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Authors

Long, Lyn
Perry, James L.

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**Bibliography on Transit Operator Stress and
Absenteeism, Workers' Compensation
and Extraboards**

UCI-ITS-WP-83-3

Lyn Long ¹
James L. Perry ²

¹ Institute of Transportation Studies
University of California, Irvine

² School of Public and Environmental Affairs
Indiana University University; Bloomington, Indiana

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Institute of Transportation Studies
University of California, Irvine
Irvine, CA 92697-3600, U.S.A.
<http://www.its.uci.edu>

INTRODUCTION

This bibliography was prepared as supporting documentation for Project #BTH-81-002 (ITS) conducted by the Institute of Transportation Studies, University of California, Irvine, under the sponsorship of the State of California's Business, Transportation and Housing Agency.

This project reviewed three facets of human resource productivity in public transit: workers' compensation costs, extraboard scheduling and operator stress. These seemingly disparate topics share a common attribute: they each have been associated with the costs of absenteeism in the transit industry. Management concerns about abuses of workers' compensation have led them to regard this program as a significant incentive for absenteeism. Extraboards, in contrast, have helped to insure schedule reliability by providing a ready pool of labor to replace absent employees.¹ The phenomenon of operator stress has occupied a middle ground, viewed by some as a cause of workers' compensation claims, and by others as a result of traditional scheduling practices, such as the extraboard.

This bibliography reviews over 50 international studies which have addressed the interrelated issues of absenteeism, workers' compensation, extraboard scheduling and stress-related illness in the transit industry. Section I provides bibliographic information and summary abstracts of each of these studies. Section II describes two recently initiated U.S. research projects which are exploring transit operator stress, hypertension, and operator performance for the U.S. Department of

¹The extraboard is the group of operators responsible for covering runs left open because of the absence of regular drivers on vacation, sick leave, industrial accident status, missouts, etc. Extraboard operators may also cover trippers not bid by regular operators and may cover charter runs or special assignments.

Transportation and the National Academy of Science's Transportation Research Board. Section III, prepared by project assistants Susan Lesh and Marianne Miasnik, lists a number of general studies of workers' compensation reviewed as background to our current study.

Special thanks are extended to the following individuals: Suzanne Crowther, Transportation Research Board; Mariana Dranscak and Winnie Muse, Urban Mass Transportation Administration; and Mary Jo Burke, U.S. Department of Transportation. Their assistance in locating and forwarding a number of the foreign studies reviewed for this project is gratefully appreciated.

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PART I. ABSTRACTS OF TRANSIT-SPECIFIC RESEARCH ON
OPERATOR STRESS, ABSENTEEISM, WORKERS' COMPENSATION,
AND EXTRABOARDS

A. OPERATOR ABSENTEEISM, WORKERS' COMPENSATION, AND STRESS-RELATED ILLNESS

Aronsson, Gunnar. Sick leave and illness patterns among transit personnel in metropolitan Stockholm local transit. (Preliminary Report No. 9). Stockholm: Stockholm University, Psychological Institute, 1976.

Studied sick leave and illness patterns among employees of the metropolitan Stockholm local transit agency. Data for a full-year period were drawn from the records of 4500 full time operating and 865 office personnel to enable comparisons between these two groups. Results indicated that the transit personnel had a significantly higher rate of absence than the office personnel. The difference between the two groups was most pronounced for those illnesses attributed to stress and psychological strain (insomnia, fatigue, circulatory and digestive disorders) and environmental factors (musculoskeletal disorders, respiratory infections, etc.), with transit personnel affected to a considerably higher degree than office personnel.

Aronsson, Gunnar, & Barkloff, Klas. Working environment for local transit personnel in large and medium sized towns. Translated from the original Swedish for the U.S. Department of Transportation under contract #UMTA-VA-06-0034-82-1. Stockholm: Stockholm University, Psychological Institute, 1980. (Available from the U.S. Department of Transportation Library, Washington, D.C.)

Administered a questionnaire to 1500 local transit employees in six Swedish cities to explore the relationship between employee absenteeism and environmental, demographic and social factors. In comparison with a control group of 10,000 Swedish civil service employees, the transit personnel were found to have more frequent absences of longer duration, and more frequent reports of absence due to fatigue or disinclination to report to work.

The authors hypothesized that the degree of stress-related illness suffered by the transit personnel were a function of the interrelationships among the employees' work load, resources (personal and organizational support), demographic and personality variables, and the degree to which the individual's schedule conflicted with social and family demands. They further hypothesized that those workers with a high work load and few resources for control of stress would be most susceptible to illness and, conversely, those individuals with low work load concerns and many resources for control would be less prone to psychosomatic and physiological disorders.

These hypotheses were supported. Results of their statistical analysis showed a strong correlation between the work load, resources and reported ill health. Work load and resources were systematically related to health conditions (psychological and physiological exhaustion, back and joint pains, stomach trouble, insomnia, slight mental distress) and sick leave. The pattern showed that with increased work load, health problems increased at every resource level, and that health problems lessened at each work load level when resources increased.

In the group with the lowest work load level and highest resources, 13% were absent from work in a one year period, while for the highest work load/lowest resource group, the corresponding figure was 52%.

