vehicle Accidents"), bodily reaction accidents and overexertion accidents. Brief reviews of workers' compensation files disclosed that the other two major types of accidents were outside the scope of this research. "Struck by or against" type accidents were frequently the result of assaults, and were not directly related to vehicle design problems. Falls typically occurred outside of the drivers cab and immediate work space and were therefore not specifically related to cab design problems.

D. DEMOGRAPHIC DATA

In order to comprehensively evaluate the origin and cause of driver injuries, demographic data on the transit drivers was collected and considered. Each transit company was requested to provide a listing of driver ages and driver sex proportions for each year during the study period (1980-1986). These figures were compared to injured driver figures to determine if a correlation exists between the likelihood of injuries and driver age or driver sex. Only current (1987) information on driver age and sex proportions was available from Lane Transit District. As a result, the multiple year computations in the following summary are based upon Tri-Met and Cherriots transit systems alone.

Driver Sex and Injury Probability

As Table 22 shows, the current proportion of men to women is slightly higher at Tri-Met than at the smaller transit companies. The overall percentages, for all three companies combined, are roughly 78% men to 22% women. According to Tri-Met and Cherriots data, the proportion of women has gradually increased over the past seven years from 15% to 20% in Salem and from 19% to 23% in Portland. Women seem more likely to be part-time operators than men. Currently 33% of women drivers are working part time while only 10% of men drivers are part-time operators. These proportions may partially reflect the recent employment of women drivers since newly hired drivers have lower
Table 22. Percentages of Men vs. Women Transit Drivers in 1987

<table>
<thead>
<tr>
<th>Company</th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Number</td>
<td>%</td>
</tr>
<tr>
<td>Tri-Met</td>
<td>731</td>
<td>77</td>
<td>210</td>
<td>23</td>
</tr>
<tr>
<td>Lane Transit</td>
<td>100</td>
<td>81</td>
<td>24</td>
<td>19</td>
</tr>
<tr>
<td>Cherriots</td>
<td>51</td>
<td>80</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>882</td>
<td>78</td>
<td>247</td>
<td>22</td>
</tr>
</tbody>
</table>
seniority and therefore tend to accept the generally less desirable part-time shifts.

While women account for only 22% of the transit driver workforce, over 34% of the transit driver workers' compensation claims are made by women drivers. The number of claims per year were too small at Cherriots to make significant conclusions regarding the driver sex-injury relationship, but Tri-Met data indicated that the proportion of women injured was consistently higher than the proportion of men injured. The realization that many women are part-time drivers, reducing their actual driving hours, emphasizes the finding that women drivers may be more likely to be injured than their male counterparts. The proportions of male and female drivers in the workforce along with proportions of injured drivers for the years 1982 through 1986 are given in Table 23 and illustrated graphically in Figure 3.

One of the WCD summary tables provided an opportunity to determine if men or women drivers were more highly represented in certain types of accidents. The majority of accidents followed the overall ratio of 35% women to 65% men. Exceptions were overexertion types of incidents where the ratio was 43% women to 57% men, indicating that women may be more likely to injure themselves as a result of "excessive physical effort". Other exceptions to the 35/65 ratio of injured women and men were bodily reaction and 'both vehicles moving' type incidents where a higher percentage of men (approximately 74%) were injured. These figures indicate that even in the incident types with the highest percentages of male drivers, female drivers were still more highly represented than the workforce percentages would suggest.

There are several reasons that may explain the higher proportion of female driver injuries. First, as noted in the British study of bus passenger accident [Brooks et al., 1980], women may be more likely than men to report injuries. It is difficult to determine the validity of this suggestion as long as the only records of injuries are reported by the drivers themselves. Comparing the records of an objective observer reporting all injuries to the record of driver reported injuries would enable the accurate assessment of this suggestion. Without this objective assessment, research like the Leyland study, has shown that women may be more likely to report injuries and this may
<table>
<thead>
<tr>
<th>Year</th>
<th>Men</th>
<th></th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
<td>Work Force</td>
<td>Injuries</td>
<td>Work Force</td>
</tr>
<tr>
<td>1982</td>
<td>81</td>
<td>61</td>
<td>19</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>80</td>
<td>70</td>
<td>20</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>80</td>
<td>66</td>
<td>20</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>80</td>
<td>64</td>
<td>20</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>79</td>
<td>65</td>
<td>21</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 3. Percentage of Women Drivers and Injuries - Tri Met
account for part of the difference in injury proportions between men and women.

A second possible explanation is that women are, in fact, more likely than men to be injured while driving a transit bus. This suggestion could be explained by the assumption that women are, in general, more easily injured than men (a conclusion not supported by WCD claims in other industries) or, more likely, that current transit bus cockpits are not designed specifically for female drivers. Inappropriate vehicle dimensions may cause fatigue or put unnecessary stress or strain on various body parts due to frequent extending and reaching, improper body angle, or exaggerated arm and torso movements during a turning maneuver. Only recently has the female transit driver population grown to relevant proportions and buses may still be designed for a predominantly male user population. The 1985 SAE Handbook on Highway Vehicles and Off-Highway Machinery explains the use of a three dimensional H-point machine "in defining and measuring vehicle seating accommodations." These design aids are currently calibrated to accommodate 10th, 50th, and 95th percentile adult males. A different set of standards may be needed for the vehicles where females make up a relatively large proportion of the user population. In summary, transit vehicles may not be currently designed with female drivers in mind, and the possibly inappropriate cab dimensions may be partially responsible for the high proportions of female driver injuries.

Driver Age and Injury Probability

In considering driver age, several questions arise. Do injuries become more or less likely as driver age increases? Are certain types of injuries more likely to occur in certain age groups? Do specific age groups experience more severe accidents as measured by claim cost?

Driver populations were broken down according to driver age (in five year increments) for each year of the study period. Current age distributions differed slightly from one transit company to another. Lane Transit drivers are slightly older, on the whole, than Cherriot or Tri-Met drivers. Approximate average ages increase slightly from
41.5 at Tri-Met to 43.7 at Cherriots and 45.7 at Lane Transit. Current driver populations by age group are shown in Table 24.

Age data for all drivers in the work force was then compared with age data for injured drivers to evaluate whether certain age groups are more likely to be injured. Percentages of the number of injured drivers in each age group were calculated for each test period. Due to the small number of injuries occurring in Salem and Eugene each year, Tri-Met data was used as the basis for this analysis.

The percentage of injured drivers in each age group for each year during the study period is shown in Table 25. No specific age group had a consistently higher percentage of injuries than any other age group. It appears, at first glance, that 60-65 year old drivers may be more likely to be injured. However, percentages, in this case, are misleading; the high percentages in years 1982 and 1983 are based on two and four drivers and two or four injuries. Eighteen drivers were in this age group in 1986 with no injuries occurring. Figure 4 compares the number of Tri-Met drivers in the work force to the number of injured drivers in each age group in 1986. The similar distribution of drivers and injured drivers indicates that driver age is not related to the probability of driver injury.

A review of the driver age versus injury type versus driver sex WCD summary tables revealed no correlations between driver age and the type of injury occurring. Similarly, the WCD summary tables indicated that no relevant relationship exists between driver age and the nature of the injury.

E. STATISTICAL ANALYSIS OF DRIVER INJURY DATA

As mentioned earlier, the Workers' Compensation Department (WCD) in Salem was able to provide summary tables displaying claim frequencies in terms of certain claim variables (type, nature, etc.) and employee characteristics (sex, age, etc.). Summary statistics involving claim costs were also available from Salem. However, while useful descriptive information could be obtained from these tables, statistical tests of the relationships between variables were not available through the WCD. The statistical analysis of the driver
Table 24. Current Transit Driver Population Ages (Percent of Drivers in Each Age Group)

<table>
<thead>
<tr>
<th>Age</th>
<th>Tri-Met</th>
<th>Lane Transit District</th>
<th>Cherriots</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-25</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>26-30</td>
<td>8</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>31-35</td>
<td>16</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>36-40</td>
<td>21</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>41-45</td>
<td>18</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>46-50</td>
<td>14</td>
<td>24</td>
<td>17</td>
</tr>
<tr>
<td>51-55</td>
<td>10</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>56-60</td>
<td>7</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>61-65</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Average Age (Years) 43.7 41.5 45.7
Table 25. Percentage of Drivers Injured in Each Age Group

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>21-25</td>
<td>30</td>
<td>31</td>
<td>64</td>
<td>11</td>
<td>44</td>
</tr>
<tr>
<td>26-30</td>
<td>33</td>
<td>32</td>
<td>45</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>31-35</td>
<td>21</td>
<td>22</td>
<td>43</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>36-40</td>
<td>20</td>
<td>24</td>
<td>36</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>41-45</td>
<td>30</td>
<td>20</td>
<td>41</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>46-50</td>
<td>22</td>
<td>15</td>
<td>21</td>
<td>17</td>
<td>13</td>
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<tr>
<td>51-55</td>
<td>18</td>
<td>14</td>
<td>13</td>
<td>15</td>
<td>12</td>
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<tr>
<td>56-60</td>
<td>19</td>
<td>24</td>
<td>18</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>61-65</td>
<td>100</td>
<td>100</td>
<td>67</td>
<td>30</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 4. Number of Drivers and Injured Drivers by Age Group - Tri-Met, 1986
injury data was done using a statistical graphics software package - Statgraphics Statistical Graphics System.

Statgraphics is a software package developed for personal computers that offers a wide array of statistical procedures as well as sophisticated graphics capabilities. Data is stored in variables which are organized in files and both numeric and character data may be manipulated and analyzed. Several OSU departments (including the Industrial and Manufacturing Engineering Department) recently purchased the program because of its strong capabilities on a personal computer. The package was chosen for this research because of its broad selection of statistical tests coupled with its easy availability.

A computer printout (format shown in Table 9) with a listing of the WCD incidents occurring at the three transit agencies between 1980 and the beginning of 1987 provided the input for the Statgraphics program. Quantitative variables such as driver age, total claim amount, and total days lost from work were included in the program, along with other variables such as the sex of the driver, the year of the incident, and the WCD file number. Originally, the qualitative variables: type, nature, and source of the injury and the part of the body affected were to be included as well. It was hoped that contingency tables could be used to analyze the qualitative data to determine if two classification factors (such as type of injury and part of the body affected) were related and, if so, the degree of the association. Unfortunately, a test sample of 150 data values indicated that the distribution of the variables was not appropriate to accurately complete these tests. (The Chi-squared test requires that fewer than 20% of cells in a contingency table have less than five occurrences and no cells have expected frequency of less than one.)

After further research concerning the types of statistical tests available for categorical data sets, it was decided that the variables would include: WCD file number, driver age, driver sex, year other claim occurred, claim amount, total number of days lost from work (tldays) and driver initials. The decision not to include the variables injury type, injury source, injury nature, and body part was based partially upon the time required to input these qualitative variables, compared to the potential information that could be gained
over and above the information that was available through the WCD summary tables. Limitations of the Statgraphics program concerning character matrices of the proposed file size also contributed to the decision.

Each of the variables included in the Statgraphics program served a specific purpose. The quantitative variables (driver age, claim amount, and total days lost from work) enabled the statistical relationships among these variables to be explored. Summary statistics were developed for each of these variables and regression analysis was used to examine the relationships between them. Driver sex and the year of the claim were included so that significant differences in the quantitative variables between the sexes and from one year to another might be identified and explored. Driver initials provided a way of computing the number of injuries claimed by each driver (discussed in the Multiple Claims Section of Chapter IV) and the WCD file number provided identification for the specific claims that warranted further study at the Workers' Compensation Department in Salem.

A general picture of transit driver injuries was developed using frequency tables to break the quantitative variables down into meaningful groups. The results of these breakdowns are discussed in Chapter V (Driver Injury Scenario). Statistical parameters of the quantitative variables (driver age, claim cost, and total days) were calculated with the Summary Statistics procedure. These parameters provided a useful means to look at the distribution of the variables themselves as well as a means to compare the effects of secondary variables (such as the year of the claim and the sex of the driver) on the quantitative variables.

Table 26 shows the summary statistics for the variables driver age, claim amount, and the total number of days lost from work (tldays). The summary statistics indicated that injured transit drivers in the past seven years have ranged from 20 to 65 years old with 50% of the drivers between the age of 32 and 44. Injured driver ages followed a normal distribution that is skewed slightly toward older drivers; the average age was 38. Claims costs have ranged from a mere $37 to a high of $82,572. Most claims (75%) are less than $3,184 and 25% of the claims are less than $451. This indicates a skewed
<table>
<thead>
<tr>
<th>Variable</th>
<th>Age (Years)</th>
<th>Amount ($)</th>
<th>Total Days (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>1,342</td>
<td>1,239</td>
<td>1238</td>
</tr>
<tr>
<td>Average</td>
<td>38.57</td>
<td>3,561.73</td>
<td>33.59</td>
</tr>
<tr>
<td>Variance</td>
<td>77.17</td>
<td>5,102,670.00</td>
<td>4516.34</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>8.78</td>
<td>7,143.29</td>
<td>67.20</td>
</tr>
<tr>
<td>Minimum</td>
<td>20</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>65</td>
<td>82,572</td>
<td>755</td>
</tr>
<tr>
<td>Lower Quartile</td>
<td>32</td>
<td>451</td>
<td>4</td>
</tr>
<tr>
<td>Upper Quartile</td>
<td>44</td>
<td>3,184</td>
<td>33</td>
</tr>
</tbody>
</table>
distribution with an extremely long upper tail. The average claim cost including the upper outliers was $3,562. The distribution of the total days lost from work (variable tlday) closely paralleled the claims cost distribution. While days lost ranged from 0 to 755, the average number of days off (including upper outliers) was 34 and 25% of the claims were less than four days.

Significant differences in driver injuries between the sexes and between different age groups were examined by dividing the data into subsets and comparing the summary statistics generated for each subset. The test for the difference between two means was used to determine if the amount of the claims and the total days lost from work differed significantly between men and women. Although the average claim cost and days lost from work were slightly higher for women, the test for the difference between two means showed that differences were not significant at the 5% level; outliers were likely to be responsible for the slightly differing trends. Summary statistics indicated that injured driver ages were similarly distributed for both men and women.

