OTREC

OREGON
TRANSPORTATION
RESEARCH AND
EDUCATION CONSORTIUM

FINAL REPORT

Bus Operator Perceptions of Safety Risks

OTREC-RR-13-09
July 2013

A National University Transportation Center sponsored by the U.S. Department of Transportation's Research and Innovative Technology Administration

BUS OPERATOR PERCEPTIONS OF SAFETY RISKS

FINAL REPORT

OTREC-RR-13-09

by

James G. Strathman
Sung-Moon Kwon

Center for Urban Studies
Portland State University

Steve Callas

TriMet

for

Oregon Transportation Research
and Education Consortium (OTREC)
P.O. Box 751
Portland, OR 97207

July 2013

Technical Report Documentation Page

1. Report No. OTREC-RR-13-09	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Bus Operator Perceptions of Safety Risks		5. Report Date July 2013
		6. Performing Organization Code
7. Author(s) James G. Strathman (corresponding author), CUS Portland State University, strathmanj@pdx.edu, (503) 725-4069 Sung-Moon Kwon, k2580@gmail.com, CUS Portland State University, (503) 725-4068 Steve Callas, callasc@trimet.org, TriMet, (503) 962-7502		8. Performing Organization Report No.
9. Performing Organization Name and Address Center for Urban Studies, Portland State University, P.O. Box 751, Portland, OR 97207 TriMet, 4012 S.E. 17th Ave., Portland, OR 97202		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 2012-462
12. Sponsoring Agency Name and Address Oregon Transportation Research and Education Consortium (OTREC) P.O. Box 751 Portland, Oregon 97207		13. Type of Report and Period Covered
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This paper presents the results of a survey of TriMet bus operators addressing safety risks in their assigned work. Surveyed risk factors were organized into five categories: vehicle design and condition; route layout; operating conditions; fatigue; and stress. Operators perceived fatigue and stress to be the greatest sources of safety risk, with split shifts, schedule pressures, passenger distractions, and negligence of other roadway users being the primary contributors to these conditions. Operators were also surveyed on the frequency and nature of "close calls," with two-thirds of the operators indicating that such incidents occurred at least weekly and most often involved being cut off by other roadway users. Operators endorsed high visibility enforcement initiatives to improve safety, focusing primarily on negligent behavior. Other operator-recommended changes addressed scheduling practices and the need for more public information and outreach on safety risks.

17. Key Words Transit safety, operator fatigue and stress, vehicle design, route design		18. Distribution Statement No restrictions. Copies available from OTREC: www.otrec.us	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 30	22. Price

ACKNOWLEDGMENTS

The authors acknowledge the financial support provided by TriMet and the Oregon Transportation Research and Education Consortium. The authors are also grateful for comments and suggestions on the survey design and earlier drafts of this paper by Bill Coffel, Kathryn Coffel, Harry Saporta, and Ken Zatarain. The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of TriMet or the U.S. Department of Transportation.

DISCLAIMER

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This paper presents the results of a survey of TriMet bus operators addressing safety risks in their assigned work. Surveyed risk factors were organized into five categories: vehicle design and condition; route layout; operating conditions; fatigue; and stress. Operators perceived fatigue and stress to be the greatest sources of safety risk, with split shifts, schedule pressures, passenger distractions, and negligence of other roadway users being the primary contributors to these conditions. Operators were also surveyed on the frequency and nature of "close calls," with two-thirds of the operators indicating that such incidents occurred at least weekly and most often involved being cut off by other roadway users. Operators endorsed high visibility enforcement initiatives to improve safety, focusing primarily on negligent behavior. Other operator-recommended changes addressed scheduling practices and the need for more public information and outreach on safety risks.

1.0 INTRODUCTION

In 2010 TriMet, the Portland region's transit provider, formed a safety task force to review its bus operations. Among other things, the task force recommended that the agency develop and implement a comprehensive performance monitoring and analysis program to better integrate safety in its planning and operations practices (*1*). Like other urban transit providers, TriMet has long maintained general safety performance information for decision support and for reporting to the Federal Transit Administration's National Transit Database (NTD). Thus the task force's recommendation effectively sought a deeper understanding of the types of incidents that are occurring, when and where they occur, and, through analysis, why they are occurring. The task force also recommended that operators complete a recertification program annually to ensure that safe driving practices remain fresh. This commitment to training exceeds common practice in the transit industry (*2*).

Generally, the U.S. transit industry's safety record compares very favorably to that of other personal travel modes (*3*). However, bus safety incident rates exceed those of other transit modes. For example, while buses in fixed route service accounted for 39% of the transit industry's passenger miles in 2009, their associated casualty and liability costs accounted for 51% of the industry total (*3*).

There is a fairly extensive literature on the safety risks associated with bus operations. While information from this literature has helped to shape TriMet's safety policies and practices, it was recognized that there was also a need to obtain a more cohesive perspective of safety risks that are present in the agency's operating environment. The operator recertification program provided an opportunity to gain such a perspective through the eyes of those who collectively encounter the full range of safety risks in their daily work. Thus a survey of operator perceptions of safety risks was added to the training exercise. This paper presents the survey results.

The remainder of the paper is organized as follows: The next section provides a brief review of prior research on the safety risk factors covered in the survey. The survey design is then described, followed by a presentation of the findings. The paper concludes with selected observations on how information obtained from the survey relates to operations policies and practices.