This pattern also influenced other employee behaviors, including the intent to quit. In the group with the highest work load (the high stress group) as many as 45% considered quitting, while in the group with low work loads and high resources the figure was only 8%. Employees who reported a desire to quit reported health problems to a far greater extent, a pattern which was similar regardless of age level. Among those reporting that they had seriously thought of leaving, the most important reason given was the working hours involved, followed by excessively strenuous work, stress, family problems due to working hours, and health problems.

To supplement the results of their questionnaire analyses, Aronsson and Barkloff conducted an intensive physiological study of 52 bus drivers at the Greater Stockholm transport company. The purpose of this study, which included a medical examination, was to determine whether a relationship could be established between the drivers' working conditions, physiological reactions (measured by levels of the hormones adrenalin, noradrenalin and cortisone, and blood pressure) and health/well-being.

In this intensive study, 52 bus drivers were followed for four hours at work. Psychological impressions and measures of physiological activation were collected and the latter compared with data from an inactive session (film showing) at the same time on another day.

Time pressure and problems with passengers were used as separate measures of work load. The results indicated that drivers operating in congested traffic reported more time pressure, irritation and effort. They also showed a somewhat greater increase in adrenalin excretion. Inadequate control of the traffic environment was thus associated with both physiological and hormonal stress reactions at work.

Drivers with a high work load in the form of frequent time pressure reported feelings of stress and fatigue more often than other drivers. The elevation of cortisone during traffic peaks was also systematically greater in drivers subjected to high time pressure than in those with low time pressure; the increase in blood pressure during peak traffic, in relation to the baseline from the medical checkup, was greatest with high time pressure. Drivers who had to deal with troublesome or threatening passengers tended to increase their adrenalin and cortisone excretion while driving to a greater extent than those with fewer encounters of this kind.

It was also found that these hormonal increases were related to health and absenteeism, with drivers who worked in denser traffic reporting more stomach, heart, shoulder and back trouble than drivers in less dense traffic. These somatic complaints were found to be directly related to illness-related absence.

Baker, Harry S., & Schueftan, Oliver. Study of operator absenteeism and workers' compensation trends in the urban mass transportation industry. Prepared for the U.S. Department of Transportation under contract #UMTA-PA-0050-80. Washington, D.C.: Peat, Marwick, Mitchell & Co., 1980. (NTIS #PB 81-180937).

Conducted a major study of operator absenteeism and workers' compensation trends in urban mass transportation for the U.S. Department of Transportation under the direction of the Port Authority of Allegheny County (Pittsburgh, PA). The principal goals of the study were to examine the extent and costs of nationwide transit operator absence and to suggest approaches for improving employee attendance. Data were drawn from a mail survey of approximately two hundred U.S. transit properties, site visits to twenty-three of these properties, and extensive interviews with management and labor personnel. Analysis of the data provided estimates of the extent of transit operator absence as measured by work days lost per operator due to sick leave, injury-on-duty and other absences, and the direct costs of absence such as workers' compensation expenses, medical expenses, and sick leave payments for extraboard operators. The report also summarizes currently used management strategies for improving employee attendance and makes a preliminary assessment of their effectiveness.

The extent and cost of operator absence were found to be significant. Operator absence of all types, exclusive of holidays and vacations, averaged 29 days per operator per year. The two principal components of this absence--sick leave and job-related injury leave--increased by 24 percent and 148 percent respectively from 1974 to 1978, with injury-on-duty leave by far the most rapidly growing category of absence in the transit industry. From 1974 to 1978, injury-on-duty absence increased sixfold. Data from the U.S. Department of Labor further indicated that transit operator absence from sick leave and injury-on-duty was three times higher than in the private sector as a whole and approximately 50 percent higher than that of the average private sector transportation employee.

The identifiable costs of operator absence totaled approximately \$187 million per year, or more than one quarter of the total federal operating subsidy for transit in 1978. Sick leave and workers' compensation expense per operator increased by 175 percent and 238 percent respectively between 1974 and 1978. Of the total cost of operator absence, 28 percent was attributed to job-related injury payments, and 40% to the cost of maintaining a pool of extra operators.

A number of strategies for mitigating the adverse impacts of operator absenteeism were proposed and evaluated including improving extraboard sizing and scheduling techniques, self-insurance for workers' compensation, and limitation of workers' compensation availability. Appendices to the report include a sample of the survey instrument and an extensive annotated bibliography on workers' compensation and absenteeism.

Baker, H. Scott, Schueftan, Oliver, & Routh, Francis. Transit operator absenteeism: Extent, costs, and strategies for reducing it. Transportation Research Forum. Proceedings of the Twenty-First Annual Meeting. Oxford, Indiana: Richard B. Cross, 1980, pp. 105-115.

Summarizes a major U.S. study of operator absenteeism and workers' compensation in urban mass transportation. For a description of this research, see preceding entry.

Berlinguer, Giovanni. Maladies and industrial health of public-transportation workers. Translated from the original Italian for the U.S. Department of Transportation under contract #UMTA-VA-06-0034-82-2. Citta di Castello: Italian Institute of Social Medicine, 1962. (Available from the U.S. Department of Transportation Library, Washington, D.C.)