Claims were also separated by year (the year that the claim was initiated), and tests for the difference between two means for each variable (claim cost, tldays, and driver age) were calculated. Assuming an inflation rate of 10%, the tests for the difference between two means showed no significant differences in claim amounts with the exception of 1981 and 1984. Upon further study, it was seen that outlying cost amounts differed by over $30,000; the outliers were likely responsible for the different claim amounts. Differences in the total days lost from work closely paralleled claim amount differences and were also likely caused by outliers. No major differences in injured driver ages from year to year were found. In summary, none of the quantitative variables (driver age, claim amount, tldays) showed significantly different values from one year to another. The relationships between the variables of amount, tldays, and driver age were explored using simple linear regression. Demographic data indicated that driver age was not related to the likelihood of an injury; similarly, driver age was not related to the cost of a claim. The linear regression of driver age on claim amount yielded an $R^2$ value of .39 percent indicating that driver age and claim amount are not
correlated. Likewise, no correlation was indicated in the regression of driver age on tldays (R^2 = .06 percent).

As expected, claim amount and the total days lost from work were highly correlated. The regression of amount on tldays yielded an R^2 of 86.10 percent indicating that 86% of the variability in claim amount can be explained by the number of days the driver was unable to work due to the injury. The high correlation between claim amount and tldays points out the value of the modified work program of some transit companies which encourages drivers to return to work in the office until they are able to continue driving.
V. DATA ANALYSIS

The foregoing data was collected for the purpose of identifying the major human factors problems in the mass transit bus driver cockpit and to direct an in-depth investigation of the most hazardous human factors problems. The data also enabled the identification of the operational activities within the transit system that are most likely to produce injuries and accidents. In the following section, a scenario of driver injuries, based upon the quantitative data collected from the WCD and transit companies, will be developed, and qualitative data involving the perceptions of drivers, transit officials and workshop participants will be briefly reviewed and summarized. Through this discussion, the most hazardous and most pressing human factors related problems will be identified and an in-depth study approach will be formulated.

A. DRIVER INJURY SCENARIO

A scenario of driver injuries indicating the overall characteristics of driver injury incidents was developed using quantitative data from the WCD along with demographic data received from the transit companies. The most frequently occurring type of accident, accounting for one fourth of all driver injuries, was the non-collision accident (see Table 27). A closer look at this type of accident in the workers' compensation files indicated that approximately two fifths of the accidents were related to the driver's seat and another two fifths were related to vehicle steering. The final fifth of these accidents resulted from a sudden bump or jar, the force of the roadway being transferred to the driver through the seat, steering wheel or controls. Further, several of these incidents directly resulted from the failure of some vehicle component. For example, the seat, being unable to withstand the force of the jolt from the road, would give way, consequently injuring the driver.

The next three most frequently occurring accident types each accounted for close to 15% of the driver injuries. The "struck by or against" type incident accounted for 15% of Tri-Met injuries, but did
Table 27. Scenario of Driver Injuries

<table>
<thead>
<tr>
<th>Type of Accident</th>
<th>Part of Body Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Non-Collision Accident</td>
<td>24% Multiple Parts</td>
</tr>
<tr>
<td>15% Bodily Reaction</td>
<td>23% Back</td>
</tr>
<tr>
<td>15% Struck By or Against</td>
<td>11% Shoulder</td>
</tr>
<tr>
<td>14% Overexertion</td>
<td>7% Neck</td>
</tr>
<tr>
<td>11% Falls</td>
<td>6% Knee</td>
</tr>
<tr>
<td>20% Other</td>
<td>29% Other Body Parts (Less than 4% for Each Part)</td>
</tr>
</tbody>
</table>

Nature of Accident

<table>
<thead>
<tr>
<th>Source of Accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>67% Sprain/Strain</td>
</tr>
<tr>
<td>10% Bruise</td>
</tr>
<tr>
<td>23% Other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Driver Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>61% 31-45 Years Old</td>
</tr>
<tr>
<td>23% &gt; 45 Years Old</td>
</tr>
<tr>
<td>16% &gt; 30 Years Old</td>
</tr>
</tbody>
</table>

Driver Sex

| 66% Male                                |
| 34% Female                              |

Total Days Lost

<table>
<thead>
<tr>
<th>Amount of Claim</th>
</tr>
</thead>
<tbody>
<tr>
<td>47% &lt; 10 days</td>
</tr>
<tr>
<td>36% 10-50 days</td>
</tr>
<tr>
<td>17% &gt; 50 days</td>
</tr>
</tbody>
</table>

Number of WCD Claims

| 59% 1 Claim                             |
| 19% 2 Claims                           |
| 22% > 3 Claims                         |
not account for any of the Cherriots or LTD injuries. This category of injury frequently relates to the case of one person being struck by another person, and likely points to the problem of assault which is more prevalent in Portland than in the smaller cities of Salem and Eugene. While assault is a serious problem, it is more closely related to social problems than to vehicle design problems and is beyond the scope of this research. The remaining two accident type categories (bodily reaction and overexertion), together accounted for almost 30% of all driver injuries. A closer look at WCD files indicated that bodily reaction incidents frequently involved the driver experiencing pain in some part of his/her body without any directly apparent cause. This could be caused by an improper relationship among various vehicle components. Inappropriate control relationships combined with prolonged confinement in the driver's seat could consequently result in driver injuries.

Overexertion injuries result from extreme physical effort on the part of the driver. Closer examination of this type of incident in the WCD files revealed that almost 60% of the overexertion incidents involved turning or steering the bus. Overexertion incidents involved a higher percentage of women drivers than other types of incidents indicating that the currently driven vehicles may require forces that are not easily produced by women. The proportion of women transit drivers has gradually increased in the last several years and the large proportion of women being injured by overexertion may indicate that transit vehicle designers have not taken the relative strength of this emerging group of users into account.

Injuries affecting multiple body parts were experienced most often followed by injuries affecting the back. Shoulder, neck, and knee injuries were also represented in a relatively large proportion of driver injuries; all other specific body parts were injured in less than 4% of all incidents. Consistent with WCD claims in most industries, sprains and strains are the principle characteristics of injuries affecting drivers. Bruises occurred in 10% of the injuries and the remaining 23% of injuries had a wide variety of characteristics. The source of driver injuries was typically a "highway vehicle" i.e. the bus, but bodily motion was also responsible for 16% of the
injuries. The working surface source category refers to surfaces used as supports for workers such as the floor, ground or sidewalks when they directly resulted in the injury.

The majority of injured drivers were between the ages of 31 and 45; 23% of the injured drivers were over 45 years old and 16% of the injured drivers were less than 30 years old. The ages of all drivers in the work force followed a very similar distribution indicating that driver age is probably not directly related to driver injuries. Drivers of all ages (23-59) were represented in the WCD files, and statistics from transit companies combined with WCD statistics strengthened the conclusion that no definite relationship exists between driver age and driver injuries. Sixty six percent of all driver injuries involved male drivers and 34% involved female drivers. The relatively different work force proportion of approximately 78% men to 22% women indicated that women may be more likely to be injured than men. Several possible explanations for the higher percentage of female driver injuries were put forward in Chapter IV; one likely possibility is that current bus cab dimensions may be more suitable for men than for women.

Also as discussed in Chapter IV, WCD claim costs are closely related to the number of days lost from work. In almost half of the claims the driver lost less than ten days from work and cost the state less than $1000 apiece. Another 36% of the injured drivers lost between 10 and 50 days from work and cost between $1000 and $5000 apiece. Only 2% of the drivers suffered extremely severe injuries that cost over $25,000. The relatively minor nature of the bulk of driver injuries implies some consistently occurring driver injuries potentially caused by design problems.

Finally, it was noted that 22% of the workers' compensation claims are made by drivers who made three or more claims during the seven year study period. A closer look at the specific claims made by these drivers indicated that certain drivers may be overly willing to make WCD claims and that the claims may be made for somewhat nebulous or disputable causes.
B. ANALYSIS OF OBSERVATIONAL DATA

The similarities and discrepancies found among the various sources of qualitative data denote differing perceptions of transit problems—differing according to the role that an individual plays within the transit system. For example, workshop participants, including transit officials, some drivers, transit users, and state and government agency officials perceived the major problems in the driver's workplace quite differently than the transit drivers themselves. All of the major driver concerns were listed in the brainstorming session at the workshop, but the major problems identified by workshop participants differed from the major problems perceived by drivers. As might be expected, workshop participants generally had a broader perspective on transit problems, while drivers focused more on the immediate concerns of physically driving the bus. Workshop participants focused on time and budget considerations as the most difficult to improve problem, followed by education (of both transit employees and the public), driver communications with management and dealing with local government. Dealing with management was the only item mentioned that coincided with a frequently mentioned driver concern. The "wish list" developed by the workshop participants came somewhat closer to driver wish lists, although many additional wishes were included by the drivers. The top two wishes perceived by workshop participants involved loosening tight schedules; the most frequent wish of Eugene drivers also involved loosening tight schedules, and several drivers in Salem and Portland wished for schedule changes as well. Workshop participants also placed a priority on changing bus routes to avoid narrow streets; drivers, on the other hand, focused on preferring a smaller bus that would be easier to handle on narrow streets and wished to change the bus routes to make them more safe (e.g. avoid left turns across traffic).

Transit officials and bus drivers recognized many of the same problems facing the driver, but they often placed different priorities upon the problems. Most transit officials recognized holding to a tight schedule as a major cause of driver stress, but only the drivers pointed out that tight schedules are less of a problem than schedules
that simply don't fit the given route. Several drivers mentioned that
schedules that require waiting at stops to stay on schedule are also
stressful as well as schedules so tight that the driver cannot take a
break.

Interestingly, but not surprisingly, a major concern recognized by
workshop participants, but not by transit officials, was the problem of
driver - management relations referred to by drivers in all cities.
Traffic and vehicle accident concerns were not particularly noted by
transit officials, but are real and pressing concerns for many drivers.
Some of the concern about accidents, from the drivers point of view,
may arise from the fact that after a specified small number of
accidents, they lose their job. Vehicle design concerns are indirectly
related to traffic and vehicle accidents in so far as an uncomfortable
work place may distract the driver from the driving task. Tri-Met
officials and drivers alike recognized the problems with the wheel
chair lift on the articulated buses, but neither group had suggestions
for reducing the problems. In spite of a few differences in percep-
tions of minor problems and concerns, transit officials and drivers
alike (along with quantitative data from the WCD files) agreed that the
primary vehicle design problem involved the driver's seat. Transit
officials in all cities recognized the seat as a major cause of back
injuries and the workers compensation files studied in detail supported
that perception. While drivers and officials agree in identifying the
driver's seat as the major problem, their perceptions of the exact
nature of the problem and potential solutions to it differed in several
respects.

Tri-Met officials, recognizing the driver's seat as a major cause
of injuries, have initiated several programs aimed at reducing the
problem. The first of these involves the Acuback and Sacro Ease seat
supports (as discussed in Chapter III) being made available to drivers
at a reduced cost. However, while Tri-Met officials are concerned
about the lack of back support, drivers were more concerned about the
lack of seat adjustments along with poor seat maintenance. Drivers in
all cities perceived that the main problem with the driver's seat is a
lack of adjustments, both vertically and longitudinally. Tri-Met
officials felt, based on a questionnaire distributed to drivers, that a
lack of knowledge concerning seat adjustments is more of a problem than a lack of adjustments themselves. A combination of these varying perceptions (a lack of seat adjustments along with a lack of knowledge concerning seat adjustments) may denote the actual problem.

Several drivers mentioned seats that could not be adjusted because of physical obstructions. For instance, radios behind seats prevent them from going all the way back and pneumatically adjusted seats may not be adjustable because the seat is likely to bottom out if adjusted anywhere except at the highest or lowest positions. Maintenance of bus seats was another major problem identified by the drivers. Misaligned bus seats (caused perhaps by removal and then reinsertion of the seat), have caused serious discomfort, and rocking or bouncing seats have caused several injuries. Drivers in all cities suggested that new seats with more adjustments be designed and installed in buses. They also suggested that experienced drivers should test the seats and that seats should be covered with cloth instead of vinyl.

In addition to the seat itself, the location of the seat within the cab along with the relationship of the seat to other controls are considerations that need to be addressed. Steering was identified by Tri-Met officials as the second most pressing problem and drivers in all cities also mentioned problems with vehicles. While the ease of steering is a major factor in back and shoulder problems (emphasized by non-power steering buses), the relationship of the seat to the steering wheel is also of prime importance and may contribute to steering problems.

C. DRIVER INJURY CLASSIFICATION - WCD FILES

The WCD injury type classifications are designed to apply to all Oregon occupations and injuries and, as a result, are of a fairly broad nature. Thus, while the WCD type classifications provide a useful foundation to begin a study of driver injuries, another classification based upon specific driver problems may provide more insight into the specific causes of driver injuries. For this reason, all of the workers' compensation files that were examined in detail, were divided
into three categories relating to the specific vehicle components that caused driver injuries (as identified by the transit officials, literature review and workshop). The first two major categories of injuries are injuries related to vehicle steering or turning and injuries related to the driver's seat. The third category involves several other vehicle components that cause injuries less frequently, but are, nonetheless worthy of consideration.