2.0 PRIOR RESEARCH

The sources of safety risk in bus operations can be organized into five general categories: 1) vehicle design and maintenance; 2) route design and location/design of stops; 3) operating conditions; 4) operator fatigue; and 5) operator stress. Under vehicle design and maintenance, attention has focused on blind spots from the location of pillars, posts and mirrors (*4, 5*). It has also been found that "low floor" bus designs contribute to safer customer boardings and alightings (4, *6*). The design and operation of lift and securement systems have posed risks for wheelchair users and other customers with mobility impairments (*7, 8*). Lastly, older buses can present safety risks from either a design or state-of-repair standpoint (*4*).

Among the most important safety considerations in the design of routes is the location of stops, with options typically being at the near or far side of intersections. Far-side stop locations are considered safer because they avoid conflicts with right-turning vehicles and improve the visibility of signals and pedestrians in crosswalks (*4, 5, 9*). However, far-side stop locations may face a higher risk of bus rear-end collisions. Mid-block stop locations are less common, and their safety risks are mainly associated with the incidence of "jaywalking" which, when combined with higher traffic speeds, results in incidents with more severe consequences (9). Portland's extensive network of bicycle lanes oftentimes coincides with bus-stop locations, resulting in greater conflict potential. Routes with right- or left-hand turns pose a collision risk with pedestrians, parked vehicles, or other vehicles in traffic (*4, 10*).

In daily operations, safety risks are greatest during peak travel times when buses are navigating in heavy traffic on streets with narrow travel lanes and on-street parking (*10, 11, 12*). Safety risks are also greater outside the daylight hours, especially when street lighting is inadequate or when poor weather limits visibility (*10, 12*). Work zones present special safety risks, as does temporary re-routing of service (*13*). In general traffic, crash rates tend to be lower under higher posted-speed conditions, likely reflecting greater roadway-design safety margins (*11*). However, this may not hold for bus operations, where moving into and out of higher-speed traffic streams may pose greater safety risks.

Considerable research has been devoted to operator health and wellness in the transit industry. Fatigue has been a particular concern given work assignment practices (*14*). Assigned work hours have been gradually increasing, as has the reliance on voluntary overtime. Operators choosing extraboard work, which covers absences, usually work the longest hours, with assignments that can vary daily. Lower-seniority operators sometimes work split shifts in covering morning and afternoon peak periods. Sustained over time, all of these practices can contribute to fatigue, which negatively affects attention, judgment and driving performance (*15, 16*).

Stress is common among operators, and its effects have been manifested in a higher risk of such chronic medical conditions as hypertension, coronary disease and obesity (*16,17*). Stress also contributes to sleep disruptions and thereby affects fatigue. Stress can affect attention and judgment, thus posing greater risk through diminished driving performance. Common sources of stress include the need to maintain a schedule, which is generally written for a "typical" operator under "normal" traffic conditions and "expected" passenger loads (*4, 5, 18*). Passenger disruptions, most commonly involving fare payment disputes, also contribute to stress (*19*). Fare payment itself can be a source of distraction and stress, especially in bus systems that still rely heavily on cash fares or flash passes. Threats and acts of physical violence on operators, although not commonplace, occur with sufficient frequency to weigh on an operator's mind in any unpleasant encounter (*19*). As has been the experience in commercial vehicle operations, other roadway users tend to be unaware of a bus's blind spots, lack of maneuverability and longer required stopping distances. These vehicle design and performance features combine to magnify both the safety risks and the consequences of incidents involving negligent roadway users. They also likely amplify the stress associated with "close calls." Lastly, being "held responsible" for disruptions to passengers' schedules associated with bus breakdowns can be stressful for operators.

Although the substantive coverage of transit-safety research has been quite extensive, the relative risks of the factors discussed above remain largely unknown. Thus, for example, the relative importance of fatigue as a critical reason for transit-safety incidents has not been established. This contrasts with research on heavy trucks (*20*) and passenger vehicles (*21*), which has documented the relative importance of various factors contributing to crash risk.

3.0 SURVEY DESIGN

The operator survey was designed to address the previously discussed vehicle, route design, operating, fatigue and stress-related safety risk factors. Risk factors were identified in each of the five categories, and operators were asked to rank the factors in order of importance. Previous experience with operator surveys suggested that a rank ordered (rather than scaled) response would be more likely to yield differentiation among the safety risk factors. A funneling approach (*22*) was also employed in which, following the rank ordering of specific safety risk factors in each of the five categories, the operators were asked to rank order the categories themselves on the basis of perceived safety risk.

Beyond the five safety risk categories, the survey also sought operators' views on safety enforcement activity. A question was adapted from the high-visibility enforcement program developed by the Federal Motor Carrier Safety Administration and the National Highway Safety Administration (*23*), wherein operators were asked to provide a rank ordering among four alternative types of roadway user negligence: negligent/distracted motorists; negligent/distracted cyclists and pedestrians; drug/alcohol impaired road users; and road users ignoring the "Yield-to-Bus" sign located on the rear of the vehicle. Regarding the final alternative, Oregon is one of seven states that have passed legislation requiring road users to yield to transit vehicles that are re-entering the roadway after servicing a stop (*24*).

The survey also sought information about the frequency and nature of "close calls" involving the bus or its passengers. Another question sought suggestions for changes in TriMet's established standard operating procedures (SOPs) that would potentially improve safety.