Conducted a longitudinal study of illness and industrial accidents among the 11,000 employees of the ATAC (public transportation agency) in Rome. For the years 1956-1961, data were collected for three groups of personnel: white-collar workers, laborers (i.e., shop personnel) and travelling personnel (drivers and conductors). Distinct differences were found among these groups. In comparison with the white-collar workers, travelling personnel were found to be absent due to illness almost 2.5 times as frequently, and were twice as likely to be absent due to disability. Compared to both white collar and laboring personnel, the drivers and conductors had a significantly higher incidence of disease in all twelve major disease categories for which data were collected. Compared to the white-collar workers, the drivers and conductors suffered five times as frequently from digestive disorders, four times as frequently from musculoskeletal disorders, and three times as frequently from nervous and mental disorders. In spite of the lower age of the driver/conductor group, hypertension affected these workers more frequently than both other groups, with 38.13 absences per 1000 for drivers and conductors for hypertension compared with 27.77 for laborers and 16.60 for white-collar workers. While laboring personnel suffered more frequently from accidents on the job than both white-collar workers and drivers/conductors, this category of absence rose most rapidly within the driver/conductor category from 1956-1961, while remaining stable for the laborers.

Berlinguer concluded that there was a close relationship between the public transportation workers' illness and their working conditions. Absenteeism among drivers was fostered by uncomfortable and fatiguing working conditions, long hours of work, and a frequent need to 'call in sick' when denied the leave requested. Of additional concern was the tendency of drivers to work overtime and on regularly scheduled days off.

Blau, Gary. An empirical investigation of job stress, social support, service length, and job strain. Organizational Behavior and Human Performance, 1981, 27, 279-302.

Administered a questionnaire to 123 bus drivers in a midwestern transit property to assess the interrelationships between job stress and strain; job satisfaction/dissatisfaction; job performance; seniority; and perceived social support from supervisors, co-workers and family and friends. Data from the questionnaire were supplemented by information from organizational archives.

Factor analysis was used to cluster perceived stressors into three categories: (1) passenger/intracompany stressors (i.e., passenger respect and adherence to rules, management concern, helpful field supervision, adequately maintained equipment, fair company rules, opportunity for participation in rule setting); (2) scheduling/

assistance (i.e., flexible bus schedules, adequate layover time, adequate radio communication, opportunity to learn one's route); and (3) physical dangers (i.e., serious accidents, crime, or serious physical threats). The job satisfaction measures consisted of 50 items taken from the Minnesota Satisfaction Questionnaire (MSQ). Job performance was measured in terms of chargeable accidents, suspension, unexcused absence, missouts, supervisory reports, and passenger commendations/complaints.

Results of the analysis confirmed the relationship between job stress and psychological strain but revealed little support for the hypothesis that job stress leads to poorer job performance. Strong statistical support was found, however, for the importance of work-related social support as a useful means for offsetting negative worker feelings about their jobs and for offsetting some perceived job stresses, particularly those related to feelings of personal danger. Bus drivers with lower perceived superintendent social support showed a relationship between physical danger stress and working condition dissatisfaction of $r = .33$, while drivers with higher perceived superintendent support revealed a relationship of $r = .11$. Contrary to expectations, off-work social support (family and friends) was not perceived as very important by the bus driver sample.

Seniority (years of service) proved to be another significant correlate of driver attitudes and behaviors. Drivers with higher seniority were found to exhibit more job satisfaction, less passenger/intracompany stress and strain, higher perceived superintendent social support and better job performance than their new peers--but reported greater perception of physical danger with increasing years of service. Blau hypothesized that the positive attitudes and behaviors exhibited by the senior drivers were manifestations of their learned ability to deal with the stresses and strains of the job, increased opportunity to develop affiliative relationships with their supervisors, and greater flexibility in choosing routes and schedules that were compatible with their needs and desires. Increased feelings of physical danger among these senior drivers were hypothesized to be the result of the fact that the longer a bus operator had been on his/her job, the more exposure he/she has had to dangerous situations--despite the fact that with increasing seniority, bus operators have more choice as to which bus runs they will drive.

Dalton, Dan R., & Perry, James L. Absenteeism and the collective bargaining agreement: An empirical test. Academy of Management Journal, 1981, 24(2), 425-431.

Explored the relationship between employee attitudes and transit performance in a sample of twenty-four western U.S. properties. Data were collected from organizational archives, interviews, and questionnaires administered to operating employees. Statistical analyses were conducted of the various relationships between employee job satisfaction, commitment, turnover, absenteeism and organizational efficiency and effectiveness. Absenteeism was found to be a serious cost factor for the transit organizations, significantly correlated with operating expense per revenue vehicle hour (.50) and operating expense per employee (.67). The research disclosed certain organizational practices which may unintentionally encourage

absenteeism. Absenteeism was higher in those properties that had more generous provisions for sick leave accumulation and paid higher wages to their operators. The research further indicated that absenteeism may be a deliberate coping strategy for some employees and the result of a rational decision making process. Several strategies for managing absenteeism were reviewed for appropriateness to the transit industry.

For additional information on this research, see:

Perry, James L., Angle, Harold L., & Pittel, Mark E. The impact of labor-management relations on productivity and efficiency in urban mass transit. Prepared for the U.S. Department of Transportation under contract #DOT/RSPA/DPB/50/79/7. Irvine, Calif.: University of California, Institute of Transportation Studies and Graduate School of Administration, 1979. (NTIS #PB 294721.)

Perry, James L., & Angle, Harold L. The impact of labor-management relations on productivity and efficiency in urban mass transit: Employee attitudes, withdrawal behavior, and bargaining unit structure. Prepared for the U.S. Department of Transportation under contract #DOT/RSPA/DPB-50/80/5. Irvine, Calif.: University of California, Institute of Transportation Studies and Graduate School of Administration, 1980. (NTIS #PB 80-177223.)