Steering Problems

Thirty eight percent of all WCD claims examined in depth involved a driver injury related to turning or steering the bus. Seventy-five percent of these accidents involved men and twenty-five percent involved women. Unfortunately, only two thirds of the WCD files identified the bus number of the vehicle that was being driven at the time of the incident and thus the make and model of the bus could not be readily determined. Of the injuries where the vehicle was identifiable, only one injury occurred on a 1972 FLX bus, 22% of the incidents occurred on 1976 AMG buses, and the large majority of incidents (72%) occurred on the 1974 FLX bus. Transit company officials are aware of the vehicle steering problems on the manual 1974 FLX buses and are trying to remedy the situation by retrofitting the buses with "air power assist" steering. The 1976 AMG buses are also equipped with air power assist steering which was added after the buses were purchased. One fact of interest is that, of all the manual steering buses in the fleet, (47% including the 1974 FLX), only the buses with air power assist steering were represented in the WCD claims examined. Although 1971, 1972, and 1973 FLX buses all have non-power steering, only one incident occurred on a 1972 FLX bus and no injuries occurred on 1971 or 1973 FLX buses. It is also interesting to note that, in the WCD files, more drivers referred to buses with "stiff steering" in describing their injuries than to buses with manual steering. This may indicate air power assist steering buses may be difficult to steer in spite of the air power assist. This explanation is consistent with the comments of several drivers interviewed who indicated that 1974 FLX or 1976 AMG buses are their least preferred buses because steering is still
difficult, in spite of the addition of air power assist. The shorter length (35 feet) of the 1971, 1972, and 1973 FLX buses may also make their handling somewhat easier than the 40 foot length of the 1974 FLX and the 1976 AMC buses. Finally, two of the steering injuries occurred when the air power assist malfunctioned, causing the steering wheel to lock, severely injuring the driver’s shoulder.

A large majority (44%) of the incidents involved making sharp turns - either in a sudden quick action to avoid a collision, or in a slower hard pull to get around some obstacle in the road. The majority of men injured in making sharp turns were taking "severe evasive action" (driver's words from WCD files) to avoid a collision. "Severe evasive action" probably involves abrupt movement and a sudden wrenching or twisting of the wheel. The large mass of the bus inhibits its quick movement and a strong resistance is felt by the driver's shoulder and back, consequently injuring the driver. While this situation is not optimal, it is certainly understandable and unique engineering measures may be required to improve it.

On the other hand, half of the drivers injured in making sharp turns were women and all but one of these women were injured while slowly maneuvering the bus around some obstacle in the road. This indicates that while sharp turns may cause a problems for many drivers (especially in emergency situations which require quick movement of a large bus), simply maneuvering a heavy bus out of a tight situation may be more hazardous to women drivers. One possible explanation for this situation is that design dimensions and required forces are more suitable for men than for women. If the vehicle controls have dimensions that fit large male drivers, then smaller women drivers may have more difficulty and be injured more frequently in using those controls. The greater force required to turn a slowly moving bus and maneuver it around an obstacle in the road may emphasize the problems of non-optimal control layout or inappropriate dimensions. Finally, inappropriate dimensions could potentially cause even more serious injuries should a woman driver be forced to take "severe evasive action" and attempt to rapidly turn the heavy bus.

The importance of appropriate cab dimensions is understood, at least intuitively, by bus drivers themselves. One woman explained (in
the WCD files) that she had to repeatedly adjust the air in the seat on a particular bus; when the air in the seat was low, she was not at the proper height to turn the bus and she consequently strained her shoulder in making a right hand turn.

Several injuries were described as the sudden onset of pain in some part of the body while a driver was completing a simple turning maneuver. These conditions may have developed gradually and then made themselves apparent suddenly with a simple maneuver that would not normally cause an injury. Several situations could be responsible for the gradual development of the sudden injury. Some of the injuries were experienced by drivers who had experienced previous injuries to the same body part; other injuries involved drivers who had been working 14-16 hour days for several days prior to the injury. Finally, inappropriate control layout or dimensions could potentially be responsible for the gradual development of a sudden injury.

Seat Problems

The second category of the driver "specific injury" classification of the WCD files includes all injuries involving the driver's seat (twenty percent of all the WCD files examined). Seventy one percent of the seat related claims identified the bus being driven at the time of the incident. Of these claims, half of the seat related injuries occurred on 1976 AMG buses and all of the "bottoming out" incidents occurred on the 1976 AMG or the articulated buses. Due to the small sample size, no significant conclusions can be drawn from these numbers, but the data definitely points to the seat in the 1976 AMG bus as a potential hazard and strongly suggests further research on the mechanical design of this bus seat.

The seat bottoming out was the cause of the injury in 43% of the seat related injuries. Typically, the seat would bottom out after the bus hit a chuck hole or some bump in the road. Other incidents involved the seat loosing air pressure (although not completely bottoming out) and then bouncing up and down during the rest of the route. Broken seats that rocked and stiff seat adjustments also caused several driver injuries. The same buses that were cited for steering problems were
also cited for seat problems (1976 AMG, 1974 FLX, Crown/Ikarus articulated). One injury occurred on a 1980 GM ADB bus. Almost all of the seat incidents caused back injuries and the majority of drivers injured by seat problems were considerably overweight. While the relatively small sample size makes conclusive statements inappropriate, the data definitely suggests some major strength and durability problems with driver seats; the mechanical design and physical limitations of the seats also warrant further consideration.

Additional Problems

The remaining 42% of the WCD claims studied in detail resulted from a wide variety of causes and involved several vehicle components. Table 28 shows the most frequently cited driver injuries along with their probable causes and potential solutions; injuries are listed in order of most frequent occurrence among the WCD files examined. The most frequently occurring injury, after seat and steering related injuries, was the gradual onset of pain in some part the driver's body, sometimes the neck or knee, but often multiple parts. While there is no directly apparent cause for these injuries, an improper relationship between vehicle controls and the driver's seat could be partially responsible. Improper posture or inappropriate body angles could be encouraged by the overall layout of the cab and specifically by the relationship between the driver's seat and the other vehicle controls. The driver might not be aware of the stress being put on the body by the poor body position until the stress became so great that an injury occurred and the driver experienced definite pain. Many of these injuries seemed to be precipitated by prolonged periods of driving (several 14-16 hour days) further supporting the possibility that inappropriate cab dimensions might be partially responsible for the injuries.

A second frequent injury was tripping or slipping while the driver was walking to, from, or around the bus. These injuries seemed to occur at any time during a driver's shift and did not appear to be related to driver fatigue or vehicle design. Another frequent injury involved a driver slipping on the bus steps - usually when he/she was
Table 28. Additional Driver Injuries - After Seat and Steering Injuries  
In Order of Most Frequent Occurrence of Injury

<table>
<thead>
<tr>
<th>Injury</th>
<th>Probable Cause</th>
<th>Potential Solutions</th>
</tr>
</thead>
</table>
| Gradual onset of pain in various body parts | Improper design, layout or relationship between driver’s seat and vehicle controls  
Injuries often become evident after prolonged periods of driving (14-16 hr days) | Redesign seat/control relationship for current driver population  
Improve seat and/or control design |
| Driver tripped or slipped while walking or running to or around the bus | Uneven terrain, potholes, or slippery substances on pavement around bus | Smooth out bus lot parking lots |
| Driver slipped on steps while deboarding bus or adjusting mirrors | Somewhat slippery or uneven steps  
Stiff mirrors may exacerbate problem | Add nonslip substance to steps  
Keep mirrors oiled and easily adjustable |
| Bus hit chuck hole or bump in road - impact injured driver | Force of the road transmitted to driver through seat or controls | More shock absorbent seat and vehicle controls |
| Back injury due to driver bending over from seat to pick up transfer book | Transfer book falling to floor | Convenient holder for transfer book |
| Back injury while lifting wheelchair over barrier at end of lift | Wheelchair lift malfunction | More reliable wheelchair lifts |
attempting to adjust the inside mirrors. A few injuries also occurred as the driver attempted to adjust the outside mirrors and slipped off the bus bumper etc. Both problems could be solved by having remote adjustments for the mirrors or at the least, assuring that the maintenance department keeps the mirrors oiled and easily adjustable. Drivers hitting chuck holes and bumps in the road and experiencing the impact of the road through the seat or controls was another fairly common injury that might be mitigated by more shock absorbent vehicle components. A transfer book holder would hopefully eliminate the problems of drivers bending over from their seats to pick up fallen transfers and reliable wheel chair lifts would eliminate back injuries due to lifting wheel chairs over barriers.

D. SUMMARY OF MAJOR PROBLEMS

The detailed data collection concerning transit driver occupational safety and health problems pointed out several interesting results. Driver's seats were recognized as a source of problems by all data sources - literature, transit officials, drivers, and WCD files - but perspectives on the specific problems differed. Transit officials focused on a lack of seat support and lack of driver knowledge regarding adjustments. Drivers tended to focus on the lack of adjustments along with the poor fit and discomfort of the seats. The WCD files pointed to the poor durability and mechanical failures of seats as a major problem along with the anthropometric considerations of proper seat position.

Schedules were also recognized by all sources as an operational problem, but again perspectives on the problem differed according to the source. Workshop participants listed a change in schedules as the number one wish for changes and clearly distinguished between allowing enough time for the driver to complete the route on schedule and allowing enough time for driver breaks along with staying on schedule. Transit officials at Tri-Met and Eugene were concerned about the lack of driver breaks resulting from tight schedules. Drivers themselves focused on scheduling buses to fit the route and employing different schedules according to traffic conditions. Some drivers also expressed
the desire that bus routes be changed to avoid left hand turns across heavy traffic and other potentially dangerous maneuvers.

Both the authors cited in the literature and transit officials expressed concern related to the wide variability of control locations among different buses; drivers, on the other hand, did not express a similar concern. The general perspective of drivers was that some time is needed to become familiar with different buses and their control layout, but that, on the whole, different control layouts do not create a driving hazard. Likewise, considerable concern regarding driver fatigue and related safety hazards was found in the literature. Transit officials expressed a similar concern, but drivers were divided in their perception of the safety and health hazards associated with fatigue. Approximately half of the drivers who had worked long hours felt that fatigue effects were inevitable and potentially harmful; the other half felt that fatigue effects were minimal and certainly not hazardous. Workshop participants recognized the friction between drivers and management that was clearly expressed by drivers in all cities. Driver age was found to have very little relationship to the probability or severity (as measured by claim amount) of a driver injury.

Driver sex, on the other hand, was clearly related to the likelihood of an injury but not related to injury severity (claim amount). While approximately 22% of the transit driver population is female, almost 35% of the transit injuries are occurring to women. The prevalence of female driver injuries pointed to potential anthropometric problems with current transit cab designs. Anthropometric considerations were further suggested by WCD files which pointed to driver seating and vehicle steering as the two major causes of driver injuries. While mechanical failures were directly responsible for several of the seating and steering injuries, improper driver positions resulting from suboptimal cab dimensions may have added to the problems.
VI. HUMAN FACTORS IN-DEPTH ANALYSIS

Driver's complaints concerning a lack of seat adjustment, the prevalence of women driver injuries, and the WCD files indicating injuries with no specific cause all point to potentially inappropriate cab dimensions as one of the major human factors problems. The additional work station design fact that two of three constraints must be adjustable for the work station to comfortably fit the population indicated that an anthropometric study of the bus cab could be valuable. The location and design of the driver seat is directly related to the fit of the bus cab to the range of drivers.

The last section summarized the data collected and narrowed the field of problems down to a problem associated with the relationship between the driver's seat, steering wheel and pedals. This problem directly involves seat location and design. The occupational safety and health hazards of the driver's seat may be divided into two broad categories. The first aspect involves the relationship of the driver's seat to other vehicle controls. The location of the seat with respect to other major controls, such as the steering wheel and pedals, could potentially cause many of the problems related to these other vehicle components. For example, many of the arm, shoulder, and back injuries related to vehicle steering may be due to awkward or extended positions that are inevitable due to the location of the driver's seat. The relationship of the seat to other controls depends upon two major factors: the body size of the driver and the adjustability of the seat. Both of these factors will be looked at in detail in the human factors analysis that follows.

Secondly, many injuries are caused by problems with the durability, strength and physical limitations of the seat. Often times, the driver's seat is unable to withstand the force of bumps or jars from the road, and is apt to give way suddenly (bottom out) and injure the driver. Other times the seat may simply wear out and start rocking or bouncing - causing back problems and more driver injuries. While the durability and strength of the seat is a major problem and should be given further consideration, it is primarily a mechanical design problem and will not be focused on in this study.
A. APPROACH - PROCEDURE

The basic approach chosen for the in-depth study was an anthropometric analysis of bus cab layouts. A brief literature review helped to focus the study and provided a general framework from which to start. Using the key concepts from the literature, a check list of vehicle dimensions was developed (cab layout checklist, Figure 5), focusing on the driver's seat within the cab and the relationships between the seat and other controls.

After the initial draft of the cab layout checklist, several drivers were observed in action and the checklist was revised taking the dynamic actions of the driver into account. The Corvallis Transit System was used for these observations because of its easy availability. The refined checklist provided a framework for a detailed study of three buses.

The three buses chosen for the in-depth study included the 1984 Gillig Phantom (Gillig), the 1976 Flxible "New Look" (FLX) and the 1980 General Motors "Advanced Design Bus" (GM ADB). These buses were chosen from those available to the project staff because they presented the widest variability in style among the buses that were easily accessible. Also, these buses were most preferred by the majority of drivers surveyed, indicating that they are some of the most comfortable buses currently in use in the study area. Problems with many of the less preferable buses have been identified and improved in newer models, and a closer look at the newer bus models should refine the remaining problems and allow the occupational safety and health hazards still present to be identified and resolved. The cab layout checklist provided a basis for an overview of the cab layout and the relationship of the seat to the vehicle controls. Several relevant findings were identified in this preliminary study and the study helped to direct input on the specific focus of the anthropometric study.