The final part of the survey asked operators whether they were employed on a full- or part-time basis, as well as how long they had worked at TriMet. Differences in employment status and experience have potentially important safety-related consequences with respect to operators' work assignments. For example, as Table 1 shows, part-time operators are much more likely to draw split-shift assignments, and their revenue service miles are disproportionately concentrated in peak periods. Consequently, their passenger loads are typically greater and they are more likely to fall behind schedule than full-time operators. Thus, part-time operators generally face greater safety risk exposure related to traffic conditions, schedule maintenance pressures, and passenger distractions, which can be expected to distinguish their safety risk perceptions from those of full-time operators. The most notable distinction with respect to experience is the greater likelihood that junior operators will draw split-shift assignments, which may influence their perception of the importance of fatigue-related safety risks.

A draft survey was pretested on about 150 operators in August 2011. The revised survey was fielded in the fall of 2011 during the course of operator recertification training.

TABLE 1 Selected Assigned Work Characteristics, Fall Quarter 2011

Characteristic	Full-Time Operators	Part-Time Operators
Number of Operators (percent)	736 (71.2%)	297 (28.8%)
Scheduled Revenue Miles (percent)	77.5%	22.5%
Scheduled Weekday PM Peak Revenue Miles (percent)	58.7%	41.3%
Assigned to Split Shifts		
Less Than Five Years Experience (percent)	32.4%	72.5%
Five or More Years Experience (percent)	22.8%	44.5%
Average Maximum Load Per Trip (weekdays)	18.5	20.1
Incidence of Late Departures From Time Points (percent)	14.1%	17.7%

4.0 SURVEY RESULTS

Valid responses were obtained from 210 operators, or 20.4% of the study period population. The sample slightly over-represents part-time operators (31.7% of the respondents). With respect to experience, 42.2% of the respondents had been on the job less than five years. Employment status and experience are also related, given that all operators are first hired on a part-time basis. Thus, the mean experience of part-time operator respondents was 6.8 years, compared to 12.5 years for full-time respondents.

Several tests were initially performed on the questions with rank-ordered responses. First, a chi-square test was used to evaluate the hypothesis that the mean rank-ordered response values were equal. With respect to the survey question on fatigue, for example, failure to reject this hypothesis would indicate that operators perceived no safety risk differences among fatigue-related factors. The chi-square test rejected the null hypothesis (at the .05 level of significance) for each of the survey questions seeking rank-order responses. Second, each rank-ordered response was tested for differences attributable to operators' employment status and seniority. Instances where significant seniority or employment status-related differences were found will be discussed in the presentation of the survey findings.

Mean rankings of the various safety risk factors associated with vehicle design, route layout, operating conditions, fatigue, and stress are presented in Table 2. Within each category, the risk factors are listed in order of ranked importance. Discussion of the findings follows in the subsequent subsections.

TABLE 2 Mean Survey Rankings of Operational Safety Risks

Category/Factor	Mean Ranking	Responses
Vehicle Design and Condition		
Blind Spots from pillars, posts, or mirror position	1.271	210
Vehicle age or level of maintenance	2.457	210
"High floor" vehicle designs	3.171	210
Lift operation or maintenance	3.862	210
Lift design	3.938	210
Route Layout		
Left or right turns	2.024	208
Stops in bike lanes	2.317	208
Near-side stops at intersections	3.034	208
Long routes	3.654	208
Far-side stops at intersections	3.769	208
Operating Conditions		
Narrow travel lanes	2.214	210
Limited visibility	2.452	210
On-street parking	3.252	210
Traffic congestion	3.371	210
Work zones and temporary re-routes	3.648	210
Where posted speeds exceed 30 mph	5.452	210
Fatigue		
Working long splits	1.780	200
Working the extraboard	2.440	200
Working long straight runs	2.715	200
Working regular days off	2.835	200
Stress		
Related to disruptive passengers	2.306	209
Related to the schedule	2.330	209
Related to negligence of others on the roadway	2.368	209
Related to concerns about personal safety	3.943	209
Related to handling fare payment	4.359	209
Related to road call and lost service incidents	5.033	209
Overall		
Stress	2.155	207
Fatigue	2.174	207
Operating Conditions	2.739	207
Vehicle Design and Condition	3.638	207
Route Layout	3.855	207

4.1 VEHICLE DESIGN AND CONDITION

Blind spots from pillars, posts and mirror positions represent the greatest perceived safety risk among vehicle design and condition factors. Moreover, the perceived risk is ranked significantly higher among low-seniority operators (mean rank of 1.19) than among those with higher seniority (mean rank of 1.40). Vehicle age or level of maintenance ranked a somewhat distant second in perceived safety risk. NTD data (*25*) show that the average age of TriMet's bus fleet was 12.2 years in 2010, or 63% above the industry average of 7.5 years. Thus, the operator responses may indicate a perception that safety is being affected by the agency's reliance on relatively older vehicles. However, previous research on safety incidents involving this fleet found no relationship between vehicle age and incident frequency (*8*). "High floor" designs ranked third in perceived safety risk.

Lowest ranked in perceived safety risk are the two lift system factors. This may reflect that fact that lifts are not very frequently deployed (averaging about once per trip). Actual safety risk may be greater after controlling for the relatively low level of exposure, as Strathman et al. (*8*) have found.