Fitzgerald, Dennis J. Absenteeism controls at Capital District Transportation Authority. Paper presented at the Annual Meeting of the American Public Transit Association, Boston, Massachusetts, October 1982. Albany, N.Y.: Capital District Transportation Authority, 1982.

Reduced operator absenteeism at the Capital District Transportation Authority by 24% between 1980-81 and 1981-82 through implementation of a comprehensive absenteeism control program. The author briefly outlines the importance of absenteeism control; managerial and organizational prerequisites (i.e., management commitment, agreement on goals and objectives, clear lines of communication, agreement on 'who is absent'); types of absence; and application of absenteeism control techniques which are specifically directed at the different forms of operator absence.

Foissin, B. et al. Study concerning the job of bus driver in road system. Translated from the original French for the U.S. Department of Transportation under contract #UMTA-VA-06-0034-82-5. Paris: Paris Metropolitan Transportation System, Department of Occupational Medicine, 1978. (Available from the U.S. Department of Transportation Library, Washington, D.C.)

Foissin, B. et al. Etude de poste-mechiniste-receveur du reseau routier: Annexes (In French). Paris: Regie Autonome des Transports Parisiens, Service Medical du Travail, 1978. (Available from the U.S. Department of Transportation Library, Washington, D.C.)

Studied occupational illness in a sample of 775 bus drivers in the Paris Metropolitan Transportation System. Diseases of the musculoskeletal system were pronounced, with the neck and shoulders (24.52%) and lumbar region (17.43%) most commonly affected. About one fourth of the drivers reported medically important digestive disorders including gastrointestinal ulcers, gastritis, and diseases of the colon. Twelve percent of the sample reported mild neuropsychiatric problems.

Foissin characterized the job of the bus driver as "biotechnically illegitimate," i.e., combining two fundamentally incompatible tasks: driving a vehicle in increasingly heavy traffic and identifying and checking bus tickets with an increasing number of passengers, while simultaneously observing the requirements of all operations necessary to driving a bus, such as respecting the speed limit and ensuring passenger safety. Work shifts were found to be outmoded and, in some cases, out of conformance with current sociological standards.

Garbe, Claus. Health and health risks among city bus drivers in West Berlin. Translated from the original German for the U.S. Department of Transportation under contract #UMTA-VA-06-0034-82-3. West Berlin: Ministry of Health, Institute for Social Medicine and Epidemiology, 1980. (Available from the U.S. Department of Transportation Library, Washington, D.C.)

Conducted a comparative cross-sectional study of the frequency of illness in bus drivers (n = 811) versus administrative employees (n = 417) in Berlin. Both samples were controlled to include only males between 40-49 years of age. Significant differences were found between the two groups. Compared to the administrative employees, the bus drivers showed an increased frequency of individual risk factors for coronary disease (smoking, obesity, lack of physical exercise and metabolic disorders); exhibited more frequent symptoms of cardiac functional disorders; cited more gastric and digestive complaints and more involuntary nervous disorders (headaches, loss of appetite, trembling hands and insomnia); complained much more frequently about back pain, particularly in the areas of the cervical vertebrae and lower back, and exhibited increased levels of metabolic, hepatic and infectious diseases.

Compared to the group of administrative employees, the drivers left their jobs an average of ten years earlier and were ten years younger when they left. Severe occupational stress and the attendant effects on health among the bus drivers were said to cause the majority of them to leave their jobs permanently. Four major disease groups were isolated as the underlying cause of premature retirement from duty: cardiovascular disorders, degenerative changes in the spinal column, involuntary nervous disorders, and diseases of the gastrointestinal tract. More than 75% of the drivers who left their jobs prematurely were found to have these diseases. Twenty-five percent of those drivers who left for health reasons had significantly elevated blood pressure.

Gardell, Bertil. Stress research and its implications in Sweden. Working Life in Sweden, No. 20, October 1980.

Found hormones related to stress (serum catacholamines) to be elevated in both male and female bus drivers at a rate higher than would normally have been expected for that population. The rate of elevation was also higher among city drivers than their rural and suburban counterparts. Gardell concluded that this difference was attributable to the fact that the city drivers experienced greater pressure from a traffic situation which they cannot control and more threat and aggressiveness from passengers.

Gardell, Bertil, Aronsson, Gunnar, & Barkloff, Klas. The working environment for local public transport personnel. Stockholm: Swedish Work Environment Fund, 1982.

Summarizes a major study of absenteeism and occupational illness among Swedish public transit workers. For more detailed information on this project, see:

Aronsson, Gunnar. Sick leave and illness patterns among transit personnel in metropolitan Stockholm local transit. (Preliminary Report No. 9.) Stockholm University, Psychological Institute, 1976.

Aronsson, Gunnar, & Barkloff, Klas. Working environment for local transit personnel in large and medium sized towns. Translated from the original Swedish for the U.S. Department of Transportation under contract #UMTA-VA-06-0034-82-1. Stockholm: Stockholm University, Psychological Institute, 1980. (Available from the U.S. Department of Transportation Library, Washington, D.C.)

Gardner, Godfrey. The higher-order needs of London bus crews: A two-factor analysis. Human Relations, 1977, 30(9), 767-785.

