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Article *in* Journal of Occupational Health Psychology · May 1998

DOI: 10.1037/1076-8998.3.2.130 · Source: PubMed

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Journal of Occupational Health Psychology
1998, Vol. 3, No. 2, 130–146

1076-8998/98/$3.00

Objective Stress Factors, Accidents, and Absenteeism in Transit Operators: A Theoretical Framework and Empirical Evidence

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The authors used observational job analysis as a conceptually based technique to measure stress factors unbiased by worker appraisal with 81 transit driving tasks on 27 transit lines. Stressor dimensions included work barriers that interfere with task performance due to poor technical–organizational design, time pressure, time binding (autonomy over time management), and monotonous conditions. Line-specific average stressor values were assigned to 308 transit operators who mainly worked the particular line. Logistic regression analyses showed associations for high work barriers and sickness absences (odds ratio [OR] = 3.8, $p = .05$). There were elevated risks for work accidents for high time pressure operators (OR = 4.0, $p = .04$) and for the medium time-binding group (OR = 3.3, $p = .04$) and significant ($\alpha = .20$) unadjusted interaction terms for barriers and time pressure in predicting accidents and absences, and barriers and time binding in predicting absences. Findings suggest guaranteed rest breaks and flexible timing for accident prevention and removal of work barriers for reducing absenteeism.

Urban transit operators are at high risk for several health problems. When contrasted with the general population or to other occupational groups, city bus drivers show higher rates of heart disease (Gustavsson et al., 1996; Netterström & Laursen, 1981; Ragland et al., 1987), hypertension (Winkleby, Ragland, & Syme, 1988), and sickness-related work absences (Gardell, Aaronson, & Barkloff, 1982; Kompier et al., 1990). They also retire earlier with physical disabilities (Garbe, 1990; Kompier et al., 1990), die at a younger age from coronary heart disease (Alfredson, Hammar, & Hogstedt, 1993; Rosengren, Anderson, & Wilhelmsen, 1991), and demonstrate lower levels of job satisfaction as well as unfavorable scores on mental health ratings (Duffy & McGoldrick, 1990). The reasons usually suspected are the highly stressful job conditions of urban transit driving. For example, when compared to a cohort of building trade workers, bus drivers had higher ratings on all stressor dimensions including qualitative underload, quantitative overload, strictness, time pressure, noxious exposures, aversiveness, and conflict–uncertainty (Belkic, Savic, Theorell, & Cizinsky, 1995).

The classic stress situation for transit operators, as characterized by Gardell et al. (1982), is seen in the conflict between safe driving, staying on schedule in the face of heavy traffic, and serving the public in a courteous manner. However, little is known about the specific factors of the work situation that might exacerbate or alleviate this conflict, as most research has treated transit operators as a homogenous occupational group in contrast to others. Research suggests that one potential source for the conflict might be factors in the traffic environment, such as traffic congestion (Carrere, Evans, Palsane, & Rivas, 1991; Evans & Carrere, 1991; Netterström & Suadicani, 1993). Other researchers have pointed out that organizational factors are important, such as lack of supervisory support (Krause, Ragland, Greiner,

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A draft of this article was presented at the conference "Work, Stress, and Health 1995: Creating Healthier Workplaces," held by the American Psychological Association and the National Institute of Occupational Safety and Health in Washington, DC, in September 1995 as part of a symposium on risk factors for transit operators. The study was supported by the National Institute on Alcoholism and Alcohol Abuse (Grant R01 AA08949) and by the Alcoholic Beverage Medical Research Foundation.

We would like to thank the observers who conducted worksite observations: Georg Bauer, Monika Dovalle, Jane Koehler, Alixe Millar, Karen Spaniel, Mary-Alice Stevenson, and Roberta Welling. We would also like to thank the management of San Francisco Municipal Railways and the Transport Workers Union Local 250A for their support. We gratefully acknowledge Barbara Holman's support in keeping and maintaining the medical charts and the study roster at San Francisco General Hospital.

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Syme et al., 1997) or unrealistic run schedules that do not adequately reflect the time needed to cover the distance between two terminals (Syme, 1991). Also, operator perception of control and specific coping strategies might be an important source or mediator of stress (Bartone, 1989; Evans & Carrere, 1991; Kühlmann, 1990).

Research results in this area are limited in two ways. First, detailed analyses of organizational factors of operator stress that pertain to practical suggestions for job redesign and organizational development are rare. Second, the interpretation of findings is limited, as most research is based on self-report. Self-report data do not allow us to distinguish to what extent reported stress reflects the perceptions of operators rather than the actual work environment (Spector, 1992). This problem might also explain some unexpected results found in studies about transit operators' stress and health. Winkleby et al. (1988) reported an inverse association between self-reported stressors and hypertension. Others found an excess risk of ischemic heart disease for drivers with high job satisfaction, with low exhaustion, and for drivers who reported high variation in their job (Netterström & Suadicani, 1993). These unexplained results have been attributed to possible confounding of self-report stressor measures with personality factors or coping.

To remedy the problem of confounding, the use of "objective" stressor measures has been suggested for job stress research in general (Evans, in press; Frese & Zapf, 1988; Kasl, 1993) and in stress research with transit operators in particular (Evans, 1994; Netterström & Suadicani, 1993; Winkleby et al., 1988). Objective measures are assessed independently of the individual operator's perception and interpretation. One approach is the analysis of archival data. For example, Evans and Carrere (1991) used data derived from street-carrying capacity and traffic volume and determined that traffic congestion, in combination with the perception of no control, was a stressor that predicted elevated blood pressure. However, usually archival data allow for only gross indicators of stressor exposure. An alternative approach is worksite observations by external observers (Greiner & Leitner, 1989; Jenkins, Nadler, Lawler, & Camman, 1975).

The discussion about self-report versus observational measures of stressors has often been controversial, addressing the issue in terms of which measure is better or less confounded. However, it has been shown that both approaches are vulnerable to measurement effects, each approach to different ones, and that different stressor dimensions might be distorted by these effects to different degrees (Semmer, Zapf, & Greif, 1996; Zapf, 1989). Because observational measures are less confounded with personal characteristics of the worker than most self-report data on stressors, they might be useful in several ways. First, they might provide an objective picture of the work situation if researchers think that confounding of their self-report stressor measures might result in unexplained findings for their particular outcome (e.g., Winkleby et al., 1988). Second, when combined with self-report stressor and coping measures, they can be used to determine the relative importance of appraisal, coping, and the objective work situation for the stressor–health association. Third, they can be used to obtain additional information such as the detailed description and analysis of organizational causes of stressors that go beyond workers' attributions. This might be helpful if researchers want to develop organizational solutions for stress reduction more detailed than global recommendations to reduce psychological work demands.