Literature

A brief separate literature review on driver seating revealed that while a fair quantity of work has focused on automobile drivers'
VEHICLE MEASUREMENTS

Angles

Seat back with seat pan -
Accelerator pedal with floor -
Brake pedal with floor -
Plane through steering wheel to vertical -
Angle of seat bottom to horizontal -

Dimensions

Seat Back - width -
  - height -
Seat Bottom - depth -

Diameter of steering wheel -
  width of wheel -

Seat Adjustments

Height: top of seat at midpoint of seat pan to bus floor
  - max height
  - min height
  - number of adjustments

Forward and Back movement: horizontal distance from front edge of seat to rear edge of accelerator pedal
  - seat adjusted forward
  - seat adjusted back
  - number of adjustments

Also: Horizontal distance from front edge of seat to rearmost point of steering wheel
  - seat adjusted forward
  - seat adjusted back

Figure 5. Cab Layout Checklist
**Vertical Distance**

- front edge of steering wheel to floor -
- front edge of steering wheel to seat pan -

**Horizontal Distance**

- bottom edge of accel. pedal to bottom edge of steering wheel -

**Transverse Distance**

- center of accel. pedal to midpoint of front edge of seat -
- center of accelerator pedal to base of steering wheel -
- mid point of front edge of seat to base of steering wheel -
- center of seat to left edge of fare box -
- center of seat to inner side of window -

**Furthest Control**

- reference point = mid point of front edge of seat (farthest position forward)
  - horizontal distance to farthest control -
  - horizontal angle to farthest control -
  - vertical angle to farthest control -

**Additional notes**

- Seat cover material?
- Location of mirrors?
- Amount of windshield covered by wipers?
  - radius of area wiped -
  - height of window -
  - width of window -
- Location of controls?
  - windshield wipers -
  - 4-way hazards -

Figure 5. (Continued)
seating comfort [Grandjean, 1980; Rebiffe, 1980; Jurgens, 1980; Babbs, 1979], and some work has emphasized vehicle seating in general, relatively little work has been done focusing on transit bus driver seats and seating comfort. Of the literature focusing on driver seating, several reports [Hapsburg and Middendorf, 1980; Babbs, 1979; Dieschlag and Muller Limmroth, 1980; Andersson, 1980] have focused specifically upon the seat itself and the shape and contour of the seat that will provide the most comfortable posture and position for the driver. Other authors [Huchingson, 1981; Van Cott and Kinkade, 1972; Grandjean, 1980; Rebiffe, 1980] have focused on the body angles of the driver for determining seating comfort.

The relative comfort and utility of seats in general, including the driver's seat, is determined by the physical dimensions of the seat coupled with the physical structure and biomechanics of the human body. Some of the basic principles of seat design involve seat dimensions; the length of the seat bottom should be suitable for smaller drivers and the seat width should be adequate for larger drivers, the dimensions and contours of the seat back should provide adequate lumbar support. The height and shape of the seat should prevent excessive pressure on the thighs, and the design of the seat should allow the weight distribution of the human body to be spread out over the seat with the weight distributed primarily throughout the buttock region surrounding the ischial tuberosities. Appropriate weight distribution can be achieved through proper contouring of the seat pan combined with appropriate height and back dimensions and seat angles [McCormick and Sanders, 1982].

Designing driver's seats involves several additional principles (beyond the principles of general seat design) due to constraints imposed by the fixed dimensions of the driver's work space and the required movements of the driver's job. The driver's work space is severely limited by the nature of the driving task and requires the driver to maintain a fairly static position for a relatively long period of time. R. Rebiffe noted this in his reflections on the postural comfort of drivers and the consequences of seat design,

"The requirements of the task determine the posture of the driver for long periods of time in a relatively set way,
without having any real possibility of changing position... 
The driver's seat will thus be designed to accommodate a 
determined posture." [Rebiffe, 1980]

The driver's work space envelope (arm reach etc.) is further 
limited by the apparel of the driver and seat restraints (i.e. seat 
belts). Yet, while the driver is required to maintain a fairly static 
position overall, the driver's job is still a dynamic function, 
requiring an interactive application of the controls. It is important 
to remember that in dynamic movement, body parts do not operate 
completely independently, but work together in concert. McCormick 
[1982] illustrated this point using arm reach,

"The practical limit of arm reach for example, is not the 
sole consequence of arm length [and seat position]; it is 
also affected in part by shoulder movement, partial trunk 
rotation, possible bending of the back and the function that 
is to be performed by the hand."

Further, the driver's seat must be designed to accommodate the 
widely varying body dimensions of the driver population both in terms 
of the design of the seat and also with respect to the location of the 
seat within the cab. The location of the driver's seat should be 
adjustable to comfortably accommodate at least 90% of the driver 
population. The minimum seat elevation will determine the largest 
driver's maximum overhead visibility through the windshield. The 
maximum seat elevation will determine the downward vision through the 
windshield of the smallest driver. To accommodate the entire driver 
population, Van Cott and Kinkade [1972] recommended a minimum vertical 
adjustment range of four inches in one inch increments.

The longitudinal position of the seat is also important. The 5th 
percentile woman should be able to reach all controls comfortably while 
the 95th percentile man should have thigh support and must have knee 
clearance with respect to the steering wheel and control panel. The 
recommended longitudinal adjustment range is six inches in one inch 
increments [Van Cott and Kinkade, 1972]. Finally, on top of all the 
human factors considerations, seat design, "... is not fundamentally 
based on ergonomic criteria, but also according to stylistic, aero-
dynamic, technological and economic factors." This point was il-
Illustrated by one of the most frequent driver complaints - that bus seats were chosen based on economic factors rather than ergonomic ones.

B. PRELIMINARY VEHICLE STUDY

As discussed in the literature review, relatively little work has been done in defining optimal seat configurations specifically for buses. One exception is Wesley Woodson's *Human Factors Design Handbook* 1981, which gives a few selected recommended dimensions for public transit buses compatible with fifth percentile female to ninety fifth percentile male drivers. These dimensions represent an ideal design that should be used as a guide. Van Cott and Kinkade also list a few dimension recommendations in their *Human Engineering Guide to Equipment Design* [1972]. Both of these references were employed in evaluating the study bus dimensions.

The overall dimensions of the seat itself were very similar for each of the three buses studied as is shown in Table 29. There were slight variations in specific dimensions, but the overall design of the seat and relative dimensions remained consistent among the three different models. These dimensions were, for the most part, within the recommended vehicular seat dimensions. The one exception was the height of the seat back - approximately eighteen inches on the study buses and recommended as 24 inches by Woodson. The longer seat back recommended by Woodson would provide considerably more shoulder support for the driver.

The number and range of seat adjustments varied considerably among the three study buses. Three to six horizontal adjustments were possible (depending on the bus) but none of the seats came close to the longitudinal recommended ranges of adjustability - eight inches according to Woodson and six inches according to Van Cott and Kinkade. The location of the seat (in its farthest back position) ranged from 9.5 to 12.5 inches away from the back of the accelerator pedal. Vertical adjustments on seats came closer to the recommended four inch range, and seat back angles were adjustable to include the 105 degree angle recommended by Woodson. Ranges and numbers of seat adjustments for the three buses studied are given in Table 30.
Table 29. Driver's Seat Dimensions (Inches)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seat Back</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Width at top</td>
<td>14</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>B Width at bottom</td>
<td>19.5</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>C Height of back</td>
<td>18</td>
<td>18</td>
<td>17.5</td>
</tr>
<tr>
<td>D Height to bottom</td>
<td>20</td>
<td>20</td>
<td>19.5</td>
</tr>
<tr>
<td><strong>Seat Bottom</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Width at front</td>
<td>20.5</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>F Width at back</td>
<td>17.5</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>G Length</td>
<td>16</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>H Depth</td>
<td>3.5</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Front View

Top View
Table 30. Seat Adjustments (Inches)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seat</td>
<td>Seat</td>
<td>Seat</td>
</tr>
<tr>
<td></td>
<td>Forward</td>
<td>Back</td>
<td>Forward</td>
</tr>
<tr>
<td>A Front edge of seat to rear edge of accelerator pedal</td>
<td>12.5</td>
<td>16.5</td>
<td>9.5</td>
</tr>
<tr>
<td>B Front edge of seat to front edge of steering wheel</td>
<td>3</td>
<td>-1</td>
<td>5</td>
</tr>
<tr>
<td>Total range of adjustability</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of increments</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>C Top of seat bottom to floor</td>
<td>18</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>D Top of seat to bottom edge of steering wheel</td>
<td>8</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Total range of adjustability</td>
<td>3</td>
<td>4</td>
<td>3.5</td>
</tr>
<tr>
<td>Number of increments</td>
<td>Continuous</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>E Bottom to horizontal (greatest angle)</td>
<td>10°</td>
<td>15°</td>
<td>15°</td>
</tr>
<tr>
<td>Number of adjustments</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>F Back to vertical (greatest angle)</td>
<td>15°</td>
<td>20°</td>
<td>15°</td>
</tr>
<tr>
<td>Number of adjustments</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

*Distance measurements made with seat bottom down flat.
†Steering wheel adjusted to position closest to seat.
Table 31 shows dimensions of the steering wheel and gives the relative locations of the steering wheel and foot pedals with respect to the driver's seat. The diameter of the steering wheel and the grip circumference varied from one bus to another; the widest diameter wheel had the smallest grip circumference emphasizing the variability in wheel size - from large 'skinny' wheels to smaller, thicker wheels. All of the wheels were tilted within the recommended tilt range, but the Gillig had the minimum recommended tilt while the Flxible was at the maximum end of the recommended tilt range. Both the Gillig and the GM ADB had a grip circumference close to the recommended dimension of 3.14 inches, the Flxible, with a grip circumference of 2.5 inches, was somewhat further off. All steering wheels were considerably larger than the recommended diameter of 16-17 inches [Woodson, 1981].

The height of the steering wheel above the seat also varied quite a bit from one bus to another with the adjustable wheel allowing for a much closer seat to wheel dimension. Comments from several drivers concerning the misalignment of seats to steering wheels prompted a check on this aspect of the cab layout. All of the buses used for the human factors in-depth study appeared to have the steering wheel and seat well aligned with one another.

One of the study buses, the GM ADB bus, is equipped with an adjustable steering wheel. The shaft of the steering wheel is hinged approximately three fourths of the way down the column. Loosening the lever on the right side enables the driver to tilt the wheel forward or back and tighten it in one of four positions. The tilt of the wheel had a large impact on the angle of the steering wheel (tilt of the plane through the steering wheel to the horizontal plane) allowing it to vary a total of 20 degrees. The tilt of the wheel also affected the height of the wheel above the seat and allowed this distance to vary a total of 3.5 inches.

Seat cover material can have an impact on driver comfort. Cloth covered seats are generally considered more comfortable than vinyl or plastic seats; however, cloth seats also tend to be more expensive and less durable, limiting their actual use in transit vehicles. All of the seats in the current study were covered with smooth or textured
Table 31. Steering Wheel Dimensions

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A Diameter (in.)</td>
<td>20</td>
<td>22</td>
<td>20.75</td>
</tr>
<tr>
<td>Circumference of Grip (in.)</td>
<td>3.5</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>B Angle of Plane through Wheel to Horizontal</td>
<td>15°</td>
<td>30°</td>
<td>Adjustable 10-30°</td>
</tr>
</tbody>
</table>

Location in Cab

| C Back Edge of Wheel to Back Edge of Accelerator Pedal (in.) | 11 | 13 | 15-18 |
| D Center of Accelerator Pedal To Center of Steering Wheel Base (in.) | 10.5 | 10 | 11.5 |
| Wheel Alignment with Seat | Good | Good | Good |
| E Bottom of Steering Wheel to Floor (in.) | 26.5 | 28 | 22.5-26 |
| F Bottom of Steering Wheel to Seat Bottom* (in.) | 8 | 7 | 2.5-6 |

*Seat adjusted to highest vertical position.
vinyl. Two of the seats had air holes in the vinyl - an important feature for adequate ventilation on hot days [Hutchinson, 1981].

The general work space of the driver was considered to be from the window on the left to the left edge of the fare box on the right; the passenger separator in the back to the windshield in the front. The overall dimensions of the cab determine the atmosphere and general feeling of spaciousness or narrowness of the cab as a whole. Cab dimensions varied quite a bit from one bus to another with the Gillig Phantom giving the smallest work space and the GM ADB providing the roomiest cab layout, but all dimensions were considerably larger than the minimum recommendations made by Woodson. Pedal angles were fairly uniform from one bus to another with 35 to 40 degree angles being the norm. The 35 to 40 degree angle clearly exceeded the Woodson recommended angle of 15 to 30 degrees [Woodson, 1981]. Pedal angles, cab dimensions, and seat cover materials for the three study buses are shown in Table 32.

As discussed in the Literature Review (Chapter III), a comprehensive study was done by the Essex Corporation in 1972 directed toward the standardization of control locations. Toward this end, a standardized Essex panel was developed based on the following specific guidelines:

- follow established conventions
- use the right hand rule (placing controls used when the vehicle is in motion on the right side of the steering wheel)
- group controls and displays by common function
- ensure quick response to higher priority controls and displays
- ensure minimum hand-off-wheel and eyes-off-road time
- locate and code controls to be identifiable without visual access

None of the buses examined in detail conformed very closely to these guidelines. The right hand rule was not followed on any of the buses and controls used when the vehicle is in motion were placed in a variety of locations including the left hand panel, the front panel (to the left of and behind the steering wheel) and the right side seat.
Table 32. Cab Dimensions and Pedal Angles

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of Seat to Left Edge of Farebox (in.)</td>
<td>22</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Center of Seat to Window (in.)</td>
<td>18</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>Windshield to Back of Cab (in.)</td>
<td>48</td>
<td>51</td>
<td>53</td>
</tr>
<tr>
<td>Cab Area (sq. in.)</td>
<td>1920</td>
<td>2244</td>
<td>2544</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerator Pedal with Floor</td>
<td>40°</td>
<td>40°</td>
<td>43°</td>
</tr>
<tr>
<td>Brake Pedal with Floor</td>
<td>35°</td>
<td>40°</td>
<td>43°</td>
</tr>
</tbody>
</table>
Controls and displays were grouped by common function to some extent in every bus. The three wiper controls (one for each blade separately and one for both blades together) were consistently together, as were wheel chair lift controls. However, engine condition displays, light controls, and environment controls were not normally grouped together. Hazard light controls typically were marked by long plastic ends which made them easily identifiable and ensured a quick response. Most other controls were identically coded with simple toggle switches; the similarity between control switches makes them difficult to identify without visual access, and does not ensure a quick response to the highest priority controls.