Studied job satisfaction and motivation in a sample of 104 male bus drivers and conductors employed by London Transport in 1973. For the sample as a whole, the overall level of job satisfaction was higher than that found in other occupations and compared well with other driving occupations. Gardner found that employees in the sample were more generally concerned with lower-order needs (working conditions, pay, supervisory relationships, etc.) than with higher-order needs (achievement, recognition, responsibility, personal advancement). Of the traditionally recognized higher-order needs, only autonomy and the work itself were mentioned favorably by the sample employees. Achievement, recognition, responsibility, opportunity for advancement and opportunity for personal growth were either evaluated negatively or not mentioned at all.

Gardner hypothesized that younger workers would show more interest in the higher-order needs than their older co-workers by virtue of their higher level of

education and higher standard of living. This was not supported by the data. In both the younger and older groups, the mention of lower-order needs outnumbered the higher order needs by a ratio of three to one. For both groups, areas of particular job satisfaction included the work itself, pay, autonomy, absence of close supervision, interaction with fellow workers, and security of employment. Areas of particular job dissatisfaction included shift work (especially late shifts and weekends), working conditions (schedules, traffic, violence and the public), company policy and administration, interactions with supervisors and lack of recognition.

Holme, I. et al. Coronary risk factors in various occupational groups: The Oslo study. British Journal of Preventative and Social Medicine, 1977, 31, 96-100.

Conducted a major epidemiological study of the distribution of coronary heart disease among the male population of Oslo. The authors found that bus and taxi drivers had very high risk levels for coronary disease in comparison with other occupational groups and had correspondingly high levels of mortality from coronary disease. Bus drivers were found to exhibit a constellation of risk factors including heavy smoking, sharply higher levels of serum cholesterol and blood pressure readings, and physical inactivity during leisure time.

Laarman, U. Stress and strain on bus drivers in Tübingen city traffic. Ph.D. Dissertation, Eberhard-Karls-Universität, Tübingen, West Germany, 1974.

Studied stress and strain of bus drivers in the city of Tübingen (West Germany) and found that this strain can be exacerbated by unrealistically tight time schedules, weather and traffic delays. Under pressure of time the driver is subjected more frequently to risky, emotionally charged situations and the demands on his vigilance and on his audiomotor and visual systems increase.

Leahy, Arthur, Sprauge, Carol, & Schlegel, Larry. Bus operator absenteeism: Some causes and cures. Transit Journal, Fall 1979, 5(4), 29-38.

Conducted an in-house study of operator absenteeism at the Southern California Rapid Transit District (SCRTD). The goals of the study were to identify the major causes of absenteeism, to quantify the scope and extent of the problem, and to develop a set of programs designed to reduce the rate of absenteeism. Recognition of an absenteeism problem at the district stemmed, in part, from an increasing need to provide extra-board operators to cover for absent drivers. Data for the study were obtained from the district's weekly manpower reports and a detailed review of personnel files of moderate- and high-absenteeism drivers. This information was used to determine historical absenteeism rates; to compare these rates with other factors such as manpower shortages and seasonal variations; and to construct a profile of problem attendance employees. A review was also made of contract work rules and other provisions which might encourage higher absenteeism levels.

The following general conclusions were reached: (1) absenteeism was widespread, with more than 30 percent of the drivers having more than seven absences in a 12 month period; (2) short-term absenteeism rates were strongly correlated with manpower shortages ($r = .74$) and operator work on regular days off ($r = .46$); (3) one-day absenteeism was strongly linked with weekends; (4) problem attendance was not correlated with seniority, reportable accidents, or sick pay claimed; and (5) one-day absence, perceived as the major attendance problem, represented only 22 percent of all lost days. A number of strategies for reducing absenteeism were reviewed for application within the transit industry including strengthening attendance monitoring programs and data collection, demonstrating personal concern for employees, limited duty work programs for employees who have been injured or ill, reducing scheduled overtime, maintaining full operator staffing levels, paying sick leave automatically for the first day of absence, attendance incentive plans, reducing the length of work runs, and establishing four-day work weeks and part-time operator positions.

Meijman, T. F. et al. Differential neuroendocrine reactions of intracity bus drivers during work and leisure. Ergonomics, 1982, 25(4), 338-339.

Studied intracity bus drivers in the city of Gronigen (Netherlands). The authors found that drivers appeared to suffer to an unusual degree from occupational stress. Drivers in the sample had a high rate of absence (approximately 20%); and, historically, about 60% of the drivers had retired for reasons of medical disability by the age of 47 years. To investigate factors responsible for the drivers' stress, the authors undertook a pilot investigation employing two groups of six drivers apiece who differed with respect to their absence rate during the previous year. Catecholamine (adrenaline, noradrenaline and dopamine) excretion rates were measured from urine samples obtained at 3-hour intervals over two working days and, for control purposes, over the first and second consecutive non-work days. 'Best' and 'worst' case working days were identified on the basis of the drivers' subjective assessments. Overall adrenaline excretion rates at work were found to be higher in the high absence group. This difference persisted through the first non-work day, but was not evident in the second free day. Noradrenaline excretion rate was always similar for both groups, but the dopamine excretion rate was always higher for the high absence group. The authors concluded that the different reactions of the groups during and after the driving task provided evidence of differences in individual stress reactions that might be responsible for other objective manifestations, including absence from work.

A companion study evaluated the relationship between these objective measures of stress and a standardized measure of subjective stress/activation (Thayer's method) in the same sample. Obvious difference were found between the high and low-absenteeism drivers.

Morris, J. N. et al. Coronary heart disease and physical activity of work. Lancet, Saturday, November 21, 1953, 1053-1057.