In this article, a study will be presented that used observational stressor measures in a sample of San Francisco urban transit operators. The purposes of this article are (a) to introduce a theoretical framework for detailed analysis of transit operating tasks, (b) to describe an observational job analysis instrument to determine transit operating stressors, (c) to describe organizational stressors found in the study, and (d) to report results about associations between observational stressors and health and safety outcomes. Furthermore, this article might help to familiarize the English-speaking reader with action regulation theory, which served as the theoretical basis of the stressor model and which is well known in Germany and Scandinavia but not in the English-speaking countries.

Health and safety outcomes included sickness-related absenteeism and work-related accidents. Absenteeism was selected as one outcome, as it creates a major problem in transit companies, and absenteeism rates are usually very high in this industry (Kompier et al., 1990; Long & Perry, 1985). In several transit operator studies, absenteeism has been associated with self-reported job stress (Gardell et al., 1982; Kompier et al., 1990). Work-related accidents were selected because accidents are a special problem in transit driving because of their impact on public safety. Work-related accidents have been shown to be associated mostly with temporal factors of the job such as duration of rest breaks and

type of shift in transit drivers (Pokorny, Blom, & Van Leeuwen, 1987). However, to our knowledge, there are no studies that examine the association between more detailed organizational factors and accidents or absenteeism in urban transit operators.

General Framework About Operator Stressors

The stressor model applied in this study is based on action regulation theory (Hacker, 1994; Oesterreich & Volpert, 1986; Volpert, 1982; see Frese & Zapf, 1994, for a review). This model was chosen because it allows for a conceptualization of stressors that does not depend on worker appraisal without omitting mental processes in general. Stressors are defined as demands which, because of poor technical or organizational work design, are incompatible with mental regulation processes such as information processing, planning, and movement execution. On one hand, the worker is required to complete the task in a certain way; on the other hand, the task is set up in such a way that work conditions interfere with task performance (Greiner & Leitner, 1989; Greiner, Ragland, Krause, Syme, & Fisher, 1997; Leitner, Volpert, Greiner, Weber, & Hennes, 1987).

The unit of analysis in action regulation theory is the mental task structure. This is the structure of mentally regulated processes, such as perception and processing of information, required by the worker to carry out the task and reach his or her goals. Using this approach, the transit operator's job reveals a complex of task elements that go beyond "moving a vehicle." In fact, operating tasks require several intertwined information-processing and motor processes. Table 1 shows common task elements for most transit operating tasks, as derived from a review of the literature and analyses of our sample. Column 1 displays observable work task elements as they occur in chronological order from the beginning to the end of a shift. Depending on the particular work organization, operator tasks can include specific elements to various degrees. For example, some tasks might include safety checks and maintenance, whereas others do not. Column 2 shows the corresponding task elements as they are defined by the action regulation theoretical framework and gives typical examples. Theoretical task elements include information processing, such as the processing of traffic- and vehicle-related information and of passenger-related information, and motor execution of the task, such as operating controls, moving the vehicle, locomotion and body posture, equipment handling, and maintenance of body posture. Organizational and technical conditions of the task can hinder either of the task elements. The benefit of theoretical task elements is that they provide a general framework for describing and analyzing qualitatively different work steps in detail. In this way, stressors that seem qualitatively different can be summarized by depending on the theoretical work operation affected.

Based on this model, four stressor dimensions are differentiated (for more details, see Greiner et al., 1997).

Work Barriers

Barriers are those factors of the task design that directly hinder the task performance without effective worker control. Barriers are events or conditions that require the worker to frequently change plans and either impede ("impediments") or interrupt the task execution ("interruption"). They require either extra work operations to compensate for the barrier (e.g., search for missing information, awkward maneuvering of vehicle) or risky behavior. Risky behavior, often done to avoid extra work, includes behavior against traffic and safety rules (e.g., speeding to compensate for delays).

Time Pressure

Time pressure, as a measure of work load under average traffic and passenger conditions (with no barriers present), is the second stressor dimension. Under time pressure, the job conditions interfere with human task performance because the action cannot be done as planned within the given time frame. The greater the time pressure, the higher the demands for the operator to process much information per time unit and/or to execute the task very fast. Severe time pressure can result in no possibility to detach from task performance by taking rest breaks.

Time Binding

Time binding as the third dimension describes the level of autonomy over time management independent of the work pace. The level of time binding is a measure for how much the operator can modify the timing or pace of incoming information or task execution. Under restrictive time binding, job conditions interfere with action regulation, as the worker cannot respond to psychophysical variations in performance capacity (e.g., slow down during the "midday low," to compensate for delays in the run schedule, or respond to passenger needs).

Table 1
General Framework to Analyze Operator Tasks

Observable work activities	Theoretical task elements
	Preparation
Receive information from supervisor, dispatcher, or coworkers	Processing of driving- and vehicle-related information (e.g., read run schedule, read information about detours)
Pick up vehicle (from garage, in the street)	Processing of driving- and vehicle-related information (e.g., find assigned vehicle) Vehicle moving (maneuver out of garage)
Maintenance, safety checks, cleaning	Equipment handling (e.g., rinse vehicle with hose) Operating controls (e.g., check window wipers) Processing of vehicle- or driving-related information (e.g., test engine sound)
Set up vehicle	Equipment handling (e.g., set up fare box, adjust mirrors and seat) Operating controls (e.g., set up destination sign, program radio)
	Driving
Drive from Terminal A to Terminal B	Vehicle moving (in accordance with traffic and safety rules) Operating controls (e.g., gas, brakes, gears) Processing of driving- and vehicle-related information (e.g., monitor air pressure gauge, watch out for bicyclists, watch traffic lights)
	Providing customer service
Loading and unloading of passengers, ticketing	Processing of customer-related information (e.g., checking tickets) Equipment handling (e.g., transfer cutter) Operating controls (e.g., doors, wheelchair ramp) Locomotion (e.g., conductor moving through vehicle to check passes)
Provide information and help passengers	Processing of customer-related information (e.g., deal with questions) Locomotion (e.g., help passengers with luggage)
	Finishing
Pull vehicle into garage or turn over to next operator	Vehicle moving (e.g., maneuver into garage)
Turn in money, tickets, and transfers	Processing of customer-related information (count tickets)
Communicate with supervisor, other operators	Processing of driving- and vehicle-related information (e.g., report abnormal vehicle or road conditions to supervisor)

Monotonous Working Conditions

Monotonous conditions are defined as task requirements for continuous visual attention in combination with understimulation because of repetitive task elements and homogenous incoming information. This condition interferes with human action regulation as task execution cannot be done in a routine way. A lapse of concentration can lead to unfavorable consequences including overlooking important information, making mistakes, or causing accidents.