C. ANTHROPOMETRIC STUDY PROCEDURE

The next component in the study of transit bus cab layouts was an anthropometric analysis of the cab using human subjects of various percentiles. Anthropometry refers to the study of the measurement of humans; a study that is essential for the proper design of any equipment used by humans. Most equipment is designed to accommodate 90% of the user population. Equipment that cannot be designed to accommodate this range of people with fixed dimensions will usually be adjustable. Since women are typically smaller than men, equipment designed for use by both men and women will normally be designed to accommodate 5th percentile women at the lower end of the scale and 95th percentile men at the upper end of the scale. The question raised by the data collected in the current research was whether the adjustments of the bus seats are adequate to insure a comfortable and safe seating position for the current transit driver population. To answer this question, a checklist of the most pertinent driver dimensions, Figure 6, was developed using the literature and the cab layout criteria as a guide. Assuming that the bus cab should be designed to accommodate 90% of the user population (including both men and women), a 5th percentile woman and a 95th percentile man were chosen as the subjects for measurements in the bus cab. Fiftieth percentile men and women were
### ANGLES

<table>
<thead>
<tr>
<th>Angle Description</th>
<th>5th% W</th>
<th>50th% W</th>
<th>50th% M</th>
<th>95th%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body angle in seat (90-110)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee angle (95-135)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper arms to torso (20-30)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper arms to vertical (20-45)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle between foot and horizontal (90-110)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow angle (120 max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfortable driving position</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended for turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist Angle (170-190)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfortable driving position</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended for turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### DISTANCES

<table>
<thead>
<tr>
<th>Distance Description</th>
<th>5th% W</th>
<th>50th% W</th>
<th>50th% M</th>
<th>95th%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drivers eyes to windshield (horz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drivers eyes to dash (vert)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top of leg to steering wheel (vert)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back of knees to seat cushion (vert)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


---

**Figure 6. Anthropometric Study - Driver Dimension Checklist**
also measured to determine the appropriateness of the cab layout for the "average" driver.

In selecting the individuals fitting the particular percentiles, choices were made based upon the two variables of height and weight. As Kyropoulos and Roe [1968] pointed out, a truly 5th, 50th, or 95th percentile person does not exist because it is unlikely that any one person exhibits more than one or two dimensions in a small range around a particular percentile. Therefore, while the variables of height and weight will not be adequate to completely define a subject in a particular percentile, they are appropriate to identify an individual who is close to a particular percentile. Additionally, height and weight are common measures that are known by most people, and these measures provided a quick and convenient reference point during the identification process. Leg length, arm length and age were also determined for each subject, but were not used in the identification process.

The subjects used in the test were not experienced drivers; this population provided the advantage of an unbiased approach to the various buses and perspectives free of preconceived notions. The disadvantage of using non-driver test subjects is that the perspectives and comments of the subjects are devoid of the driving experience that transit drivers could draw upon. All of the subjects were white, caucasian, individuals - a group representative of the majority of Oregon transit drivers. Height and weight of the percentile groups, collected from several sources, are shown in Table 33; Table 34 shows the dimensions of the subjects used in the study.
Table 33. Anthropometric Data

<table>
<thead>
<tr>
<th></th>
<th>50th Percentile Woman</th>
<th>50th Percentile Man</th>
<th>5th Percentile Woman</th>
<th>95 Percentile Man</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Height</td>
<td>5' 2.9&quot;</td>
<td>5' 3.2&quot;</td>
<td>5' 4.1&quot;</td>
<td>5' 8.3&quot;</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>137</td>
<td>135</td>
<td>122</td>
<td>166</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th></th>
<th>Woman</th>
<th></th>
<th>Man</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5th Percentile</td>
<td>50th Percentile</td>
<td>50th Percentile</td>
<td>95th Percentile</td>
</tr>
<tr>
<td>Height (Stature)</td>
<td>61.5&quot;</td>
<td>64&quot;</td>
<td>71&quot;</td>
<td>73&quot;</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>103</td>
<td>145</td>
<td>183</td>
<td>217</td>
</tr>
<tr>
<td>Leg Length</td>
<td>34.50&quot;</td>
<td>37.75&quot;</td>
<td>38.50&quot;</td>
<td>40.25&quot;</td>
</tr>
<tr>
<td>(Hip to Ankle)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Length</td>
<td>37.5&quot;</td>
<td>40&quot;</td>
<td>42.5&quot;</td>
<td>43.5&quot;</td>
</tr>
<tr>
<td>(Hip to Floor)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm Length</td>
<td>19.88&quot;</td>
<td>20.75&quot;</td>
<td>22.25&quot;</td>
<td>23&quot;</td>
</tr>
<tr>
<td>(Shoulder to Wrist)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>23</td>
<td>24</td>
<td>52</td>
<td>46</td>
</tr>
</tbody>
</table>
Research Technique Considerations

As mentioned previously, in the research techniques section human factors research does not typically lend itself to neatly compact quantitative experiments as many branches of science do. Nevertheless, careful scientific experimentation is possible and essential to evaluate human factors improvements in procedures and equipment. Chapanis [1959] described the important features that an experiment in human research includes:

"It is a series of controlled observations undertaken in an artificial situation with the deliberate manipulation of some variables in order to answer one or more specific hypotheses."

The importance of the controlled observations is that with the situation controlled and specified, the experiment can be repeated by other investigators and the results can be publicly verified. One of the possible disadvantages of the controlled observation is that it results in an artificial situation being studied. Although driving a bus is usually a dynamic function, data in the current research was collected on subjects in a static situation. Somewhat different results may possibly be obtained with the measurements of actual drivers at work, but control of the real life situation is not possible and elements of distraction to the driver along with time and money constraints made this type of research infeasible. The variables that were deliberately manipulated in this study were the size of the subjects to be measured in the vehicle cockpit. The systematic variation of subject size resulted in another artificial element in that the subjects were lay people of the appropriate percentile rather than actual bus drivers.

Finally, the purpose of manipulating the size of subjects was to evaluate a hypothesis involving the appropriateness of current vehicle dimensions and locations for the present population of drivers. While the small sample size of four subjects (one from each percentile) will not allow statistically significant tests to be completed, the clearly marked trends in the data allow for some conclusions to be made. In summary, while the current research is not a comprehensive experimental
evaluation of transit vehicle dimensions and relationships, it is, nonetheless, a valid beginning in the study of the anthropometric considerations of transit vehicle design.

Before any measurements were made, the subjects were asked to adjust the seat to a comfortable driving position. All possible adjustments of the seat were explained and the subjects were given adequate time to identify the most comfortable seat position. Two separate sets of measurements were made for each subject. First, a quantitative analysis of driver comfort was done by measuring the pertinent body angles of each subject. Measurements were made using a goniometer, a protractor type device with two movable arms; goniometers are commonly used by physicians to measure joint angles and served well to measure the body angles of the subjects. Certain body angles (elbow, wrist, and back to seat) were measured both in the comfortable driving position and when the arm was extended to the top of the steering wheel for turning. Secondly, a more qualitative study of driver comfort was done by asking the subjects to reach for various controls and requesting their subjective observations on the ease and comfort of control operations.

Quantitative Analysis of Driver Comfort

As mentioned earlier, several studies have focused on the body angles needed to insure a comfortable driving position [Grandjean, 1980; Huchingson, 1981; Rebiffe, 1982]. While these studies have been undertaken with automobile drivers in mind, the focus on driver comfort readily avails them for transit driver studies as well. The angles determined by the different studies agree with a surprising consistency on the optimal angle limits; angles determined by Rebiffe [1982] were used as a reference for the current study.

The transit driver's body position is constrained primarily by three vehicle components (or controls) the three points where the driver is in nearly continuous physical contact with the vehicle. These three components are the driver's seat, the steering wheel, and the accelerator pedal. In order for a work space to be completely adjustable and adaptable to individuals of different sizes, two of the
three constraints must be adjustable. This consideration was pointed out by Cakir, Hart and Stewart [1980] in their discussion of office work station layouts, "Having fixed any one of the three variables ..., both of the remaining two must be adjustable."

However, the adjustability of two out of three constraints alone, will not insure a comfortable and adaptable design. Anthropometric considerations of the size of the driver population must also be taken into account. In other words, the range of adjustments must be appropriately spaced within the vehicle to insure comfortable and safe driving positions for all of the driving population.

Table 35 shows the pertinent body angles measured for each of the subjects on each of the study vehicles, along with the comfortable body angles recommended by Rebiffe. As seen in Table 35, the body angles of all of the drivers were within the comfortable range. The seat angle adjustments were fairly similar for all the buses with three seat pan angles and four seat back positions possible. The comfortable body angles for all four subjects indicate that these adjustments are adequate to provide the driver population with a comfortable body angle. The majority of knee angles were also within the comfortable ranges. The majority of ankle angles, on the other hand, were more acute than the angles recommended by Rebiffe. Ankle angles were close to the recommended range and allowing for some error in measurement (plus or minus ten degrees), would bring them within the appropriate range. However, the angles would still be on the high end of a comfortable range. The ankle angle was noted by both the 5th percentile woman and the 95th percentile man to be quite awkward and uncomfortable on certain buses. The ankle angle can be increased by the driver moving his/her foot up on the pedal - a strategy tried by the 5th percentile woman. However, moving the foot up on the pedal may require more muscular effort since the heel support of the floor is removed and also the knee angle will be increased - perhaps beyond the comfortable position.

Even allowing for measurement errors of plus or minus ten degrees, arm angles for all subjects were still distinctly outside of the comfort zone recommended by Rebiffe. Since nearly all of the knee angles were within the comfortable range, it appears likely (and
Table 35. Body Angle Measurements for Anthropometric Study

<table>
<thead>
<tr>
<th>Pertinent Angles</th>
<th>Woman</th>
<th>Man</th>
<th>Comfortable Angle Recommended by Rediff *</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A Body Angle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus Make</td>
<td>5th Percentile</td>
<td>50th Percentile</td>
<td>50th Percentile</td>
</tr>
<tr>
<td>Gillig</td>
<td>110</td>
<td>105</td>
<td>100</td>
</tr>
<tr>
<td>FLX</td>
<td>110</td>
<td>100</td>
<td>102</td>
</tr>
<tr>
<td>ADB</td>
<td>97</td>
<td>105</td>
<td>100</td>
</tr>
<tr>
<td>GMC</td>
<td>102</td>
<td></td>
<td>110</td>
</tr>
</tbody>
</table>

| **B Knee Angle** |       |     |                                          |
| Bus Make         | 5th Percentile | 50th Percentile | 50th Percentile | 95th Percentile |
| Gillig           | 145   | 118 | 132                                     | 115 | 95-135 |
| FLX              | 125   | 117 | 145                                     | 100 |
| ADB              | 113   | 113 | 130                                     | 103 |
| GMC              | 136   |     | 118                                     |     |

| **C Ankle Angle** |       |     |                                          |
| Bus Make          | 5th Percentile | 50th Percentile | 50th Percentile | 95th Percentile |
| Gillig            | 80    | 80  | 88                                      | 85  |
| FLX               | 90    | 84  | 90                                      | 88  |
| ADB               | 85    | 90  | 94                                      | 80  |
| GMC               | 84    |     | 75                                      |     |

| **D Upper Arms to Torso Angle** |       |     |                                          |
| Bus Make                | 5th Percentile | 50th Percentile | 50th Percentile | 95th Percentile |
| Gillig                  | 55    | 57  | 55                                      | 60  |
| FLX                     | 70    | 50  | 52                                      | 52  |
| ADB                     | 55    | 55  | 65                                      | 70  |
| GMC                     | 47    |     | 44                                      |     |

| **E Elbow Angle** |       |     |                                          |
| Bus Make          | 5th Percentile | 50th Percentile | 50th Percentile | 95th Percentile |
| Gillig            | 130   | 125 | 124                                     | 130 |
| FLX               | 157   | 125 | 124                                     | 130 |
| ADB               | 135   | 130 | 157                                     | 117 |
| GMC               | 124   |     | 122                                     |     |

| **Extended**      |       |     |                                          |
| Bus Make          | 5th Percentile | 50th Percentile | 50th Percentile | 95th Percentile |
| Gillig            | 165   | 165 | 170                                     | 180 |
| FLX               | 180   | 180 | 170                                     | 180 |
| ADB               | 180   | 180 | 170                                     | 180 |
| GMC               | 180   |     | 180                                     |     |

| **F Wrist Angle** |       |     |                                          |
| Bus Make          | 5th Percentile | 50th Percentile | 50th Percentile | 95th Percentile |
| Gillig            | 155   | 140 | 158                                     | 155 |
| FLX               | 180   | 157 | 180                                     | 153 |
| ADB               | 180   | 170 | 180                                     | 160 |
| GMC               | 161   |     | 180                                     |     |

| **Extended**      |       |     |                                          |
| Bus Make          | 5th Percentile | 50th Percentile | 50th Percentile | 95th Percentile |
| Gillig            | 180   | 170 | 170                                     | 170 |
| FLX               | 180   | 160 | 180                                     | 174 |
| ADB               | 165   | 180 | 180                                     | 180 |
| GMC               | 180   |     | 180                                     |     |

discussions with some of the drivers confirmed) that drivers adjust the seat to achieve a comfortable leg position. Given the fixed position of the steering wheel, the driver is then constrained to a less comfortable arm angle. The fifth percentile woman commented on the awkward and uncomfortable position that resulted when she held the steering wheel on either side in the typical driving position. Greater arm comfort was achieved by holding the wheel further down at the point closest to her torso, but this position has the disadvantage of limiting vehicle control. The upper-arm-to-torso angle is directly related to the elbow angle, and both tend to become more acute as an individual moves closer to the fixed object he/she is grasping. For example, if the driver is grasping a fixed position steering wheel, and moves the seat forward, both the upper arm to torso angle and the elbow angle (along with the knee and ankle angles) will simultaneously become more acute.

According to one Portland trainer, drivers are advised to turn the bus using a sort of 'hand to hand shuffle' at the bottom of the wheel closest to the driver's torso. Many drivers, however, find this maneuver awkward, and instead turn the bus by pulling the wheel around to one side or the other with their hand gripping one point on the wheel and bringing it around. This pulling procedure may also be preferred on manual or stiff steering buses where the additional leverage provides more force for turning the wheel. Given the current steering wheels, the pulling maneuver requires the driver to fully extend his/her arm when the hand reaches the top of the wheel.