Morris, J. N. et al. Coronary heart disease and physical activity of work. Lancet, Saturday, November 28, 1953, 1111-1120.

Studied 31,000 male bus drivers and conductors aged 35-64 employed by London Transport. The authors found that coronary heart disease occurred much more frequently among the drivers of double-decked buses in the central city than among conductors on the same vehicles. While the occurrence of angina pectoris (chest pain associated with coronary disease) was somewhat higher among the conductors, the more serious manifestations of coronary heart disease (myocardial infarction and sudden heart failure) occurred more than three times as frequently among the drivers. The investigators identified the critical difference between the two groups as the extra physical activity of the conductors, who are constantly moving in their job, particularly on the double-decked buses.

While analysis was not made of the psychophysiological stressors to which the employees were exposed, it was noted that drivers on the 'central buses' had a coronary heart disease incidence rate almost twice as high as the tram and trolley-bus drivers in outlying areas, and conductors in the central cities had an incidence rate 2.5 times higher than their suburban counterparts.

Morris, J. N. et al. Incidence and prediction of ischaemic heart-disease in London busmen. Lancet, Saturday, September 10, 1966, 553-559.

Conducted a longitudinal study of a group of 687 drivers and conductors of double-decked buses in London. For five years (1956-60) all cases of new occurrences of coronary heart disease in this group were recorded. As hypothesized, the incidence rate for coronary heart disease among the bus drivers was higher than among the conductors; 8.5% for drivers in comparison with 4.7% for the conductors.

Data on selected health parameters (family history, blood pressure, serum cholesterol and obesity) were correlated with the incidence of coronary heart disease in this sample. High blood pressure readings and high plasma cholesterol proved to be the predominant risk factors. Among those employees in the high risk group, 83% were drivers and only 17% were conductors. This difference was attributed to the degree of movement involved in the job of the conductor as opposed to the driver's more sedentary tasks.

Mulders, H.P.G. et al. Heart rate variability and task performance of city bus drivers during pauses and after work. Ergonomics, 1982, 25(4), 340.

Studied twelve city bus drivers participating in a study of occupational stress in the Netherlands. The drivers were separately tested during breaks from driving and immediately after work during the early and day-shifts of two days at work. Drivers were divided into two equal groups on the basis of high and low absence frequencies during the previous year. They performed a rapidly paced sequential arithmetical problem solving task in three minute trial blocks, separated by 3 minute recovery

periods, for 15 minutes per test. ECG was recorded and analyzed to determine the Heart Rate Variability (HRV) components as a measure of mental load. Differences between the high and low absence rate drivers were documented.

Netterstrom, B. et al. Incidence and prevalence of ischaemic heart disease among urban bus drivers in Copenhagen. Scandinavian Journal of Social Medicine, 1981, 9(2), 75-79.

Evaluated cardiovascular disease morbidity and mortality in 1741 Copenhagen bus drivers, using other Copenhagen males for controls. While both groups had similar rates of death from all causes, the bus drivers were found to have a significantly higher rate of death due to cardiovascular disease, and an incidence of angina (chest pains associated with cardiovascular disease) twice that of the controls.

Norman, L. G. The health of bus drivers: A study in London Transport. Lancet, Saturday, October 18, 1958, 807-812.

Studied absenteeism and illness among 14,000 male drivers and 12,000 male conductors, aged 24 to 65 employed by London Transport between 1949-1952. For both groups, observations were clustered into five-year age groups. Age was found to play a significant role in absence patterns. At the younger ages (24-40), both groups had high numbers of short-term absences (i.e., 1-3 days) with short-term absenteeism dropping sharply after age 40. Long-term absence (4 or more days) rose markedly with age/length of service. For both drivers and conductors, the amount of long-term absence was about four times as great at age 60 as at age 30, with conductors reporting higher absence rates than drivers in all age categories. Except in the age group 40-45, conductors had more sickness-related absence than drivers, with this difference becoming progressively greater as age, and therefore length of service, increased beyond age 45. The author proposed a number of theories to account for this difference, including individual genotype and selection factors, the effects of occupational differences, and the fact that drivers can remain at work when suffering from a degree of illness that would require the conductors--who are extremely mobile on London double-decked buses--to be absent.

To determine the role of occupational stress in illness-related absenteeism, absence rates for drivers and conductors were compared with data for a control group of male office workers also employed by London Transport. For the three groups of employees, data were gathered on average annual duration of absence caused by (1) functional nervous disorders and (2) diseases of the stomach and duodenum--two disease groups which consist mainly of psychosomatic illness. All three groups were found to experience roughly similar rates of absence from these diseases until the age of 50, when absence rates began to diverge considerably. At the ages of 55-59, conductors experienced about twice as much absence due to these illnesses as the office staff, with drivers occupying a middle position. About a third of this excess in conductors was due to the functional nervous disorders and two-thirds to diseases of the stomach and duodenum.

The author hypothesized that the marked increase in functional nervous disorders among conductors after age 50 was due to a number of occupational factors, including the strain of the job, constant interaction with difficult passengers, and the need to work at a rapid pace. He further hypothesized that the high rates of gastrointestinal disorders among both drivers and conductors may be a function of the effects of irregular shift work not experienced by the office personnel.