Several pathways can be hypothesized leading from the four stressor dimensions to sickness absenteeism and accidents. Table 2 displays the most plausible pathways for the main stressors. First, there might be a direct physical pathway between ergonomic work barriers and musculoskeletal disorders, one of the main reasons for sickness absence in urban transit operators. Krause, Ragland, Greiner, Syme, et al. (1997) showed associations between back and neck pain and several ergonomic factors by using data from a previous study with San Francisco transit drivers. There might be a psychophysiological link through neuroendocrine or cardiovascular reactions

Table 2
Potential Pathways Between Stress Factors and Health Outcomes

Stress factor	Potential pathway	Consequences on psychophysical and behavioral level	Potential outcome
Work barrier, e.g., ergonomic barrier	Direct physical strain	Musculoskeletal disorders	Sickness absences
Work barrier, e.g., troublesome passengers	Psycho-physiological: endocrine or cardiovascular	Stress-related disorders	Sickness absences
Time pressure, restrictive time binding, monotony	Capacity overtaxing	Fatigue, stress-related disorders	Sickness absences
Work barrier, e.g., impeded perception of traffic situation	Behavioral: misjudgment of situation		Accidents
Work barrier, e.g., troublesome passengers	Behavioral: split attention		Accidents
Time pressure, restrictive time binding, monotony	Capacity overtaxing	Fatigue, decreased concentration	Accidents
Work barrier, time pressure	Behavioral: risky behavior to "save time"		Accidents

between work barriers and stress-related disorders, as shown in several studies on transit driver stress (Carrere et al., 1991; Evans & Carrere, 1991; Gardell et al., 1982; Reimann, 1981). Capacity overload or fatigue from time pressure, time binding, and monotony might link these three stressor dimensions to sickness absenteeism. With regard to accidents, stressors might impede the perception of necessary traffic information, lead to a misjudgment of the situation, and result in accidents. For example, the operator's view of the traffic situation might be blocked because of crowding in the vehicle, and the obstructed view might result in a collision with another vehicle. Barriers, such as troublesome passengers in the back of the vehicle, might lead to split attention (attention to the traffic situation and to the passengers) and result in accidents. Time pressure, restrictive time binding, and monotony can result in inattentiveness because of fatigue and ultimately in accidents (Lauber & Kayten, 1988; for a review, see Brown, 1994). Finally, risky behaviors performed in response to either barriers or time pressure, to save time, might increase the likelihood of accidents.

Without analyzing the specific pathways in detail, we are expecting that the four stressor dimensions, measured by external observers, will be related to work-related sickness absence and accidents.

Method

Participants

The population included 2,048 individuals who were transit operators for San Francisco Municipal Railways (MUNI) between August 30, 1993 and September 29, 1995. The company transports over 900,000 passengers per day and is among the transport companies with the highest passenger use in the United States. MUNI operates approximately 90 different transit lines including bus, light rail, and cable car lines.

The testing of the stressor–health and safety hypotheses were done with a combined sample of 308 operators based on three different data sets: observational sample with the work tasks as sample elements, medical history questionnaire data, and epidemiological questionnaire data set with individual drivers as sample elements (for more details about the recruitment, see Greiner et al., 1997).

Observational sample. Worksite observations included 81 work analyses on 27 transit lines, with exactly 3 analyses for each line. The aim was to analyze work conditions while the job was being performed; therefore, each observational analysis required the cooperation of a volunteer driver. Seventy-one operators were recruited mainly by shop stewards; 10 drivers participated in two job analyses, either on different lines or during different time periods on the same line. The 27 selected lines represented about one third of all lines of this company and included diesel bus and electric trolley bus driving lines, light rail driving lines, cable car driving, and cable car conducting. The distribution of vehicle types does not differ significantly from the

distribution of operators across the different vehicle types in this particular company.

Medical questionnaire data sample. The medical questionnaire data sample consisted of 1,920 operators who filled out a questionnaire about their medical history as part of a mandatory medical exam for renewal of their driver's license between August 30, 1993 and September 29, 1995.

Epidemiological questionnaire data sample. A number of operators (1,640) who had completed the medical questionnaire also filled out a self-administered questionnaire on a voluntary basis after the medical exam and after the relicensing process was completed. The sample was representative for MUNI operators with respect to gender, age group, years as a professional driver, and sickness absenteeism.

Combined sample. The combined sample included 308 operators who mainly worked on the 27 observed lines. The observational data (with the 27 lines as unit of analysis) were linked to the self-report data by assigning average transit line-specific values to those operators who had operated a particular line for at least the past 6 months and for at least 5 days a week. This procedure resulted in a reduced sample, as only one third of the lines operated by this company were observed, and not all operators operated a specific line long enough to meet the criteria. Workers in the combined sample were predominantly male (87%). The mean age was 49 years with a range of 27 to 72 years, and the mean number of years working as a professional driver was 16 with a range of 0 to 48 years. The combined sample was representative for MUNI operators with respect to education, reported absenteeism days, and number of accidents during the past 2 years. Operators in the combined sample were older, more senior as professional drivers, and more likely to be male in comparison with the rest of the operators.

Data Collection, Instrumentation

Observational data. A semistandardized job analysis instrument was used by 8 trained observers.[1] We have described the development of the instrument and the measures of the stressor dimensions in more detail elsewhere (Greiner et al., 1997). This method consisted of a theory-based observational interview: The job analyst observed the structure of the task for about 4 hr, interviewed the operator to clarify observations, and related this information back to the action regulation theory and stressor definitions provided in an observer manual. The observers were also equipped with basic information about the transit line, such as a route map and a run schedule for the analyzed run. Three of the four stressor dimensions (barriers, time pressure, and monotonous conditions) showed good interrater reliability. The interrater agreement for time binding was moderate (Greiner et al., 1997).