4.2 ROUTE LAYOUT

Operator rankings of route layout risk factors indicate a clear concern about conflicts with other roadway users. Routes with right or left turns, and stops overlapping bike lanes are ranked first and second in perceived safety risk, and are distinctly separated from other route layout factors. Near-side stops rank third in perceived risk, again likely reflecting potential conflicts with right-turning vehicles and the inability of motorists to see alighting passengers and other pedestrians who are using the crosswalk in front of the bus. Long routes and stops located at the far side of intersections were perceived to have the lowest safety risk. More senior operators perceived greater safety risk with long routes, however (3.45 mean rank v. 3.93 for operators with less seniority).

4.3 OPERATING CONDITIONS

Among the safety risk factors related to operating conditions, operators were most concerned about narrow travel lanes. Moreover, full-time operators perceived the safety risks of narrow travel lanes to be significantly greater than did part-time operators (2.03 mean rank v. 2.60). Limited visibility conditions posed the second greatest safety risk, with more senior operators perceiving significantly greater risk than their junior counterparts (2.30 mean rank v. 2.73).

The presence of on-street parking was perceived to be the third greatest safety risk, with part-time operators considering the risks to be significantly greater than full-time operators (2.97 mean rank v. 3.39). This distinction may correspond to the fact that parking turnover increases during peak travel times, when most part-time operators are working their assignments.

Traffic congestion was ranked fourth among the perceived safety risks associated with operating conditions, with more senior operators considering it to be more serious than junior operators (3.07 mean rank v. 3.80). This was followed by work zones and re-routes where, conversely, more junior operators perceived the safety risks to be relatively greater (3.41 mean rank v. 3.82). The perceived risks related to operating where posted speeds exceed 30 mph were ranked last among the operating conditions factors.

4.4 FATIGUE

Operators perceived that working long splits posed the greatest safety risk among the four risk factors associated with fatigue. This factor clearly stood apart from the others, including (in order) working the extraboard, working long straight runs, and working on regular days off. More senior operators viewed the safety risks of working regular days off as being greater than did junior operators (2.70 mean rank v. 3.05).

One distinction that can be made between long splits and the other fatigue-related factors is that the latter are voluntary work commitments. Thus, while working the extraboard, long straights, or on regular days off can affect fatigue, an operator's voluntary decision to choose this work has what is known as a "selection effect" on safety risk. DiMilia et al. (*26*) conclude that the safety risks of fatigue are somewhat mitigated when hours worked are voluntarily chosen.

4.5 STRESS

Three of the six stress-related factors clustered at the top of operators' perceived safety risks: dealing with disruptive passengers, maintaining the schedule, and negligence of other roadway users. Part-time operators viewed disruptive passengers as a significantly lower safety risk than did full-time operators (2.52 mean rank v. 2.20), possibly because their passengers are typically peak-period commuters. Alternatively, part-time operators considered the stress of maintaining a schedule to be a significantly greater safety risk than did full-time operators (2.00 mean rank v. 2.46), which is likely attributable to greater daily fluctuations in traffic congestion and passenger activity during peak periods.

Stress related to operators' concerns about personal safety and handling fare payment fell into the next cluster of perceived safety risks, while stress related to vehicle breakdowns stood apart at the bottom.

4.6 OVERALL CONTRIBUTORS TO SAFETY RISK

Having ranked the safety risks of factors within each of the five categories, operators were then asked to rank the categories themselves. Stress and fatigue clustered together as the principal categorical sources of perceived safety risk. Not surprising given differences in hours of service, there is a significant difference between full- and part-time operators in the perceived safety risks of fatigue, with full-timers considering it to be a greater safety risk (2.05 mean rank v. 2.48). Thus, fatigue can be considered the principal safety risk perceived among full-time operators, while stress is the principal safety risk perceived among part-time operators.

The perceived safety risks related to operating conditions fall in the middle of the list of categories, while vehicle design/condition and route layout clustered at the bottom. It is noteworthy that part-time operators perceived significantly greater safety risks for the vehicle design/condition category than did full-time operators (3.29 mean rank v. 3.77), which may reflect TriMet's practice of assigning older buses to peak tripper service and, consequently, primarily to part-time operators.

4.7 HIGH VISIBILITY ENFORCEMENT

Operators were asked to rank high-visibility enforcement alternatives. Their responses, shown in Table 3, reveal a clear preference for focusing enforcement on the negligent or distracted behavior of other roadway users, with a slight preference for targeting cyclists and pedestrians over other motor vehicle users. Following these alternatives was a preference for focusing enforcement on alcohol or drug impaired roadway users, with full-time operators expressing a significantly greater preference for this option than part-time operators (2.59 mean rank v. 2.94). Their relative preference for this option is likely related to their relatively greater engagement in nighttime service, when incidents involving such impairments are more prevalent (*12*).