Orange County Transit District. Analysis of coach operator absenteeism at the Orange County Transit District: Phase I. Garden Grove, Calif.: Orange County Transit District, 1981. (Mimeo)

Analyzed operator absence due to sick leave from 1978-1981. Data were drawn from the personnel records of approximately 750 operators from two operating divisions and supplemented by informal interviews with fifteen groups of operators, supervisors and labor representatives. The research team determined that OCTD was experiencing increasing levels of absenteeism in its Bus Operations Department (from 18.4 average sick days/operator in 1978-1979 to 21.6 days in 1980-1981). The unscheduled absence cost to the district in direct wages alone, based on the FY 1979-80 average coach operator wage rate (\$9.35/hr.) was estimated to be \$1,228,225 for FY 1980-81.

A number of factors believed to underlie the absenteeism problem were isolated through the informal interview process. These included the inability to take a day off for personal reasons, negative contact with management, lack of incentives or rewards for outstanding performance, stress of the job, easy availability of scheduled and unscheduled overtime pay, lack of a consistent disciplinary policy for absenteeism, little inquiry into past attendance records during the pre-employment screening process, and scheduling of assignments.

The high number of split runs, lack of sufficient recovery time on routes, tight schedules, poor bus maintenance, and difficult interaction with passengers and supervisors were frequently mentioned by operators as particular sources of stress.

The inability to take a day off for personal business was highlighted as a particularly strong precursor of absenteeism, with many operators expressing the feeling that the district did not make allowances for the operator's personal life. Operators indicated a willingness to accept more stringent sick leave policies provided that there were more liberal policies allowing operators to take a change of assignment or a day off for personal business. Support was also expressed for a four-day week to allow operators an extra day off to handle personal business.

Patterns of sick leave use among OCTD operators tended to confirm the experience of other transit properties which have conducted in-house studies of absenteeism. Short-term absenteeism was strongly associated with operators' work on regular days off, and was strongly linked with Saturdays, Sundays and holidays, regardless of regular days off. Operators with high levels of absenteeism also had a missout problem. Use of sick leave was polarized, with operators tending to use all or their available sick pay allowance or none at all.

Perin, Constance. Vehicle operator absenteeism and transit productivity. (Staff Study #SS-242-U.3-213.) Cambridge, Mass.: U.S. Department of Transportation, Transportation Systems Center, 1982.

Reviewed a number of studies of transit operator absenteeism, workers' compensation, and manpower scheduling/allocation to determine the scope and impacts of operator absence, to explore the organizational and individual factors influencing absenteeism, and to assess the role of manpower allocation practices in operator absence behavior. Operator absenteeism was found to be widespread, adversely affecting both productivity and service reliability. Examination of existing research on operator absenteeism--and blue-collar absenteeism in general--revealed the roots of absenteeism to be multiple and complex. A central hypothesis is that absenteeism is a reciprocal system benefitting both management and labor, one that is sustained by management's cost minimizing strategies and by labor's value of time over money.

Section II of the paper reviews a number of issues related to operator absenteeism including management's staffing plans and cost-effectiveness, employees' value of time over money, the problem employee and management's absence control practices, operator age/seniority and proneness to absence, and motivations for and impediments to absence.

Section III proposes areas for further research. These include: (1) the impact of management staffing practices on operator absence and transit system costs and productivity, (2) transit employees' income/leisure tradeoffs and the role that this may play in absence behavior, (3) the effectiveness of existing programs for improving operator absence (i.e., bonus systems, supervisor training, etc.), (4) the relationship between verified injury-on-duty (IOD) claims, operator characteristics, types of injuries and accident prevention measures, (5) benefits and costs of removing impediments to attendance (i.e., childcare programs, employee ridesharing, etc.), and (6) the role of more flexible schedules in reducing operator absenteeism.

Pikus, W. G., & Tarranikova, W. A. The frequency of hypertensive disease among drivers in public transportation. Terapevicheskiy Archiv, 1975, 47, 135-137.

Studied the frequency of hypertensive illness among bus drivers in the Soviet Union. Their sample included over 1200 drivers of all age groups; data were collected over a five year period. The evaluation showed that the frequency of hypertension rose sharply with increasing length of service, particularly after service of more than ten years. The proportion of hypertensive subjects reached 58% in the group with 21 to 25 years of service. The total number of bus drivers with hypertension was 41.6%, which far exceeds the number found in studies of other occupational groups. This high hypertensive morbidity led to increased early retirements among the driving staff, particularly between the ages of 40 to 44 years. The investigators attributed the higher susceptibility to hypertension in this occupational group to increased emotional stress and frequent states of nervous-psychic stress.

Reimann, Jorn. Investigations on the reduction of stress of drivers in regularly scheduled buses in inner city traffic. Translated from the original German for the U.S. Department of Transportation under contract #UMTA-VA-06-0034-82-4. Berlin: Berlin Technical University, Institute for Occupational Science, 1980. (Available from the U.S. Department of Transportation Library, Washington, D.C.)

Conducted field measurements of physiological stress in a sample of 28 bus drivers in Berlin. Environmentally based stress variables (noise, carbon monoxide, steering and braking forces) were found to play a subordinate role to task-specific stress variables (i.e., characteristics of the route and shift). Higher levels of vanillin-mandelic acid (a hormone indicative of stress) were found in drivers on split versus continuous shifts and among drivers whose schedules led them to experience high levels of traffic congestion and difficulty in adhering to their schedule. Further, higher levels of vanillin-mandelic acid were found among the drivers than among workers in two occupational control groups; rates for drivers were, respectively, 60% and 130% higher.