Barriers. Barriers were divided into eight categories, and their intensity was measured in extra time per 4-hr shift needed to overcome the work obstacle. Barriers were classified as impediments and interruptions. Impediments were differentiated into impediments for information processing of customer-related information (e.g., driver cannot notice passenger stop requests because of a malfunctioning passenger request signal); impediments for processing of traffic- and vehicle-related information (e.g., operators' obstructed view of traffic situation because of inappropriate location of outside mirror); impediments to vehicle moving (e.g., operator cannot pull into bus stop because of illegally parked cars); impediments for locomotion and body posture (e.g., overcrowded vehicle blocks the way for conductors); impediments for equipment handling (e.g., fare box hard to operate); and impediments for operating controls (e.g., brakes hard to reach or unreliable). Interruptions were categorized into blockages (e.g., lack of available vehicle at pick-up time forces operator to wait) and interruptions because of persons (e.g., unruly behavior of passengers after boarding).

The measurement of duration of extra work operations included either additional work steps or intensified work operations. Additional work steps are distinctively different work steps necessary to deal with the work obstacle, for example, efforts to obtain missing information, compensatory movements, or waiting. The duration of the extra work steps was documented for each barrier and weighted by the average frequency of occurrence over the month. Intensified work operations are not different from work operations under regular conditions but include a higher intensity, such as intensified concentration on task performance (e.g., increasing eye-focusing efforts as a response to glare on the windshield), increased physical strength (e.g., applying more force to operate a stiff foot pedal), or attention that is divided between different activities (e.g., shifting attention between traffic situation and passenger situation because of unruly passengers in the back of the vehicle). In the case of intensified work operations, a default value of 7 min per 4-hr shift was computed. This default value was determined in pretests through worksite observations. If extra work was avoided by risky behavior, the observer estimated the saved extra time as a measure of the severity of the barrier.

Time pressure. Time pressure was measured in terms of detachment time and was quantified as the sum in minutes per 4-hr shift. It was quantified as break time in terms of how long the worker was able to detach from the task during working hours apart from the official lunch break—for example, with mini breaks. For transit operators, detachment time can be usually taken at the end of a trip, occasionally in the middle of a trip. If detachment time was cut short because of a work barrier, (e.g., on the day of observation the operator had to pick up more passengers because of missing vehicles on the line), the observer reported the usual detachment time as if no barrier were present, as time pressure reflects a measure of work load under regular conditions.

Monotonous working conditions. These were measured as the sum in minutes of duration per day. "Monotonous" defines those conditions that demand continuous visual attention during work performance, in combination with repetitive movements or information processing for at least 30 consecutive min. In transit operating, these conditions are typically fulfilled if the traffic situation is repetitive and the driver either has no direct contact with passengers or the passenger volume is very low.

Time binding. This concept was measured on a five-level categorical scale. The most restrictive Level 5 is given when drivers have to be exactly on time at each stop. This is usually the case when passengers receive a printed schedule with exact times for each stop. Level 4 required the operator to arrive at each terminal on time and to leave from each

[1] The observational instrument can be obtained from Birgit A. Greiner.

terminal on time but not to be on time at each stop. At Level 3, the operator had to leave on time from each terminal but not arrive at each terminal on time. Level 2 applied if operators could vary the leaving time from the terminal to keep the headway to the leading vehicle constant and to avoid bunching of cars on the line. For Level 1, operators were able to vary the number of trips and the leaving times from the terminal according to passenger needs and the traffic situation.

Medical Questionnaire Data

Absenteeism because of illness since the last medical exam 2 years ago was taken from a medical history questionnaire operators had to fill out as part of their medical exam (see Appendix). Because of the high skewness of the variable, it was dichotomized into *0 days to 12 days* = 0 and *13 days or more* = 1.

Questionnaire Data

Work-related accidents were ascertained as part of a life event scale in the questionnaire (see Appendix). The variable was categorized into 1 = *any accidents during the past 2 years* and 0 = *no accidents or accident more than 2 years ago*. Data on accidents were available for 170 operators.

Statistical Analyses

Logistic regression models were used with either accidents or absenteeism as outcomes and with each of the four stressor measures as predictors. Extra time as a measure for barriers was divided into three categories, with the first encompassing from 0.0 to 19.9 min, the second 20.0 to 39.9 min, and the third 40.0 to 59.9 and more min extra time per 4-hr shift. Time pressure was categorized into three 20-min steps (0.0 to 19.9; 20.0 to 39.9; and 40.0 to 59.9 and more min). Time binding was divided into three categories by collapsing the two highest and two lowest categories. The analyses were adjusted for several control variables that were associated with both the stressors and the outcome variables. For the analyses with accidents as outcome, operator age and vehicle type (rail vehicles vs. street vehicles) were included as control variables. For the analyses with sickness absenteeism, the analyses were adjusted for age and gender, seniority as a professional driver, and vehicle type. Control variables were either entered as indicator variables with each category coded as 0/1, if they showed a nonlinear relationship with the outcome, or entered as continuous variables in cases of a linear association with the outcome.

Results

Descriptive Results With Observational Stressor Measures

All descriptive results of the observational measures were based on the sample of 81 worksite observations.

Barriers. Observers documented the barriers in detail and categorized them into one of the eight barrier categories. For the purpose of qualitative description, they were further differentiated into 31 specific barrier types during the coding process. Table 3 shows those 12 specific barriers that resulted in the longest average extra work. High measures can reflect either a high average extra time per barrier occurrence or a high frequency of barrier occurrence, or both.

"Blocked loading and unloading of passengers" (interruption due to blockage) required the highest average amount of extra work (10.0 min) per 4-hr shift. This barrier usually required longer waiting periods for the operator until passengers embarked or disembarked. This barrier was found in 14 of the 81 analyses. "Illegal behavior of passengers after boarding" (interruption due to persons) took an average of 8.0 min extra work. The extra work operations usually consisted of arguing with passengers or splitting attention—paying attention to traffic conditions and, at the same time, to the behavior of passengers in the vehicle. This barrier was found in 18 analyses. "Problems with the acceleration" (impediment for operating controls), reported in 12 analyses, required an average of 7.4 min of extra work. Other barriers included passengers unruly while boarding such as fare evaders or fare arguers (5.4 min); missing leading vehicles of the same line or a parallel line (5.1 min); road obstacles such as road construction (5.0 min); the use of transit lanes or rail tracks by unauthorized vehicles (4.8 min); double parking in narrow streets (4.7 min); door, wheelchair ramp, or kneeler operating problems (4.4 min); narrow or sharp turns (3.9 min); and problems to turn the vehicle over at the end of the shift (3.7 min).