TABLE 3 Mean Rankings of High-Visibility Enforcement Alternatives

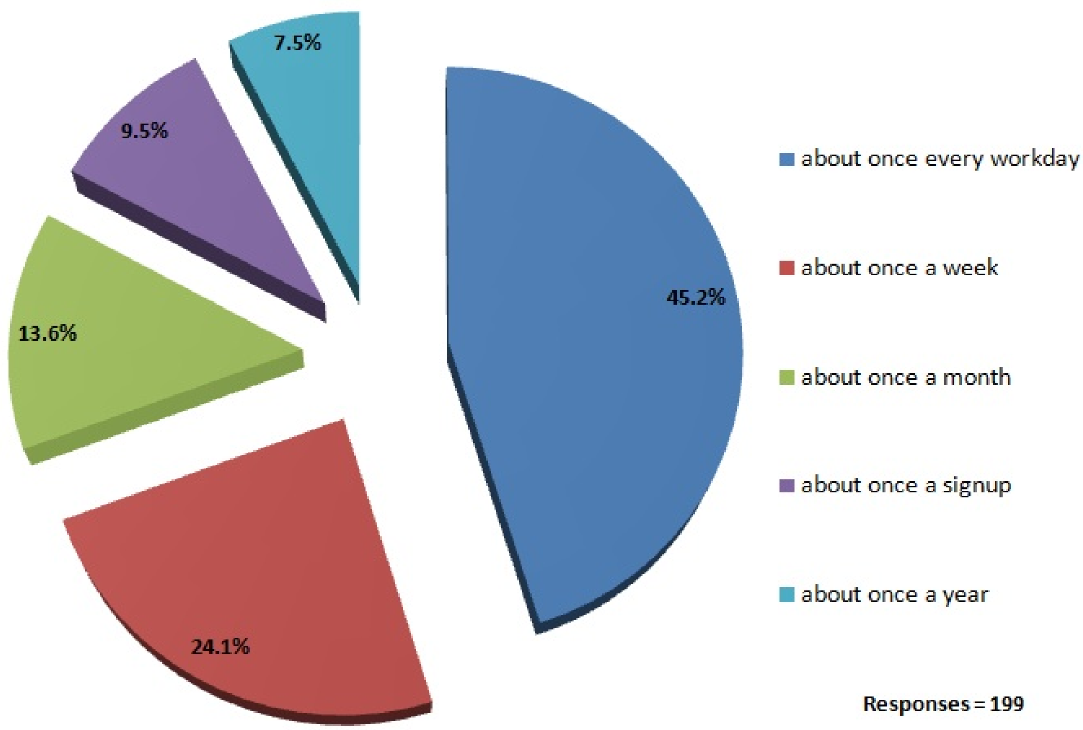
Focus of Enforcement	Mean Ranking	Responses
Negligent or distracted cyclists and pedestrians	1.917	205
Negligent or distracted drivers	2.005	205
Drug or alcohol impaired road users	2.687	205
Drivers who ignore the "Yield-to-Bus" sign	3.083	205

"Yield-to-bus" enforcement was least preferred, although both part-time and junior operators expressed significantly greater preference for this alternative than did full-time and senior operators (2.70 and 2.83 mean ranks, respectively, v. 3.25 and 3.25). Compared to their counterparts, part-time and junior operators' assigned work tends to be more concentrated in the peak periods, when moving back into the traffic stream after servicing a stop would be less hazardous if the yield requirement were enforced.

4.8 CLOSE CALLS

TriMet experiences about one reportable safety incident per operator per year. Below this "tip of the safety pyramid," little is known about the frequency of close calls. Thus, operators were asked to indicate how often they or their passengers experienced a close call. Their responses, shown in Figure 1, indicate that the base of the pyramid is quite broad. Over two-thirds of the operators indicated that close calls occurred at least on a weekly basis, with nearly half indicating that they occurred daily.

FIGURE 1 Frequency of Close Calls



An open-ended question invited operators to describe the most common type of close call they experience. Information provided in their diverse responses is summarized in Table 4. There are a number of noteworthy observations that can be drawn from the table. First, more than half of the typical close calls do not directly involve another motor vehicle. Persons on foot (pre-board/post-alight passengers and other pedestrians) were identified in connection with 30.9% of typical close calls, while cyclists were identified in connection with another 21.9%. With respect to passengers, close calls were described as being more likely to occur before boarding while running (often jaywalking) to catch the bus, while their post alighting close calls usually involved failure to use crosswalks or failure to cross with the light at signalized intersections. For pedestrians, jaywalking and crossing against the light were the most common close calls.

TABLE 4 Characteristics of Common Close Calls

		Vehicles	Cyclists			Pedestrians	Passengers			Others	Sum	Total Sum
			Pre	Post	On Road		Pre	Post	On			
Failure to Yield	Illegal Turn or Cut off (Crosswalking in front of Bus, Running for Bus)	47	3	0	3	7	15	8	0	0	83	
		26.4%	1.7%	0.0%	1.7%	3.9%	**8.4%**	4.5%	0.0%	0.0%	46.6%	
	Intersection or Approach	8	0	0	0	0	0	0	0	0	8	106
		4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.5%	59.6%
	Overtaking	3	0	0	5	0	0	0	0	0	8	
		1.7%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	4.5%	
	Others	4	0	0	3	0	0	0	0	0	7	
		2.2%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	
Distracted or Negligent		7	0	0	23	24	0	1	3	0	58	58
		3.9%	0.0%	0.0%	**12.9%**	**13.5%**	0.0%	0.6%	1.7%	0.0%	32.6%	32.6%
Others		5	0	0	2	0	0	0	0	7	14	14
		2.8%	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	3.9%	7.9%	7.9%
Sum		74	3	0	36	31	15	9	3	7		178
		41.6%	1.7%	0.0%	20.2%	17.4%	8.4%	5.1%	1.7%	3.9%		100%
Total Sum		74	39			31	27			7	178	
		41.6%	**21.9%**			**17.4%**	**15.2%**			3.9%	100%	

While other motor vehicles were identified in just 41.6% of typical close calls, these near-incidents tended to be more clearly described in the open-ended responses. These close calls commonly involved being cut off by a vehicle turning in front of the bus. Sometimes, only the maneuver itself was mentioned, while in other instances operators said that it occurred most often along the downtown transit mall, at near-side stops, along one-way streets, and on four-lane streets.