The large size of the current steering wheels tends to augment the arm angle problems. All of the steering wheels were considerably larger than the 16-17 inch diameter recommended by Woodson [1981]. While the larger wheel provides more leverage for manual steering buses, many of the present power steering buses may not require such a large wheel. Admittedly, there may also be some advantages to the large wheel such as a consistent size with the older manual steering buses, and the fact that drivers are used to a larger wheel, but a smaller wheel would decrease arm extension, and perhaps provide a more comfortable driver work place.
It is interesting to note that even on the GM ADB bus, which is equipped with an adjustable steering wheel, elbow angles were still above the recommended 120 degrees. Once again, all of the drivers tended to adjust the seat first, achieving comfortable leg angles and then, secondly, to adjust the steering wheel. Only the 95th percentile man achieved a comfortable elbow angle; all of the other subjects adjusted the steering wheel as far forward as possible achieving the minimum possible elbow angle. Still, due to seat constraints (for a comfortable leg angle), none of the drivers achieved elbow angles within the comfortable range.

One solution to the problem of extended arm angles involves a combination of pedal placement and steering wheel adjustments. Neither one of these changes would be adequate, by itself, to provide comfortable arm angles for a range of driver sizes, but together, strong potential exists for a more comfortable vehicle design. As mentioned earlier, it was observed that drivers tend to adjust the seat to obtain a comfortable leg angle. Given this leg angle, the location of a fixed steering wheel dictates their arm angle. Both of the fixed position steering wheel buses (the Gillig and the FLX) had the pedals and steering wheel located in a position that made comfortable arm angles unobtainable for the majority of subjects. Moving the pedals further back from the steering wheel could allow the seat to be adjusted to achieve a comfortable knee angle and still allow for the steering wheel to be close enough for the driver to achieve a comfortable arm angle.

Moving the pedals alone, however, would not provide a comfortable arm angle for all drivers. As mentioned earlier, given three critical equipment constraints, two of those constraints must be adjustable in order to fit a wide range of individuals. Due to mechanical design features, adjustable foot pedals are not a practical option; therefore, the steering wheel along with the driver's seat must be adjustable to facilitate a comfortable driver position for the majority of drivers. But, again, as mentioned earlier, an adjustable steering wheel alone will not provide optimal driving positions on the current transit buses. Although the steering wheel on the GM ADB is adjustable to four positions, three of the four subjects adjusted the wheel to its lowest
position and still realized an extended arm angle. A different placement of the pedals in conjunction with an adjustable steering wheel is needed to insure a comfortable arm angle for a wide range of individuals.

Wrist angles and the associated steering angle should also be considered in relation to an adjustable steering wheel. Given a more comfortable and smaller arm angle, the steering wheel may need to be tilted more to achieve the comfortable wrist angle of 170 to 190 degrees. Ideally, the steering wheel might be equipped with two adjustments; one adjustment of the column (as on the GM ADB) to insure a comfortable arm angle, and a second adjustment for the angle of the wheel itself (to the horizontal plane) to insure a comfortable wrist angle.

In summary, it is clear from Table 35 that drivers of all sizes are maintaining suboptimal body positions on each of the buses studied. Some transit officials felt that a lack of knowledge of possible seat adjustments were responsible for the seat problems. While a lack of seat adjustment know-how would probably lead to suboptimal driver positions, it is clear from Table 35 (data from drivers that were aware of all possible seat adjustments) that potential dimensional and design problems within the vehicle may also account for less than optimal driver body positions.

The subjects in the study tended to adjust the location of the seat to achieve the most comfortable leg position, and as a result, seemed to incur less comfortable arm and ankle positions. The body position problems themselves were not particularly more evident for smaller women than for the larger male drivers, but additional subjective comments and observations pointed out additional problems for the smaller female drivers. Since several critical dimensions such as leg length and arm length will differ among individuals of a particular percentile, further study with a larger sample size of each percentile is needed to conclusively evaluate current vehicle dimensions.
Qualitative Control Location Study

The second part of the in-depth study was a slightly more subjective approach encouraging examination of design aspects that might be missed in a completely objective measurement study. Each subject was asked to reach for certain specified vehicle controls, and their body position and any awkward or strained movements were noted. Additional observations, notes and comments were made on lumbar and shoulder support of the seat, and the visibility of controls, mirrors, and the road.

Two factors that help to determine the appropriate location of a vehicle control are first, the times that a control is used - i.e. when the bus is in motion or when it is stopped; and secondly, the frequency of control use. Using two categories for each of these factors, a four part matrix results. Controls in each of the four categories were chosen for the current study as shown in Table 36. From an occupational safety point of view, it is probably most important that the most frequently used controls be placed in a position that is easily accessible and causes least strain or fatigue to reach. It is also important that controls used while the vehicle is in motion may be reached easily and be identified rapidly by a quick glance or by feel.

The observations and notes resulting from the second part of the anthropometric study fall into two categories. First, certain vehicle aspects and controls presented some problems for all of the subjects; secondly, certain subjects experienced some problems in all buses.

Each of the study buses had distinctly unique control layouts and all of the study controls had different locations in each vehicle. Each vehicle had at least one control that seemed to be awkward and uncomfortable for every driver. Consistent with the comments of Eugene and Corvallis drivers, the windshield wipers on both the FLX and Gillig are located in positions that appear to cause unnecessary strain for drivers of all sizes. Due to Oregon's wet winters, the windshield wipers are used frequently while the bus is in motion. Wiper controls were located on the front panel directly above the steering wheel column (from the driver's perspective) on the FLX and were located in
Table 36. Controls Chosen for Anthropometric Study

<table>
<thead>
<tr>
<th>Relative Frequency of Use</th>
<th>Time of Use</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vehicle Moving</td>
<td>Vehicle Stationary</td>
</tr>
<tr>
<td>More Frequent</td>
<td>Windshield Wipers</td>
<td>Door Control</td>
</tr>
<tr>
<td>Less Frequent</td>
<td>Heat Control</td>
<td>Destination Signs</td>
</tr>
<tr>
<td></td>
<td>Vent Control</td>
<td>4-Way Hazards</td>
</tr>
</tbody>
</table>
the upper left corner of the front panel on the Gillig. Both of these positions make it necessary for the driver to reach around (or through on the FLX) the steering wheel in order to activate the wiper controls. It also required the full arm extension of all drivers and a definite forward lean for the female drivers. The wiper controls were also difficult to see on the FLX as was the speedometer (located the same place - directly above the steering column) on the Gillig.

Minor problems for all subjects on the GM ADB involved activation of the vent and heat controls. Vent controls are located in three different places on the GM ADB - one on the upper right front panel, one on the left side panel - approximately even with the drivers torso, and one on the right side of the seat - on a small panel located on a slant in between the driver's seat and a protective plastic barrier covering the entire panel. The right hand panel controls proved awkward to operate for the men with larger hands and control identification among the eight identical switches on the panel also proved difficult. The left hand panel control was awkward for the women who hit their elbows on the seat back trying to reach the vent control. The front panel vent control required the women drivers to lean forward.

Observations of the percentile subjects on each bus also indicated that smaller women may be at a greater risk for shoulder and back injuries given current vehicle design. The fifth percentile woman adjusted the seat forward as far as possible on both the Gillig and the FLX and commented that a further forward position would have been more comfortable. Even with the seat adjusted as far forward as possible, it was still necessary to lean forward to reach both the windshield wipers and heat controls. The angle between the drivers back and the seat back during these leans was as much as 50 degrees and averaged 43 degrees. The location of the inside mirrors on the Gillig required the fifth percentile female driver to physically tilt her head back and look specifically at the mirror to view the bus (instead of the quick easy glance of most drivers). The 5th percentile subject also commented that the blinker buttons were in an awkward position and the high beam button was difficult to reach. Finally, the large size of the steering wheel caused some tension between the shoulders. Each one
of these problems, by itself or for a short period of time, would probably not cause serious injuries, however, the combined effect of frequent leaning forward and extended arm reaching along with awkward leg movements to operate the blinker buttons could increase the risk of back injury for smaller drivers.

D. SUMMARY - RECOMMENDATIONS

The in-depth anthropometric analysis revealed that there are several areas where the design of transit bus cabs could be improved. First, it appears that following some of the recommended dimensions suggested in design handbooks such as Woodson's could provide drivers with a more comfortable driving position. Uncomfortably acute ankle angles could be eliminated by reducing the pedal angles to the recommended fifteen to thirty degree angle. Extended arm angles could be reduced by moving the pedals further forward with respect to the steering wheel along with providing an adjustable steering wheel. Decreasing the diameter of the steering wheel to the recommended 16-17 inches could also increase the comfort of smaller drivers. Finally, following recommended ranges of seat adjustability would also provide more drivers with a comfortable driving position.

Secondly, certain control locations result in extended arm angles for all drivers and can result in forward leaning for smaller drivers. The control layout guidelines suggested in the Essex report would seem to be a good starting point for locating controls in appropriate positions.

Thirdly, given the increasing population of female drivers, transit bus cabs should be designed with consideration for this emerging group of users. Smaller female driver are currently at a higher risk of back injuries and shoulder problems due to the awkward body positions required to reach several of the controls and the steering wheel on the current buses. A wider range of seat adjustments in combination with an adjustable steering wheel and properly located controls is needed to make the transit bus cockpit comfortably and safely appropriate for the full range of current transit operators.
VII. CONCLUSIONS AND FUTURE RESEARCH

The overall goals of the current research were first, to investigate the human factors problems and occupational safety hazards facing mass transit bus drivers. Secondly, to identify the most pressing human factors problems, and finally, to complete an in-depth study and human factors analysis of the most pressing problem. These goals were achieved with the cooperation and assistance of numerous transit related groups and individuals.

The current research also provided a model for similar research in other states. The methodology developed here involved the collection of both qualitative and quantitative data from numerous sources. The similarity of injury recording systems in several other states will make the quantitative data easily accessible for other studies. However, one area where the quantitative data from the WCD claims files was lacking was with respect to the completeness of the individual accident reports. While the Employer First Report of Injury form (WCD Form 801) provided very useful information on the injury incidents, two additional pieces of information could be easily collected that would enable more complete injury research. First, identification of the type of bus being driven at the time of the incident would allow research into particular problems related to specific vehicle makes. This information was available in approximately two thirds of the WCD files examined; even in these files, the make of the bus was difficult to locate and required searching through the file. A form that included a specific place for the vehicle make would greatly facilitate data collection. Secondly, a space for the time of day that the incident occurred could easily be incorporated into the 801 form. This information would combine well with information on the type of shift being driven (indicating the time that the driver started driving) to enable research into injuries associated with specific times of day as well as research regarding possible fatigue affects and extraboard policies.

Although human factors research does not lend itself to standard scientific experimentation, proven research techniques for human engineering research were carefully applied to provide reliable data
and results. An in-depth study of the most pressing problem was completed, but the research, as a whole, was of a fairly broad scope that will provide a strong foundation for further study of the human factors problems facing mass transit bus operators. A solid overview of the potential problems was developed through extensive data collection to pave the way for continued research regarding specific problem areas.

As mentioned previously, time and money constraints restricted the anthropometric study to four subjects - one from each designated percentile. In order to conclusively determine the precise measurements of the needed design changes, the anthropometric study should be done using several subjects from each percentile.

Further research is also clearly required concerning the driver's seat adjustments. The anthropometric study indicated that present seat adjustments are not adequate for the current driver population. Increasing the adjustable range to the recommended range should alleviate part of the problem, but further study on the optimal range of adjustments would be beneficial.

Regarding driver fatigue and the potential health problems and safety hazards related to it, the data collected in the current study was inconclusive. The literature review revealed some disagreement regarding fatigue affects of long haul truck and bus drivers, though the majority of authors cited certain problems as being related to fatigue. Interviewed drivers were divided in their response to the survey question regarding health and other problems related to fatigue. While drivers were divided on the extent of fatigue effects, many drivers suggested that some driver problems such as back injuries may be directly related to the prolonged sitting of the driver's job. Further research is clearly needed to determine the specific health problems resulting from long driving hours and the potential safety hazards associated with driver fatigue.

In summary, an investigation of the human factors problems facing transit drivers revealed that the most pressing problem facing transit bus drivers is the location and design of the driver's seat. An anthropometric study indicated that current seat locations do not provide optimal body positions for a majority of drivers. Modifica-
tions of seat adjustments along with changes in pedal placement and the installation of an adjustable steering wheel were suggested to reduce the problems. Further study is needed to define specific modifications and the current study will provide a solid foundation for future research of the human factors problems facing transit bus drivers.


Oregon Work Injuries & Illnesses, 1987, Workers' Compensation Department, Salem, Oregon.