Table 4 shows specific barriers that lead to extra work in the form of intensified work operations. These barriers included blocked view of traffic situation because of overcrowded vehicle or because of equipment design and barriers for providing information to passengers or to stop the vehicle. They required either intensified concentration on task performance or intensified application of physical strength.

Time pressure. Table 5 shows the descriptive results related to time pressure: Eight percent of operators had an observed average of 5.0 or fewer min break time per 4-hr shift. Eight percent were able to detach between 6.0 and 10.0 min, 6% between 1.0 and 15.0 min, 25% between 21.0 and 30.0 min, and 37% had more than 30.0 min. These observations were conservative, as time pressure can be masked, as shown in Column 2 (see Table 5). Column 2 displays

Table 3
Average Extra Work for Specific Barrier Categories, Based on 81 Work Analyses

Specific barrier subcategory	Barrier category: observed consequences for operator	Found in no. of analyses	Average extra work (min)
Blocked loading or unloading of passengers (e.g., "street furniture" blocks stop, vehicle overcrowded, passengers are jammed in and cannot get out)	Interruption due to blockage: operator has to wait	14	10.0
Unruly behavior of passengers after boarding (radio playing, graffiti spraying, smoking)	Interruption due to persons: stop vehicle and deal with passengers, split attention	18	8.1
Poor view of traffic situation due to missing, inappropriate, or poorly located mirrors	Impeded processing of traffic- and vehicle-related information: slow down, accident prone situations	8	7.0
Problems with acceleration (stiff pedal, delayed response of engine)	Impeded operating of controls: awkward movements, accident-prone situations due to delayed response of engine	12	7.4
Passenger problems during boarding (fare evaders or arguers, passengers threaten operator, passengers hassle other passengers)	Impeded processing of passenger-related information: split attention, intensified concentration, call central control or police	8	5.4
Missing leading vehicle on same or parallel line due to equipment breakdown or lack of available equipment or workforce	Interruption due to persons: operator has to pick up more passengers than usual, has to argue with disgruntled passengers	26	5.1
Use of extra transit lane or rail tracks by unauthorized vehicles	Impeded vehicle movement: waiting, slowing down, delays	14	4.8
Double parking in narrow street	Impeded vehicle movement: frequent lane changes, waiting, delays	19	4.7
Door operating problems, including operating kneeler and wheel chair ramp	Impeded operating of controls: try several times, switch from automatic to manual operation	18	4.4
Narrow, sharp turns	Impeded vehicle movement: maneuver vehicle, accident-prone situations, slow down	16	3.9
Vehicle cannot be turned over at end of shift (e.g., relief person missing, garage entrance blocked)	Interruption due to blockage: drive longer until relief person is available, wait	3	3.7

the percentages of the time that was saved by circumventing safety standards because of high work load (e.g., speeding, running through yellow lights) or by extending the work hours beyond the shift end. This time was subtracted from the observed detachment time. In this case 17% of operators had 5.0 or fewer min of detachment time, 11% had 6.0 to 10.0 min.

We also investigated whether single break periods were long enough to use for basic physical needs (restroom, eating) or for recreational purposes such as stretching exercises. Analyses of the length of rest breaks in consecutive minutes showed that on several lines even the longest break period was not long enough to attend to basic physical needs. Eight percent of operators had less than 5.0 consecutive

Table 4
Most Frequent Specific Barriers With Intensified Work Operations, Based on 81 Work Analyses

Specific barrier	Barrier type: Intensified work operations	Found in no. of analyses
Blocked view of traffic and street situation due to overcrowded vehicle	Impediment of processing driving-related information: intensified concentration, compensatory movements to "catch a glimpse" of the situation	24
Barrier to provide information to passengers (e.g., missing microphones in combination with noisy vehicle)	Impediment of processing passenger-related information: repeat calling out stops without microphone several times, raise voice, stop at "last moment" since passengers did not hear stop announcement	20
Blocked view of traffic and street situation due to equipment design (e.g., windshield design, unreliable defogger)	Impediment of processing traffic- and vehicle-related information: intensified concentration, compensatory movements to "catch a glimpse" of the situation	11
Barriers for stopping vehicle: stiff pedals, unreliable brakes, slippery conditions	Impediment of operating controls: unfavorable movements, apply more force	8

min, and another 8% had only between 5.0 and 10.0 consecutive min detachment time at least once during a 4-hr shift.

Time binding. Although most transit operators work on a strict scheduling system, the level of time binding varied depending on the specific work organization (e.g., can the number of trips be modified?) and the strictness of supervision (are operators "written up" if they are not on time at the terminals?). None of the runs were rated at the most restrictive Level 5, as timetables posted for passengers at most bus and rail stops showed only headways between vehicles but no exact arrival times for a particular stop so that passengers and supervisors did not expect drivers to be there at a particular time. Ten percent of runs were rated as Level 4. Most observed runs (58%) were rated on the medium Level 3. At this level, the operator had to leave on time from each terminal; however, the scheduled layover time at each was long enough that operators did not have to arrive on time at each terminal. Twenty-six percent of runs were classified into the less restrictive Level 2, and 6% into Level 1. On some lines, operators could vary the leaving time from the terminal to keep the headway to the leading vehicle constant and to avoid bunching of cars on the line. In this case, Level 2 applied. For Level 1, operators were able to vary the number of trips and the leaving times from the terminal according to passenger needs and the traffic situation.

Table 5
Descriptive Results for Time Pressure (Observed and Adjusted Detachment Time) Based on 81 Job Analyses

	Observed detachment time per 4-hour shift (%)	Adjusted detachment time (%)
≤5 min	8	17
6–10 min	8	11
11–15 min	6	14
16–20 min	16	16
21–30 min	25	12
30+ min	37	30

Monotonous conditions. These were found in 75% of rail operating runs, usually those runs that included stretches of subway driving for longer than 30.0 consecutive min. Subway driving included continuous monitoring of displays and repetitive information processing without any passenger contact. Monotonous conditions were also found in 40% of the analyzed bus runs, usually in night runs and runs during periods of low traffic density and low passenger volume.