The rows in Table 1 provide a breakdown of the underlying causes of typical closes calls. In more than half of the instances, enough information was provided to characterize a failure-to-yield problem. In one-third of the responses, however, the descriptions remained fairly general, with references to distracted or negligent behavior being most common. In some instances, operators specifically referred to cyclists either riding in their blind spots or not having adequate lighting at night.

4.9 STANDARD OPERATING PROCEDURES

The final section of the survey asked operators to suggest changes in TriMet's standard operating procedures that they thought would improve safety. Their recommendations are summarized in Figure 2. The most frequent reference (28.6%) was to schedules, which the responding operators stated left too little time for recovery and layover. A view commonly expressed in this regard is that the scheduling process was being driven by budget and efficiency objectives, without sufficient consideration of safety.

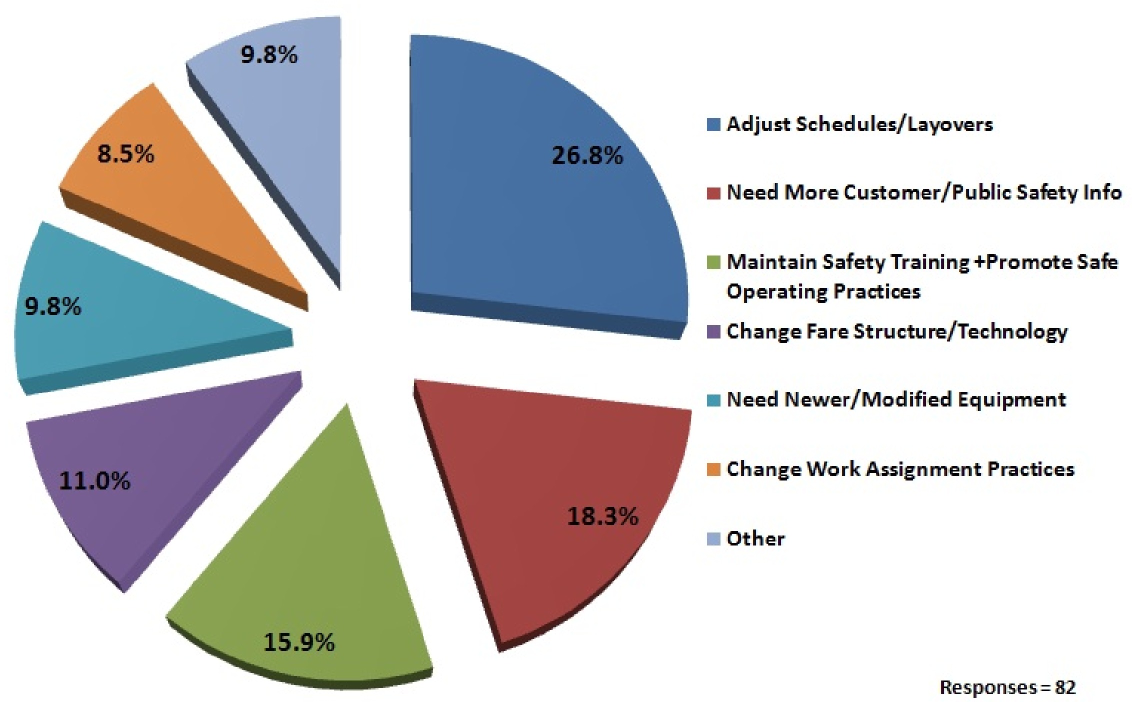
The second most frequently expressed recommendation (18.3%) concerned a need to provide more information to customers and other roadway users to increase their awareness of safety risks. In some instances, operators related their recommendation for more public information to the close calls they had previously described.

Third (at 15.9%), operators endorsed periodic training as a way of maintaining safe driving practices. Some operators also suggested that follow-up efforts be made through field supervision to ensure that the training was translated into practice.

The fourth (11.0%) and fifth (9.8%) most frequent recommendations expressed desires for new fare technology and replacement of aging vehicles. While both were covered in the previous rank ordering of safety risks - and had not stood out from other risk factors - operators may have thought that these were achievable steps that could be taken to reduce distractions and conflicts with passengers and to deal with older "problem" vehicles in the fleet. It should be noted that neither bus age nor fare technology are addressed in the standard operating procedures.

The final categorical recommendation focused on the need for new work assignment practices, mainly involving either reducing assigned hours or consistently enforcing the hours of service provisions of the working and wage agreement.

FIGURE 2 Recommended SOP Changes



5.0 CONCLUSIONS

Generally, operators perceived fairly clear and consistent differences among the safety risk factors they encounter in their work. At the same time, a breakdown of responses also shows that operators' safety risk perceptions are somewhat sensitive to their employment status and work circumstances. With this in mind, the following conclusions can be drawn from the survey.