APPENDICES
APPENDIX A

Checklists for Transit Agency Visits
CHECKLIST FOR BUS DEPOTS VISITS

AGENCY:  
LOCATION:  
CONTACT NAME:  
DATE:  
TITLE:  

Number of Vehicles in Fleet
Number of Annual Passenger Miles
Number of Annual Passenger Trips
Amount of Annual Injury Compensation to Drivers
Amount of Annual Injury Compensation to Passengers
Major work related driver injuries

Major factors

Major passenger claims

on board

bus stops

entering and exiting

OPERATIONAL POLICY

starting and stopping with passengers standing
driver orientation for elderly and handicapped passengers
designated seats for elderly and handicapped passengers
driver first aid training

are buses equipped with two way radios

policies on handling passenger problems
  on board harassment of drivers
  phone and written complaints

fare collection
  do drivers make change
  do drivers collect fares while bus is moving
  do buses start to move while fares are being collected

crowded buses
  do passengers have trouble reaching buzzer
APPENDIX B

Brainstorming Ideas at Transit Group Workshop
DRIVER SAFETY

ENVIRONMENTAL
- lack of public respect
- driver visibility
- traffic
- weather
- street design
- street maintenance
- bus stop location
- logging trucks
- bicycles
- pedestrians

OPERATIONAL
- overly long shifts
- public reprimand of driver
- rushed schedules
- lack of breaks
- driver screening
- lack of training (including first aid training)
- pre-trip inspection
- traffic at terminal
- post trip inspection - report problems
- bus stop location
- distractions (passenger conversation)
- stress management skills
- boredom
- safety incentives
- long stationary positions
- driver attire
- drug/alcohol testing - pre-employment and random testing
- supervisor relationships
- change of equipment and route

EQUIPMENT
- driver seat and seatbelt
- poorly maintained equipment
- fare box
- power steering (lack of)
- control location
- poorly designed equipment
- driver visibility
- lack of or poor communication equipment
- cab layout
- cab environment control
- step configuration - height and shape
- exhaust fumes
- noise
- temperature variation

DRIVER

- physical conditioning and health
- stress management skills
- personal problems
- physical illness
- drug/alcohol testing - pre-employment and random testing

PASSENGER

- power wheelchairs
- hit by umbrellas
- driver harassment/robbery
- passenger awareness
- sudden demands on drivers
- unruly passengers
BUS STOPS USERS

ENVIRONMENT

- weather & terrain (gravel)
- uneven terrain
- lack of visibility to driver
- curb height variances
- physical - hazards - drop off shoulder
- lighting
- footing - surface - mud, water, potholes ... unknown surfaces
- obstacles
- obvious - lack of privacy while waiting
- bikes and skateboards
- steep slopes at bus stop
- utility fixtures - guy wires
- stops near conflicts and surrounding land use
- newspaper boxes

OPERATIONS - POLICY

- schedule - time
- location/markers
- don't pull up to curb
- closing doors too fast
- accessible interchange points
- crowds
- not accessible
- expectations
- traffic
- stops near conflicts and surrounding land use
- cross walks not near bus stops
- lack of bus stops
- frequency of stops
- lack of tactile bus stop identification
- lack of shelters
- overrunning stops (can't back up)
- stations layout
- not close enough to shelter (cars & bikes passing)
- users not reporting problems
- short transfer periods
- existing layout (transfer point)
UNCONTROLLABLE

- guidance sign - signage - use, bus stop marking etc.
- traffic
- stops near conflicts and surrounding land use
- noise
- cross walks not near bus stops
- traffic control - disregard (left turns)
- education re crosswalk (drivers)
- lack of "talking bus stop"
- narrow sidewalks - wheel chair lifts
- lack of shelters
- newspaper boxes

OTHER

- sexual harassment
- friendly
- identification of bus route/lack of identification
- frequently changing situation - uniformity
ON BOARD PASSENGERS

PHYSICAL

- handrail in center of doorway (artic)
- mid-aisle step (artic)
- non uniform seating height (artic)
- artic trailer door and access
- safe securing of scooter type chairs
- floor covering
- passenger assists and stanchions
- protection from equipment (fare boxes)
- seat design
- wheelchair tiedowns
- window tints - difficult vision
- condensation on windows
- seatbelt
- objects in aisle - strollers, seeing eye dogs, shopping carts
- wet, slippery steps
- step height

OPERATIONS

- designated handicapped areas (Salem)
- cleanliness
- safe securing of scooter type chairs
- boarding while lift is working
- minimizing standees
- miscommunication on timing of lift - coordination between user and operator
- standing during deceleration
- smooth starts and stops
- smoking versus non-smoking
- lack of emergency training
- sharp turns (scooters)
- transverse seats
- driver first aid training
- lurching
- driver being distracted - conversation
- late drivers
- identifying deboarding points
- packages in aisles
- objects in aisle - strollers, seeing eye dogs, shopping carts
- perceptions of safety
OTHER

- boarding while lift is working
- passenger assault
- wheelchair occupant stability
- fear due to white cane - vulnerability
PASSenger - Priorities

1 -- boarding and alighting
2 -- on board movement
3 -- communication
4 -- bus stop safety
5 -- personal safety - vulnerability

Drivers

Problems That Defy Improvement

<table>
<thead>
<tr>
<th>Problem</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>education - both transit and public and communication</td>
<td>4.0</td>
</tr>
<tr>
<td>time and budget considerations</td>
<td>4.5</td>
</tr>
<tr>
<td>dealing with local government</td>
<td>3.1</td>
</tr>
<tr>
<td>driver - communication with management</td>
<td>3.8</td>
</tr>
<tr>
<td>balance between safety and public demand</td>
<td></td>
</tr>
<tr>
<td>behavioral change of drivers</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Wish List

<table>
<thead>
<tr>
<th>Wish</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>change in schedule - adequate time for breaks</td>
<td>5.1</td>
</tr>
<tr>
<td>change in schedule - adequate time for routes</td>
<td>4.8</td>
</tr>
<tr>
<td>reroute to eliminate narrow streets</td>
<td>2.9</td>
</tr>
<tr>
<td>reassignment of vehicles</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Safety Problems

Visual Impairment

<table>
<thead>
<tr>
<th>Impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>vulnerability</td>
</tr>
<tr>
<td>disorientation</td>
</tr>
<tr>
<td>obstacles at stops</td>
</tr>
<tr>
<td>signing</td>
</tr>
<tr>
<td>level of service</td>
</tr>
<tr>
<td>driver familiarity with routes (understand languages)</td>
</tr>
<tr>
<td>driver sensitivity</td>
</tr>
</tbody>
</table>
WHEEL CHAIR USERS

- securement of scooters
- securement of chairs in general
- driver sensitivity
  \hspace{1em} hidden disability
  \hspace{1em} let off near curb cut
- passenger ignore lift beep

OLDER USERS

- kneeling

RECOMMENDATIONS

- passenger assist improvement
- bus location marker so driver knows where to stop for wheel chair lift placement

STATE AND FEDERAL REGULATIONS

- driver qualifications
- driver tests
- driver disqualification
- drug/alcohol changes
- hours of service
APPENDIX C

Driver Survey Summaries
1. What make bus do you most prefer to drive?

100 series  400 series  1000 series
300 series  900 series  articulated  other

1a. Why do you prefer this bus?

No Preference  - 3

100  - 4
now they have power steering
comfortable seat
easy to handle

300  - 11
small, easy to handle  - 9
dependable  -3
seats comfy  - 2
shortest  - 2

400  - 2
easy to handle  - 2
dependable

900  - 25
comfortable  - 9
easier turning  - 4
sensitive power steering  - 11
has heat  - 2
reliable  - 2
better built for city work
quiet
good shocks

1000  - 1
power steering, but not too loose

artic  - 2
most comfortable seat
easiest to handle
2. What make bus do you least prefer to drive?

100 series____ 400 series____ 1000 series____
300 series____ 900 series____ articulated____ other____

2a. Why do you not prefer this bus?

100 - 7
turning is still difficult - 6
is a highway bus (not built for city)
rattles too much

300 - 2
throws driver forward on bumps because wheels are in front of cab

400 - 1
poor suspension

900 - 1
too slow, wheel base too long

1000 - 10
rattles - 3
over steers - can't control - 5
difficult to make smooth stop (transmission)
like a box - doesn't handle well - 2
can't adjust seat to comfortable position - 2

artic - 13
unreliable, breakdowns - 6
unsafe, dangerous to public - 2
seats hurt back
noisy - 3
too clumsy
wheel chair lift unreliable
back end hits objects - 2
too many door to watch
dangerous - too many blind spots
too big - 3

other - 2
1100, 1200 4 - not made for driver comfort, old and unreliable
anything without power steering

700 - 3
noise - 2
uncomfortable
unreliable
Which of the following causes you the most difficulty in operating the bus? e.g.

- controls
- steering wheel
- seat
- brake/accelerator pedals
- fare box
- blinker buttons
- steps
- emergency brake
- other

3a. What type of problem do you experience related to this aspect of the vehicle?

3b. What do you think could be done to correct this problem?

(format for answers is: type of problem - suggested correction)

NONE - 8

SEAT - 27
- no back support - new seats, get seat with cloth cover and back support
- won't go all the way back - keep old 500 seats which were manually adjustable - 2
- height often can't be adjusted (short straps) - have adjustable tie downs - 2
- seats have no vertical in between - they bottom out unless all the way up or down
- wrong position in 100 - have engineers drive bus
- can't adjust enough (11) - buy new seats (4), design new seats, put same seats in all buses, add more adjustments
- not made for thin people - let experienced drivers test seats
- not enough room (3) - use whole compartment, buy new seats (2)
- seats are misaligned (2)
- seats rock
- uncomfortable

BRAKE PEDAL - 4
- sticky, no smooth stop
- brakes vary a lot from bus to bus
- difference in slant of brake pedals causes problems
- hard to push in 300 series - hurts knees

STEERING WHEEL - 2
- 100 - steering is still hard - 2

FARE BOX - 4
- slots too small, bills get stuck (2) - make them bigger (2)
- 900 - fare box is awkward
- fare box in the way
900 - doors close too slowly
mirrors - visibility is limited
emergency brake - old ones hard to pull - get air brakes
window washer - smears and leaves a film
window defroster - doesn’t work and window stays fogged
bell - limit to one pull and dash light
blinker buttons (2) - on column - unreliable
on floor - problem for people with short legs

3c. Do you encounter any problems with the wheelchair lift? If yes, what problems?

NO - 23
   artics don’t work - 14
YES - 11
   artics don’t work - 2
   lift is sticky
   instructions not accurate
   runs don’t allow time to pick up handicapped
   barriers frequently don’t work
   back door lift is a hassle
   dust causes problems
   unreliable

OTHER
   lifts rarely used - 3
   problems with ADB’s - 4

4. Which of the following concerns you most?

vehicle accident_____ shoulder/arm problems_____ assault_____
back problems_____ road conditions_____ traffic_____
schedules_____ other _____________

4a. What could be changed to reduce these concerns?

ALL - 1
NONE - 1

VEHICLE ACCIDENT - 12
   driver stay alert - 3
   better on road training

BACK PROBLEMS - 12
   stretching and exercise program
   better seats with lumbar support - 6
   fewer hours (extra board drivers)

SHOULDER/ARM PROBLEMS - 4
   make ALL buses power steering
ROAD CONDITIONS - 4
  depends on time of year
  fix roads - 2

ASSAULT - 15
  more support from company - listen to drivers; not passengers
  have guards on certain buses (dangerous bus routes)
  enforce laws - 2
  community programs to reduce crime rate
  more fare inspectors
  an emergency button to push so dispatch could hear problems on bus

TRAFFIC - 3
  adjust schedule for heavy traffic - 2

SCHEDULES - 14
  layovers at end of route
  longer lines should have longer layovers at end of line
  loosen schedules - 6
  schedulers drive runs - 2
  adjust schedule to route - 4

5. Have you experienced any work related injuries? Yes____No____

  5a. What was the injury?

  5b. What was the cause?

NO - 18
YES - 21

  back injury(9) - seat bottomed out (2)
    - rear wheel in rut, wheel jerked (problem reoccurs with bad seats)
    - back of seat broke
    - repeated bouncing on spine
    - assault
    - long term seat problem
    - picked up coin

  fell (2) - tripped over phone cord

  shoulder (3) - reached for transfer
    - no power steering
    - changed from 100 to 1000 series

  stress - no communication with the company - company doesn't care about driver

  twisted knee when pushing out from behind steering wheel - assault (2)
  sprained thumb when slipped on wet floor
  tore ligaments in ankle when adjusting outside mirror
hurt finger on steering wheel
strained neck when seat bottomed out
muscle spasm caused by fatigue

6. Do the differences from bus to bus of the following controls and displays cause any problem in the operation of the bus?

<table>
<thead>
<tr>
<th>Control</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>wipers</td>
<td>fuel gage</td>
</tr>
<tr>
<td>blinkers</td>
<td>parking brake</td>
</tr>
<tr>
<td>gear shift</td>
<td>speedometer</td>
</tr>
<tr>
<td>ignition</td>
<td>wheelchair lift</td>
</tr>
<tr>
<td>defroster</td>
<td>door controls</td>
</tr>
<tr>
<td>other</td>
<td></td>
</tr>
</tbody>
</table>

NO - 15
YES - when you change buses - 2
- when you first start driving, different controls are confusing - 4
- hazard lights are hard to find - 6
- minor problems with confusing blinker buttons and high beams
- familiarization period is necessary - 3

NOTE: Most drivers don’t feel that different control locations are a problem. They usually express that it takes awhile to get used to the various buses, but then if you keep changing, it’s no problem. Ranges of how long it takes, until a new driver feels comfortable with different buses and controls varies depending on when the driver started (how many different buses in use at that time) and the driver; it ranges from 2 weeks to 3 months.

Because drivers in general seem to have few problems with any controls, listing the various possible controls as problems seemed superfluous. Drivers also seemed more inclined to talk about the problems with the various controls listed instead of answering the question concerning the difference in control location between buses. Therefor the general question was revised to, "Do the differences from bus to bus of the controls and displays cause any problem in the operation of the bus?"

7. What is the most difficult or demanding part of your job?

nothing - 4
dealing with passengers - 12
staying on schedule - 8
dealing with unsupportive management - 6
dealing with stress - 2
dealing with traffic - 4
long days
being safe with many accident potentials

8. What is the maximum number of hours you have ever driven in a week?

8a. Did driving this much cause you any health or other problems?

NO - 19 drivers: average hours - 67.1 +/- 23.5
YES - 19 drivers: average hours - 75.1 +/- 20.2

problems caused by long hours included:
  fatigue - 12
  stress - 2
  sleepless nights - 2
  muscle spasms - 3
  safety problems - 4

9. In your opinion, what is the biggest concern for passenger safety?

  passengers standing while the bus is in motion - 6
  having conscientious drivers (smooth ride) - 4
  assaults - need more security - 9
  passengers crossing streets to catch bus - 10
  concern for elderly (especially boarding and deboarding) - 6
  putting safety first - before schedule - 2
  harassment/assault - 6
  slick floors
  scheduling - late buses - 2
  passengers standing too close to curb
  vehicle accidents
  well rested drivers

10. If you had a wish list for changes in the equipment or operational procedures of your job, what would be your first three wishes?