Table 6
Results of Logistic Regression Analyses With Work-Related Accidents Within the Past 12 Months, Adjusted for Age and Vehicle Type (n = 167)

Stressor dimension	Stressor level	Adjusted odds ratio	$p > \|z\|$	95% confidence interval
Work barriers (extra work)	Low (0.0–19.9 min)	1.0	—	—
	Medium (20.0–39.9 min)	0.7	0.43	0.32–1.61
	High (40.0–59.9+ min)	0.7	0.40	0.26–1.71
Time pressure (detachment time)	Low (0.0–19.9 min)	1.0	—	—
	Medium (20.0–39.9 min)	2.7	0.09	0.87–8.30
	High (40.0–59.9+ min)	4.0	0.04	1.08–14.69
Time binding	Low	1.0	—	—
	Medium	6.8	0.01	1.81–25.48
	High	3.3	0.04	1.02–10.32
Monotonous conditions	Absent	1.0	—	—
	Present	1.2	0.61	0.60–2.37

Note. Dashes indicate that p and confidence interval do not apply because the odds ratio was set to 1.0.

Descriptive Results for Accidents and Absenteeism

The descriptive results for the health and safety outcomes were based on the combined sample. Thirty-two percent of operators reported a work-related accident during the past 2 years. Ten percent of operators reported being off work because of illness for more than 12 days during the past 2 years. The average of absenteeism days due to illness was 5.5 days, with a range of 0.0 to 125.0 days.

Absences were associated with age and years of professional driving. The medium age group (40–54 years) had the highest, the youngest age group (25–39 years) the lowest rates. The higher the seniority as driver, the higher the percentage of operators with high absence days. Women were more likely to be absent than men. Work-related accidents were associated with vehicle type and age. The highest accident risk was for rail, and the lowest for motor coach operators. With regard to age, the highest accident rate was in the medium age group, and the lowest risk in the youngest age group.

Results of the Logistic Regression Analyses With Accidents and Absenteeism

Accidents. Table 6 shows the results of the individual logistic regression analyses for each stressor dimension with work accidents as outcome. The low stressor group was taken as the reference group, with an odds ratio of 1.0. All analyses were adjusted for the effects of age and vehicle type. Because of the small sample size, the confidence intervals were wide and indicated an imprecise estimate of the risk. There was a clear gradient between time pressure and accidents, a significant odds ratio of 6.8 for the medium time-binding group, and a significant odds ratio of 3.3 for the high time-binding group. Because the confidence intervals of the estimated risks overlap, no clear conclusion about a potential nonlinear relationship between time-binding and accidents can be drawn from these data. The other two stressor dimensions, work barriers and monotony, were not associated with accidents. Inclusion of seniority or gender as control variables did not significantly improve the fit of the model. We also tested whether inexperienced younger drivers were more likely to be involved in accidents as reported by others (Pokorny & Blom, 1993). The multiplicative interaction term for age and seniority was not significant when included into the logistic regression model (odds ratio = .99, p = .89). Analyses for multiple interaction effects between the stressor dimension showed a significant interaction term for barriers and time pressure (odds ratio = 1.8, p = .16; data not shown).[2] The operators with the highest barriers and the most serious time pressure had the highest risk for accidents. Because of the small sample, the adjustment factors age and vehicle type were not included into the model.

[2] The significance level for testing the interaction term was set to an alpha of .20 as suggested by Selvin (1991, p. 187) to increase the statistical power, which is usually lower for determining interaction effects than for determining main effects.

Table 7
Results for Logistic Regression Analyses With Absenteeism (≤12 Days vs. >12 Days), Adjusted for Age, Gender, Seniority, and Vehicle Type (n = 167)

Stressor dimension	Stressor level	Adjusted odds ratio	$p >$ $\|z\|$	95% confidence interval
Barriers	Low (0.0–19.9 min)	1.0	—	—
	Medium (20.0–39.9 min)	0.7	0.52	0.20–2.24
	High (40.0–59.9+ min)	3.8	0.05	0.98–15.08
Time pressure	Low (0.0–19.9 min)	1.0	—	—
	Medium (20.0–39.9 min)	1.3	0.69	0.37–4.61
	High (40.0–59.9+ min)	1.4	0.58	0.39–3.34
Time binding	Low	1.0	—	
	Medium	1.3	0.69	0.37–4.61
	High	1.4	0.58	0.39–5.34
Monotonous conditions	Present	1.0	—	—
	Absent	0.6	0.28	0.21–1.56

Note. Dashes indicate that p and confidence interval do not apply because the odds ratio was set to 1.0.

Absenteeism. Table 7 shows the statistics of the logistic regression analyses with absenteeism because of illness. These analyses were adjusted for age, gender, seniority as a professional driver, and vehicle type. There was an elevated odds ratio for the high barrier group that was very close to being statistically significant. The elevated odds ratios indicated that individuals in the high stressor group were almost four times more likely to be in the high absent group in comparison with individuals in the low stressor group. Again, the overlapping confidence interval of the estimates do not allow for interpretation of these results as a nonlinear effect. Time pressure, time binding, and monotony were not associated with absences. We also tested for interaction effects of all stressor dimensions (again without including the adjustment factors). Both time pressure and time binding interacted with work barriers (odds ratio = 4.9, $p = .06$ for the barrier–time pressure interaction; odds ratio = 7.1, $p = 0.1$ for the barrier–time binding interaction). The groups with high barriers and high time pressure and with high barriers and highly restricted time binding had a proportionally higher risk for absenteeism in comparison with the group with high barriers only.

Discussion

One purpose of this study was to describe task-related stressors, measured by external observers, in more detail than is possible by using only questionnaire data. A second purpose was to show that occupational stressors, assessed as objective conditions of the job, predict important health and safety outcomes.

Descriptive Results

The description of stressors provided a detailed picture of problems. Our data, although obtained in one single company with one occupational group, showed a wide heterogeneity of stressors with various underlying organizational–technical causes. An important distinction was the differentiation between work barriers and time pressure, factors that are commonly assessed in one dimension as "work demands" (e.g., Karasek & Theorell, 1990). This differentiation allowed a precise identification of the underlying causes for "high demands." In the case of work barriers, the reasons were technical–organizational problems, such as equipment or passenger problems; in the case of time pressure, the inadequacy of the assigned routine workload was the cause.

A striking result was the high amount of time spent for extra work operations required to compensate for them. Although the amount of extra time in response to a single occurrence of a barrier was usually rather short, this time added up over the course of the workday and resulted in substantial amounts of additional work operations in some analyses. We reported an average amount of 37.6 min per 4-hr shift (Greiner et al., 1997). This finding is consistent with results about behavior efficiency under stress, which suggest that behavior in stress situations is less efficient than behavior under nonstress situations. For example, Schönpflug (1986) had reported that compen-

satory actions to deal with stressors increased psychic load and energy expenditure and led to even higher stress appraisal, so that the costs superseded the benefits of the actions.