First, it is evident that fatigue and stress are important sources of the safety risks that operators perceive in their work environment. It is worth noting that these same conditions have also been linked to the health and well being of operators (*14, 16, 17*), as well as their comparatively high absenteeism rate (*18, 27*). Thus, the consequences of fatigue and stress are manifested in multiple ways among bus operators.

Operators identified split shifts as a principal contributor to fatigue. In transit workforce planning, split shifts are favored as a cost-effective way of covering the morning and afternoon peak periods. However, the true cost effectiveness of this approach may be questionable given research showing that split-shift operators have a higher rate of absenteeism (*27*) as well as a greater likelihood of being involved in safety incidents (*8*). Thus, pay and benefit savings from the utilization of split shifts are at least partly offset by additional time loss and safety incident costs. It should also be noted that greater absenteeism among split-shift operators creates additional work for the extraboard, which operators perceived to be the second greatest contributor to fatigue.

The pressure of maintaining a schedule was found to be the most important stress-related concern of part-time operators, whose work is concentrated in congested peak periods, and was the second greatest concern among full-time operators. Schedules were also the focus of the most frequently recommended change in standard operating procedures. The working and wage agreement between the operators and TriMet stipulates that scheduled runs under eight hours include five minutes of recovery and layover for each hour of running time. The agreement also recognizes that actual conditions may prevent this from being realized for each hour or for each trip (*28*). A side letter to the agreement further stipulates that runs exceeding eight hours include one 20-minute, three 15-minute, and two 10-minute breaks.

The scheduling and run-cutting processes at TriMet account for the agreement's recovery, layover and break requirements. Data on actual running and layover times are also maintained in the agency's enterprise data warehouse. Thus, actual performance can be monitored to ensure that schedules are achievable and conform to the agreement.

In general, a "good" schedule avoids the extremes of excessive running times, wherein too many buses must hold at time points and lengthen passengers' travel delays, or insufficient running times, wherein too many buses are running late, on-time performance deteriorates, and operators feel pressured to "cut corners." The greater the variation in actual running time, the greater the challenge of writing a schedule that achieves a balance between holding/delay costs and the costs of poor schedule adherence. Thus, actions that shrink running time variance improve the prospect of producing a good schedule. For example, the main benefit of signal priority systems for scheduling is in the reduction of running-time variation rather than the reduction of average running time. Moreover, research has found that operators themselves contribute to running-time variation in that some consistently take more time to complete trips while others consistently take less. Strathman et al. (*29*) found that operator differences accounted for nearly 20% of actual running-time variation on TriMet's bus system. Work-selection practices that mix operators with inherently dissimilar running times thus result in a less reliable schedule that is more subject to "bus bunching."

A final observation relates to safety risks associated with various distracted and negligent behaviors that exist in operators' work environment. It was apparent in responses to the open-ended questions that these safety risks weigh on operators' minds, which is not surprising given their reported frequency of close calls. In light of these risks, operators saw value in public information efforts to raise awareness of safety issues. Although the survey was not structured to recover operators' preferences regarding whether such a campaign ought to be coordinated with enforcement, the tone of their responses to the open-ended questions on close calls and standard operating procedures suggests a preference for such coordination.

In closing, the perceptions of safety risks documented in the survey are intended to serve as a complement rather than a substitute for detailed analyses of safety incidents. Nevertheless, the survey findings are useful in their own right in identifying safety factors that are often not addressed in studies drawing on incident data (30). The findings also provide a cohesive perspective on the relative importance of a fairly broad range of safety risk factors, in contrast with the narrower approach often taken in transit-safety studies. Lastly, it should be emphasized that these findings reflect the operating conditions and safety risk environment pertaining to one transit provider, which may limit generalization to other properties or the industry. Although these conditions are fairly typical of those pertaining to mid-size urban bus systems, the lack of comparable survey research on safety risks suggests caution.

6.0 REFERENCES

1. TriMet Safety and Service Excellence Task Force. *Final Report.* Portland, OR: Author, 2010.

2. Moffat, G., Ashton, A. and D. Blackburn. *TCRP Synthesis 40: A Challenged Employment System: Hiring, Training, Performance Evaluation, and Retention of Bus Drivers.* Washington, DC: Transit Cooperative Research Program, Transportation Research Board of the National Academies, 2001.

3. American Public Transit Association (APTA). *2011 Public Transportation Fact Book, 62nd Edition.* Washington, DC: Author, 2011.

4. Pecheux, K., Bauer, J., Miller, S., Rephlo, J., Saporta, H., Erickson, S., Knapp, S., Quan, J. *TCRP Report 125: Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions.* Washington, DC: Transit Cooperative Research Program, Transportation Research Board of the National Academies, 2008.

5. Technology and Management Systems, Inc. *TCRP Report 66: Effective Practices to Reduce Bus Accidents.* Washington, DC: Transit Cooperative Research Program, Transportation Research Board of the National Academies, 2001.

6. Hundenski, R. Public transport passenger accidents: An analysis of the structural and functional characteristics of passenger and vehicle. *Accident Analysis and Prevention,* 24, 1992, pp. 133-142.

7. National Highway Traffic Safety Administration (NHTSA). *Research Note: Wheelchair Users Injuries and Death Associated With Motor Vehicle Related Incidents.* Washington, DC: U.S. Department of Transportation, 1997.

8. Strathman, J., Wachana, P. and S. Callas. Analysis of bus collision and non-collision incidents using transit ITS and other archived operations data. *Journal of Safety Research,* 41, 2010, pp. 137-144.