  VEHICLES
  better seats - 11
  definite training session on seats
  artic would start easily; less breakdowns - 2
  upgrade buses - get rid of 1200, 1100
  maintenance of steering/better maintenance - 4
  newer buses - 3
  move lifts to front door - 3
  better visibility (no glare) - 3
  heat for all buses - 2
  blinkers on floor and work
  equipment with standardized controls
  power steering for all buses
  quieter buses
  better shocks
  more leg room
  inside rear view mirror standardized
  clean buses inside
SCHEDULE
more layover time and breaks - 7
change schedule to fit routes - 6
loosen schedule to accommodate problems (i.e. elderly)

FARE SYSTEM
not allowing passengers on at end of line
one way transfers/less time consuming transfers
passengers pay as they exit
educating public concerning transfers, boarding etc.
change fare system
eliminate Farley square - 3
new electronic fare box
lower fare - increase ridership

POLICY
eliminate split shifts - 2

OTHER
more protection for operators (assault) - 5
more supportive management - 10
more pay - 2
sign vacation time one day at a time
no overtime or part time - everyone work 8 hours
more training (6 weeks)
weed out poor drivers
good music for buses
fewer supervisors
DRIVER SURVEY

Date _December 9, 1987_  
Time _8-10:30 am & 1-4 pm_  
Agency _LANE TRANSIT DISTRICT_  
M 17 F 2 
age 46.4 +/- 7.2

# of yrs driving - 20.8 
avg hrs/day 12 dr-8 hr;7 
avg hrs/week 12 dr-40 hr;29 
part - 4 full - 12 extra - 3

1. What make bus do you most prefer to drive?

   Gillig Phantom - 8  Flexible - 7  Canadian GMC - 4

   1a. Why do you prefer this bus?

   GILLIG PHANTOM - 8

   most comfortable - 2
   easiest to drive - 6
   best visibility
   best seat

   FLEXIBLE - 7

   most comfortable seat - 2
   better quality - 2
   design for all streets
   easiest handling
   best viability
   wheel chair lifts are fast
   compartment for driver belongings

   CANADIAN GMC - 4

   easiest to negotiate - 3
   like location of controls
   best viability

2. What make bus do you least prefer to drive?

   Gillig Phantom  Flexible  Canadian GMC

   2a. Why do you not prefer this bus?
GILLIG PHANTOM - 5

too big for streets - 5
difficult to steer
seat not comfortable
poor visibility

FLEXIBLE - 4

floats - 2
seat hurts back
rattles

CANADIAN GMC - 10

less comfortable seats - 5
noisy/rattles - 3
rough ride - 2
poor steering - 2
floats
breaks down
poor location of windshield wiper

3. Which of the following causes you the most difficulty in operating the bus? e.g.

controls ___ steering wheel ___ seat ___ brake/accelerator pedals ___
fare box ___ blinker buttons ___ steps ___ emergency brake ___
other __________

NONE - 8

SEAT - 6

OTHER - 5

3a. What type of problem do you experience related to this aspect of the vehicle?

3b. What do you think could be done to correct this problem?

(format of answers: type of problem - suggested correction)

SEAT - 6

uncomfortable seats - provide higher back, more adjustments
legs and back hurt - get better seats, better adjustments - 2
seats get worn out and are offset from steering wheel - check for squareness
seats aren't adjusted for short people and seat adjustment over maxi-button
can't adjust seats for comfort - get more and better adjustments
seats aren't comfortable for long periods - get "7 way seats" - perfect
chiropractic position

OTHER - 5

emergency lights on floor are difficult to locate
radio calls are distracting while driving
gear shift is in awkward position in 700 - put in little electric shift
brake/accelerator pedals are at the wrong angle
brake on 700 is out of place - different location for brake
middle of door on 800 is too wide for good viability - install bigger windows

3c. Do you encounter any problems with the wheelchair lift? If yes, what problems?

NO - 6  YES - 13

mechanical problems - 6
lift too slow - 4
lift comes off rails - 2
need larger lip at end
need more room at front of bus for wheelchair to turn around
tie downs should be improved, lap belt is needed
wheel chair lifts don't go all the way down
lift sometimes won't come up

4. Which of the following concerns you most?

vehicle accident___  shoulder/arm problems___  assault___
back problems____  road conditions______  traffic______
schedules____  other ____________

4a. What could be changed to reduce these concerns?

TRAFFIC - 11
  enforce bike rules
  enforce jay walking rules so pedestrians don't walk in front of bus
  cooperate with planning section for scheduling
  make bus lanes downtown; eliminate narrow lanes

VEHICLE ACCIDENT - 7

SCHEDULES - 5
  provide breaks for drivers
  loosen schedules - 4

BACK PROBLEMS - 5
  get better seats
  properly maintain seat cushions

ROAD CONDITIONS - 3
  stop buses when roads are icy - 2
streets are too small for 800 buses

SHOULDER/ARM PROBLEMS - 2

OTHER - 6
change the policy of part time drivers being penalized for absences - part timer currently drive when sick because they want to be full time
stress

5. Have you experienced any work related injuries? Yes - 6 No - 13

5a. What was the injury?

5b. What was the cause?

BACK - 2
wheel chair lifts that malfunctioned
assaulted by passenger

AND SHOULDER
drivers seat and changing signs

AND NECK - 2
car rearended bus - 2

SHOULDER
400 bus without power steering

6. Do the differences from bus to bus of the following controls and displays cause any problem in the operation of the bus?

wipers__ fuel gage__ panel light switch__ horn__
blinkers__ parking brake__ headlight switch__ heater__
gear shift__ speedometer__ high beam switch__
ignition__ wheelchair lift__ interior light switch__
defroster__ door controls__ other________
12 drivers claimed no problems

COMMENTS
switches for 700 are hidden
different controls are all a problem when you first start driving, but
after 3 weeks, they're not a problem
different controls are not a problem if you change buses frequently

NOTE: Some drivers responded more to the question of whether there
where problems with the location of any of these controls; rather than
responding that the differences in location from bus to bus where a
problem.

7. What is the most difficult or demanding part of your job?

handling difficult passengers - 9
dealing with first line supervisors - 5
maintaining the time schedule - 2
working split shifts
getting too involved in public (friendly driver - hears problems of
regular passengers)
continuous defensive driving - creates stress
getting to work on time (not allowed to be one minute late)

8. What is the maximum number of hours you have ever driven in a week?

8a. Did driving this much cause you any health or other problems?

10 drivers said no problem - avg hours/week 66.8 +/- 12.8
6 drivers said yes problems - avg hours/week 70.7 +/- 11.4
stress - 2
safety problems - 3

9. In your opinion, what is the biggest concern for passenger safety?

passengers standing while the bus is moving - 6
conscientious drivers - 2
schedules are so tight - passenger safety is sacrificed
safety belt for passengers
comfortable and safe ride
necessary sudden stops throw passengers forward
slippery floor on 800
boarding and deboarding problems
small children without supervision

10. If you had a wish list for changes in the equipment or operational
procedures of your job, what would be your first three wishes?
SCHEDULES
make schedules less tight - 6
   (put on more buses and have intersecting lines)

VEHICLE
reduce window glare - 2
better seats
change location of wiper controls

POLICY
eliminate split shifts - 2 (one driver pointed out that since most
   accidents occur within the first hour of driving, split shifts
double the accident risk)
reduce mandatory extraboard hours to 8 hours (currently 12)
better working hours (low seniority get poor shifts)
stop paying overtime to some drivers when part timers don't have a full
   shift
change policy that part timers are penalized of absences - 2

OTHER
improve employee versus management relations
set up routes so passengers aren't confused
eliminate 800 buses (800's are too big for Eugene)
more $
reduce noise level on bus (don't have radio on for all calls) - 2
keep school runs separate from regular runs (because kids are noisy)
DRIVER SURVEY

Date 12/15/87 - 12/17/87 # of yrs driving 12.6 +/- 18.9
Time 9-12 am 1-4 pm avg hrs/day 8.5
Agency CHERRIOTS avg hrs/week 42.5
M - 25 F - 4 all full time drivers
age 45.4 +/- 9.8

3. Which of the following causes you the most difficulty in operating the bus? e.g.

controls___ steering wheel___ seat___ brake/accelerator pedals___
fare box___ blinker buttons___ steps___ emergency brake___
other_________

3a. What type of problem do you experience related to this aspect of the vehicle?

3b. What do you think could be done to correct this problem?

SEAT - 12
seats don't go back far enough (because of radio behind seat) - 4
seats need more adjustments to fit properly - 4
some seats don't fit properly - buy better seats/don't cut costs on seats - 3
plastic/vinyl cover is uncomfortable - cover seat with cloth instead
one seat adjustment is directly under the seat belt - move the seat belt
driver can't get in a comfortable position - seat changes from bus to bus
back of legs hurt and there is no room to stretch legs

FARE BOX - 3
difficult to see at night - put light in fare box
is a distraction while driving - simplify fare paying procedure
too far away to reach comfortably (comment by small female) in the way

BRAKE/ACCELERATOR PEDALS - 3
brakes differ from bus to bus; it can be difficult to adjust to the correct pressure - manufacture brake pads all alike - 2
brakes squeak

EMERGENCY BRAKE - 2
snaps knuckle - put in a different lever (female)
hard to pull (female)
OTHER - 4
other cars don't use blinkers - give more citations - law enforcement of traffic violations
mirrors - center mirror inside blocks view of right hand mirror glare on windshield - put in footlights instead of ceiling lights radio speaker hurts right elbow when reaching for flashers

3c. Do you encounter any problems with the wheelchair lift? If yes, what problems?
21 drivers said no problems (but several said lift doesn't always work
3 drivers said yes problems - lift is slow
- lift may bind when it goes up and down
- some wheelchairs don't fit the lift

4. Which of the following concerns you most?

vehicle accident___ shoulder/arm problems___ assault___
back problems___ road conditions___ traffic___
schedules___ other _____________

4a. What could be changed to reduce these concerns?
NONE - 2

TRAFFIC - 10
other erratic drivers are a problem
- increase law enforcement so cars obey traffic rules
- increase flexibility in routes with layovers in non-peak hours
- dispatch buses on time
- change routes so there are no unsafe turns

VEHICLE ACCIDENT - 9
- reduce management pressure concerning accidents (fear of loosing job for one accident) - 2
- make management more understanding of problems - i.e. tree branches that haven’t been trimmed hit bus and driver is charged with the accident
- change routes so you use streets with traffic signal control
- loosen schedules so you have time at the end

BACK PROBLEMS - 6
- start an exercise program - 3
- get air cushioned seats
- redesign seats

SHOULDER/ARM PROBLEMS - 6
- caused by stress - reduce stress by getting more support from management in dealing with passengers
- injury caused by non-power steering bus - get power steering in bus old worn out buses and lack of repair cause problems
- redesign seats
- provide exercise area and paid exercise time

SCHEDULES - 4
- change schedules so they are consistent and drivers get to the various stops at the same time each day
- go back and lay out routes with a bus instead of a car
- schedules should be adjusted for the time of day - so you have more time when there is more traffic

OTHER - 2
children running in front of bus
neck problems

5. Have you experienced any work related injuries? Yes___No___
   5a. What was the injury?
   5b. What was the cause?
   NO - 18   YES - 11
shoulder/arm injury - caused by bus without power steering - 5
   - caused by vehicle accident
   - caused by assault
back injury - caused by being rear-ended - 2
   - caused by fall
   cut thumb while trying to adjust seat

7. What is the most difficult or demanding part of your job?
dealing with passengers/public - 8
dealing with traffic - 6
living by time - minutes - staying on schedule - 4
inside lights causing glare on windshield - 2
split shifts - lack of family time - 2
not having two days off together - lack of family time - 2
not knowing who wants to get on the bus (lack of designated stops)
running unsafe routes
frustration of seeing things that need to be changed (branches in road etc.) and not being able to change them
responsibility for lives and vehicles
bike lanes and cyclists that don't think and aren't aware of traffic
early shift - getting up early

8. What is the maximum number of hours you have ever driven in a week?
   8a. Did driving this much cause you any health or other problems?
   9 drivers driving 50+ hours/week (avg. 59 hours/week) said there were no problems
15 drivers driving 60+ hours/week (avg. 66 hours/week) said yes there were problems including stress, weak vision, poor judgement, poor attitude, exhaustion and then illness, mental fatigue, and fatigue in general.

NOTE: The majority of drivers agreed that driving 60+ hours is bound to cause fatigue - both mental and physical. A minority of these drivers feel that the fatigue causes definite safety problems. Several drivers indicated that there were no safety problems if the long hours were for a relatively short term (1 to 3 weeks).

9. In your opinion, what is the biggest concern for passenger safety?

- Passengers standing while the bus is in motion - 14
- Passengers crossing in front of bus to catch the bus - 7 (some drivers feel that designated stops would solve this problem)
- Boarding/deboarding accidents - falls - 5 (some drivers feel that 4 instead of 3 steps would make boarding safer - especially for elderly passengers)
- Slipping on wet steps - 4
- Lack of seat belts - 2
- Lack of padding on rails and stanchions
- Lack of supervision for small children

10. If you had a wish list for changes in the equipment or operational procedures of your job, what would be your first three wishes?

**VEHICLE**
- Air conditioned buses - 3
- Better bus seats - adjustable for weight and contour - 2
- Have ceiling lights only at back of bus or use footlights to reduce windshield glare - 2
- Better mirrors inside so you could see the whole bus - 3 (put mirrors right in front of driver - not in the center of the windows)
- Make brakes consistent from bus to bus (equal braking pressure required)
- Improve the ride in newer buses (currently ride is rough because of lack of weight of air conditioner at rear)
- Remove throttle delay

**SCHEDULE**
- Change schedules to be more consistent (same time each day) and space the time points correctly - 3
- Dispatch according to schedule - don't hold for late buses - 2

**POLICY**
- Have 4 10-hour days - 6
- Have 2-3 days off in a row - 5
- Have designated stops - 5
- Have all passengers pay as they board the bus
- No ride-arounds (passengers riding all the way around the route for one
fare - driver has no end of the line)

OTHER
develop a policy book for drivers - so drivers have something to support
their position when there is a conflict with a passenger - 2
get rid of the last old buses - 2
more service for passengers - more variety for bus drivers
more pay - 2
reroute buses to make safe routes (e.g. avoid left hand turns in front
of traffic when you could do a right turn etc.) - 4
get rid of end-of-the-line island because it is congested and unsafe - 2
paint yellow stripes so cars don’t park where bus needs to pull up to
curb