Some operators were not able to complete their trips within the given time frame provided by the official run schedule, which was an indicator for time pressure. This resulted in a considerable number of operators who could not take any break or only a small portion of the scheduled break period at the end of each trip. The results about the nonavailability of substantial rest periods are alarming considering that this occupation is safety sensitive and also considering the health and productivity benefits of breaks that are used for alternative activities, such as stretching and exercise, for video display terminal (VDT) workers (for review see Swanson & Sauter, 1989).

Analyses With Health and Safety Outcomes

The data showed distinct patterns of associations between the four stressor dimensions and absenteeism and accidents.

Absenteeism. With the finding of a borderline-significant elevated risk for the high barrier group, our study is one of the few studies to find associations between observed stressors and absenteeism. Other studies that use stressor measures obtained from external raters, either from independent observers (Algera, 1983), from supervisors (Algera, 1983; North, Syme, Feeney, Shipley, & Marmot, 1996; Spector, Dwyer, & Jex, 1988), or from expert ratings based on job descriptions (Spector & Jex, 1991), usually failed to show substantial associations between work stressors and work absences (with the exception of North et al., 1996). In contrast to these studies, our observational measures were based on direct observation of the task during work hours and not on ratings without worksite inspection. Direct observation might have contributed to higher accuracy of the stressor measures.

A major advantage of our study design was that information bias, which constitutes a problem in many studies about self-report stressors and absenteeism, can be excluded as potential explanation for the associations between stressors and absences. Information bias tends to result in overestimation of the stressor–absenteeism association in studies using self-report stressor measures, as people with ill health might be more likely to report high stress because of a recall effect (Heaney & Clemans, 1995; Kristensen, 1991; North et al., 1996). Analyses that compare observational and self-report stressor measures in our sample will further clarify this issue.

Although time pressure and time binding were not related to sickness absences in our sample, these two indicators of work stress played an important role in the stressor–absenteeism relationship, as they showed significant unadjusted interaction effects with barriers. The significant interaction barrier–time pressure and barrier–time binding suggests that the effect of extra work is exacerbated when tied into a dense or inflexible schedule. One explanation for this effect could be that extra work because of barriers is harder to be fit into a tight or inflexible schedule and might lead to problematic delays and result in higher strain for the operator.

Our results are consistent with other studies that show that self-reported high work demands and high work pace are associated with various indicators of absenteeism (Kristensen, 1991; North et al., 1996). In contrast to existing studies, the present research differentiates "demands" into two different concepts, barriers and time pressure, and the distinct patterns of associations of the two concepts with sickness absence might contribute to a deeper understanding of stressors important for work absences. Our results are also consistent with findings that are based on the demand–control model and find elevated absenteeism for those workers who work high-demand and low-control jobs (Karasek, 1979; Kristensen, 1991). According to the presented concept of barriers, barriers are those demands that cannot be responded to without efficient worker control. Control over timing of work steps was measured by time binding. Time binding that measures the specific aspect of control over time handling was not predictive for absences, a result that is consistent with Heaney and Clemans (1995). This finding might indicate that this particular aspect of control is truly not associated with absences. It might be also because of measurement issues such as the moderate reliability of the time-binding measure or the low heterogeneity of time-binding conditions in our sample.

It is important to note that sickness-related absenteeism is not necessarily an indicator for ill health; the decision to be absent is also likely to be influenced by a number of attitudinal and social factors (Geurts, Schäufeli, & Buunk, 1995). Short-term absences in particular have been hypothesized as a coping strategy to deal with psychic and somatic symptoms so that more serious diseases are avoided (Kristensen, 1991). Although the potential contribution of attitudinal and social factors needs to be considered when interpreting our results, the contribution of health factors should not be underestimated. Absences are also highly dependent on the overall

economic situation and the level of health insurance coverage. Because all operators had similar insurance coverage and were studied within a narrow time frame, a systematic bias because of these two factors can be excluded.

Accidents. Time pressure and time binding significantly predicted accidents. This points toward the importance of guaranteed rest breaks and flexible schedules for transit operators to prevent accidents. Although official breaks were scheduled at the end of each trip, operators on high time pressure lines were often not able to take these breaks at all or were able to only take very short periods. The most plausible explanation for the increased risk of accidents under time pressure and time constraints is fatigue (Lauber & Kayten, 1988). However, the role of rest breaks and fatigue for professional driver accidents has not been fully clarified yet. For example, Hamelin (1987) found an association between time at which truck drivers were at the wheel and involvement in accidents, whereas others found no association between accident risk and the duration of total added rest periods up to the moment of the accident in bus drivers (Pokorny, Blom, & Van Leeuwen, 1987).

Another potential pathway between work stressors and accidents might be risky behavior. For example, a study done with car drivers found that stress was positively associated with offending traffic laws (Simon & Corbett, 1996). The use of observational measures is particularly helpful for the study of this issue, as self-report data might introduce a systematic bias. Drivers who tend to use risky driving practices might also report higher levels of stress to excuse their behavior. The present study shows that several risky strategies, which involved offending traffic or general safety and courtesy rules, were performed as a response to time pressure. The most common risky strategy was to start driving after a stop without waiting for boarding passengers to sit down or hold onto something (47% of all analyses); running yellow and red traffic lights (15%); not operating kneeler when necessary (9%); not pulling into stops even though stop is not blocked (7%); not completely stopping at stop signs (6%); and not checking passenger passes (2%). Operators saved an average of 6 min per 4 hr by performing risky behaviors. Unexpectedly, work barriers were not associated with accidents, and their role needs to be further clarified.

The role of monotonous working conditions for absences and accidents remained unclear in our study. This dimension was not associated with the health and safety outcomes. In previous analyses with the same sample of transit operators, we have shown that this stressor was associated with smoking to cope, time to relax after work (Greiner et al., 1997), and with alcohol dependence, problem drinking, and volume of drinking (Greiner, 1996). Further analyses need to be done to understand these health outcomes in relation to sickness absences. For the analyses with accidents, periods of monotony were probably not long enough to result in fatigue, inattentiveness, and eventually in accidents.