9. Texas Transportation Institute. *TCRP Report 19: Guidelines for the Location and Design of Bus Stops.* Washington, DC: Transit Cooperative Research Program, Transportation Research Board of the National Academies, 1996.

10. af Wahlberg, A. Characteristics of low speed accidents with buses in public transport: part II. *Accident Analysis and Prevention,* 36, 2004, pp. 63-71.

11. Hadi, M., Aruldhas, J., Chow, L. and J. Wattleworth. Estimating safety effects of cross-section design for various highway types using negative binomial

regression. *Transportation Research Record: Journal of the Transportation Research Board,* 1500, 1995, pp. 169-177.

12. Ragland, D., Hundenski, R., Holman, B. and J. Fisher. Traffic volume and collisions involving transit and nontransit vehicles. *Accident Analysis and Prevention,* 24, 1992, pp. 547-558.

13. Wang, J., Hughes, W., Council, F. and J. Paniati. Investigation of highway work zone crashes: what we know and what we don't know. *Transportation Research Record: Journal of the Transportation Research Board,* 1529, 1996, pp. 54-62.

14. Gertler, J., Popkin, S., Nelson, D. and K. O'Neil. *TCRP Report 81: Toolbox for Transit Operator Fatigue.* Washington, DC: Transit Cooperative Research Program, Transportation Research Board of the National Academies, 2002.

15. Pokorny, M., Blom, D., Van Leeuwen, P. and W. Van Nooten. Shift sequences, duration of rest periods, and accident risk of bus drivers. *Human Factors,* 29, 1987, pp. 73-81.

16. Tse, J., Flin, R. and K. Mearns. Bus driver well-being review: 50 years of research. *Transportation Research Part F,* 9F, 2006, pp. 89-114.

17. Kompier, M. and V. Di Martino. Review of bus drivers' occupational stress and stress prevention. *Stress Medicine,* 11, 1995, pp. 253-262.

18. Long, L. and J. Perry. Economic and occupational causes of transit operator absenteeism: a review of research. *Transport Reviews*, 5, 1985, pp. 247-267.

19. Nakanishi, Y. and W. Fleming. *TCRP Synthesis 93: Practices to Protect Bus Operators From Passenger Assault.* Washington, DC: Transit Cooperative Research Program, Transportation Research Board of the National Academies, 2011.

20. Craft, R. *The Large Truck Crash Causation Study. Analysis Brief: LTCCS Summary.* Publication No. FMCSA-RRA-07-017. Washington, DC: Office of Research and Analysis, Federal Motor Carrier Safety Administration, U.S. Department of Transportation, 2007.

21. National Highway Traffic Safety Administration (NHTSA). *National Motor Vehicle Crash Causation Survey: Report to Congress.* Report No. DOT HS 811 059. Washington, DC: National Highway Traffic Safety Administration, U.S. Department of Transportation, 2008.

22. Frankfort-Nachmias, C. *Research Methods in the Social Sciences, 4th Edition.* New York: St. Martins Press, 1992.

23. Federal Motor Carrier Safety Administration and National Highway Traffic Safety Administration (FMCSA and NHTSA). *Guidelines for Developing a High-Visibility Enforcement Campaign to Reduce Unsafe Driving Behaviors Among Drivers of Passenger and Commercial Motor Vehicles: A Selective Traffic Enforcement Program (STEP) Based on the Ticketing Aggressive Cars and Trucks (TACT) Pilot Project.* Washington, DC: U.S. Department of Transportation, 2007.

24. Zhou, H., Bromfield, S. and P. Lin. An overview of yield-to-bus programs in Florida. *Journal of Public Transportation,* 14:2, 2011, pp. 151-163.

25. Federal Transit Administration (FTA). *2011 National Transit Database.* Washington, DC: Federal Transit Administration, U.S. Department of Transportation, 2011.

26. DiMilia, L., Smolensky, M., Coast, G., Howarth, H., Ohayon, M. and P. Philip. Demographic factors, fatigue, and driving accidents: an examination of the published literature. *Accident Analysis and Prevention,* 43, 2011, pp. 516-532.

27. Strathman, J., Broach, J. and S. Callas. Analysis of short duration unscheduled absences among transit operators: TriMet case study," *Transportation Research Record: Journal of the Transportation Research Board, 2111,* 2009, pp. 185-194.

28. Amalgamated Transit Union, Division 757 and TriMet. *Working and Wage Agreement Between Amalgamated Transit Union, Division 757 and TriMet, December 1, 2003 – November 30, 2009.* Portland, OR: authors, no date.

29. Strathman, J., Dueker, K., Kimpel, T., Gerhart, R. and S. Callas. Evaluation of transit operations: data applications of TriMet's automated bus dispatching system. *Transportation,* 29, 2002, pp. 321-345.

30. D'Souza, K. and S. Maheshwari. Multivariate statistical analysis of public transit bus driver distraction. *Journal of Public Transportation*, 15, 2012, pp. 1-23.

OTREC
OREGON TRANSPORTATION RESEARCH AND EDUCATION CONSORTIUM

P.O. Box 751
Portland, OR 97207

OTREC is dedicated to stimulating and conducting collaborative multi-disciplinary research on multi-modal surface transportation issues, educating a diverse array of current practitioners and future leaders in the transportation field, and encouraging implementation of relevant research results.