Biases

Several conservative biases might have led to an underestimation of the true associations between stressors and accidents and absenteeism. Selective separation from employment because of accidents, sickness, or high stress might have resulted in a healthy workforce at MUNI. In fact, in a previous study we showed that hypertensive employees were more likely to leave MUNI in comparison with nonhypertensives within a 4-year time frame (Ragland, Greiner, Holman, & Fisher, 1997). This bias is likely to apply to drivers with accidents, sickness absences, and high stress also, and thus would result in a conservative estimate of the association between stressors and absenteeism and accidents.

Another conservative bias might have been introduced by the run assignment system of the particular company under observation. Operators are able to change their line assignment each quarter. Although line-specific average observational stressor measures were assigned only to those drivers who drove a particular line for at least 6 months 5 days a week at the time of the data collection, the exposure time of specific stressors might have been too short to show any effects on health outcomes.

People with higher stress as well as with unfavorable health and safety outcomes might be less likely to participate in the study. Selective participation was not a problem for the absence data, as they were derived as part of a mandatory medical exam. This effect might have biased the stressor–accident association toward the null as the accident data were obtained by a questionnaire administered on a voluntary basis.

Alternative Explanations for Results

We also consider two alternative explanations that might have spuriously created associations between the independent and the dependent variables. First, traffic density, which varied between different shifts and transit lines, might have been responsible for the association between stressors and accidents. It has been argued that collision accidents in bus drivers are

a function of the number of vehicles on the street (Ragland, Hundenski, Holman, & Fisher, 1992). The authors found increased risk for collision in the morning shift because of increased traffic density during that time. When we adjusted for type of shift predominately driven by the operator during the past 12 months (morning shift versus other shifts) in the logistic regression analyses, the odds ratio for time pressure and time binding did not decrease substantially. The ratio for the medium-level stressor group dropped from odds ratio = 2.7 to odds ratio = 2.6, $p = .10$, and the ratio for the high-level group dropped from odds ratio = 3.9 to odds ratio = 3.4, $p = .07$. On the basis of these results, traffic density as a critical mediator for the association between stressors and accidents can be excluded.

Another bias might have been introduced by the retrospective subjective assessment of accidents and absenteeism. Perhaps persons exposed to higher levels of stressors report more accidents or higher absenteeism, producing an inflated association. However, this bias would have affected the four stressor dimensions to the same degree. The distinctive pattern of the associations with the different stressor dimensions makes such an explanation unlikely.

Limitations of the Study

This study was done with one occupation in one company only, and therefore the generalization of results to other occupational groups and other companies is limited. More studies using these observational measures in other transit companies and other occupations need to be conducted.

Our study is cross-sectional and does not allow for determination of the direction of causality. A reverse causation hypothesis might state that accidents or sickness causes individuals to drift toward highly stressful transit lines, for example, because supervisors assign them to the highly stressful runs. We cannot completely rule out this hypothesis; however, the sign-up procedure of the particular company under observation makes this hypothesis, as explanation for the associations, unlikely. Operators choose the transit lines based on seniority.

Conclusions, Implications, and Future Research

The conclusions and implications of this article are twofold. First, the article might stimulate further discussion on measurement issues in occupational stress research. Second, our approach and findings might be helpful to design future studies about transit operator stress.

The specific contribution of the presented job analysis instrument to the discussion of measurement issues is that it overcomes methodological limitations of other observational job analysis instruments. It has been criticized that observational job analysis provides less differentiated information than questionnaires because observers tend to overgeneralize from limited information and substitute missing parts by dominant information (Semmer, Zapf, & Greif, 1996). To limit this problem the action regulation procedure herein guides the observer to describe stressors and the underlying technical–organizational causes in detail. Furthermore, the procedure requires observers to justify their ratings. Using this approach, observational analyses might provide actually more detailed and specific information than questionnaires. Additionally, rating scales that are vulnerable to observer generalization were not used. Instead, stressors were measured in either absolute numbers or categorical scales with well-defined categories. For example, a scale such as "How fast does the worker have to work" is more likely to invite generalized observer judgments than a procedure that measures detailed work barriers in absolute minutes of extra time.

The present study was exploratory in terms of using a new instrument and establishing associations with health and safety outcomes. Next steps in using the objective approach might be to further elucidate pathways between objective stressors and health and safety outcomes. Job analysis can be particularly useful in determining the independent role of coping and personality factors as the data are less likely to be confounded by personal characteristics of the workers as is most self-report data.

For future transit operator studies we suggest conceptualization of the job of transit operators not only as driving. Transit operation includes more than just moving a bus from point A to point B. Our presented theoretical framework allows analysis of additional important task elements such as processing necessary information, communicating with passengers, and task-related exchange of information with coworkers and supervisors. The analysis of the task is incorporated in the analysis of the organizational and physical setting that surrounds the individual driver. The focus on the whole picture rather than on a single task element might help in developing practical solutions for stressor reduction. Some barriers can be removed by simple technical solutions (e.g., equipment redesign). However, our analyses show several work barriers that can only be resolved by addressing the organizational structure of the work environment (e.g., problems of communication between operators and maintenance workers). An effective intervention

might therefore require job analysis of related tasks (maintenance workers, street supervisors, dispatchers). This might be tied into a stepwise and participatory approach that involves organizational development (Kompier, 1996). To address the whole picture rather than isolated task elements is especially important for the occupation of urban transit driving, as the removal of stressors is not exclusively at the discretion of transit companies. Several stressors can be modified or removed only in collaboration with city planners, city officials, and ridership organizations (e.g., extra transit lanes, modified schedules).

Using this comprehensive approach, we found a wide variety of stressors within this single occupational group. These results suggest conducting more studies that focus on the variation of stress in transit operators rather than treating them as a homogeneous group. Future research should compare different types of work organization in transit driving and their association with specific stressors or resources to develop new forms of work organization. One solution might be to enlarge the task of transit operating by including other tasks, such as maintenance or customer service (Tränkle & Bailer, 1996). For this purpose, the present observational job analysis approach can be a helpful tool to identify detailed causes of stressors and to determine opportunities for improvement.

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Appendix

Work-Related Accidents

Below are some things that happen to many people during their lives. For each question, mark when the event happened. (If the event happened more than one time, mark the most recent).

i. Accident at work

(Within the past year; 1–2 years ago; more than 2; never)

Sickness Absences

Since your last exam, have you

c. Missed work due to illness (total # days)?

Received May 15, 1997
Revision received November 21, 1997
Accepted February 5, 1998 ■