Rusconi, C. et al. Coronary risk factors and ischaemic cardiopathy in bus drivers and conductors. Minerva Cardioangiologica, 1975, 23, 718-727.

Studied cardiovascular disease among 300 employees of a suburban bus company in Italy. The sample included 200 drivers and a control group of 100 conductors, all between 21-59 years of age. Data were collected on familial diabetes and atherosclerosis, dietary habits, cigarette and alcohol consumption, known heart attacks or angina, obesity, arterial blood pressure, cholesterolemia, and triglyceridemia. The drivers were found to have a higher incidence of ischemic cardiopathy than the conductors--a finding which could not be explained by other physiological parameters (i.e., known coronary disease risk factors and known causes of hyperlipidemia). The authors concluded that the increased incidence of cardiovascular disease among the drivers was due to the unique environmental and occupational stresses of the driving task. This study is particularly interesting in light of the earlier studies of Morris and his associates (1953, 1966) who attributed the higher incidence of cardiovascular disease among drivers versus conductors on London double-decked buses to the increased physical activity of the conductors. On Italian buses, the conductors are stationary, providing evidence that the driving task may pose special occupational risks.

Slosar, John A. Ogre, bandit, and operating employee: The problems and adaptations of the metropolitan bus driver. Urban Life and Culture, January 1973, 339-362.

Studied the social and psychological forces which influence the actions of the urban bus driver and his relationship with his passengers. The job of the bus driver is conceptualized as having three competing role segments: the driver as ogre (his role vis-a-vis the passengers), as bandit (his role vis-a-vis his fellow employees) and as

operating employee (his role vis-a-vis the organization). The driver is said to occupy a difficult boundary role, facing not only potential conflict between his interests as an employee and the interests of the organization, but, by virtue of his occupancy of a boundary-spanning role, also faced with the problem of mediating the conflicting interests of the individual consumer (i.e., the passenger) and the organization. Finding the rewards and sanctions of both the passengers and the formal organization trivial, and the requirements of the passengers and the organization often contradictory, the driver turns to his fellow drivers for support and approval. The "Society of Bandits" (i.e., the informal network of drivers) offers some support, but also imposes its own demands on the driver, intensifying the already-existing role conflicts. This article, based on the author's personal experiences as a bus driver in a large U.S. property, provides useful insight into the unique social and occupational stressors of the driving task and the role of intra-organizational dynamics in shaping driver behavior.

Taylor, James et al. Study and development of an operator/passenger training program. Prepared for the Southern California Rapid Transit District, Los Angeles, Calif. North Hollywood, Calif.: Western Center Associates, 1980.

Conducted a study of the relationship between operator attitudes, stress and performance for the Southern California Rapid Transit District. The goals of the project were to improve operator/passenger relations, reduce operator job stress, and reduce human resource costs, i.e., workers' compensation claims, stress-related illness, absenteeism, and turnover. This was to be accomplished through an operator training program and other recommended changes in SCRTD policy. Data for the study were gathered in two areas: (1) operator attitudes, job-related stress and stress coping strategies, and (2) operator performance as measured by number of accidents, cost per passenger mile, customer complaints, and adherence to schedule. Data were gathered from organizational archives and interviews with operators, supervisors, and managers, followed by a 220 item questionnaire administered to a 10 percent sample of operators. This sample was representative of SCRTD drivers on the whole, but drew a ratio of two extraboard drivers for each regular operator. Since there were no unexplainable differences between the two subgroups, the sample was believed to be valid. The operator questionnaire contained questions written specifically for the survey as well as questions taken from standardized survey instruments including the University of Michigan Survey of Organizations; the University of Michigan Job Stress Questionnaire; and the University of California, Irvine Transit Organization Survey.

Results of the analysis revealed significant relationships between operator stress, performance and human resource costs. There was also a strong relationship between disability claims and number of days absent. Operators who reported problems in one performance or human resource cost area tended to report problems in four or five other areas. High levels of operator stress were related to frequent reports of lost fares, of high absence and disability and frequent misbehaviors such as running hot, missouts, and rule violations. Operators reporting high stress symptoms also reported higher drug and alcohol use and poor performance in such areas as customer complaints and accidents. The report concludes with a

step-by-step program through which SCRTD could train operators to recognize and cope with symptoms of job related stress.

Transport and General Workers Union. Stress at work. Leeds, England: British Transport and General Workers Union, Workers Educational Association, 1981.

Developed and administered a questionnaire to evaluate the possible relationship between working conditions and occupational stress among their member employees. Hypothesized stressors were divided into five categories: (1) environmental, which included both equipment and traffic conditions, (2) task-related, which included schedules and job responsibilities, (3) social, particularly driver-passenger interaction, (4) employment-related impacts on home life, and (5) relations with other staff and management.

Results of the questionnaire revealed that a majority of the respondents had experienced serious problems in all five stress categories. The driver's worksite, the cab, was reported to be confining, poorly designed, and to be the cause of a large number of driver injuries. Demands of the job, especially during rush hour, were reported to be very high, and a serious source of stress. Organization of work, timing of breaks, shift schedules and lack of adequate sanitary facilities were also isolated as major sources of stress.

Transport Workers Union of America. Report on performance auditing and transit worker absenteeism. Prepared with consultant services provided by Rebecca Hazlewood, Spectrum Research, Albany, Calif. San Francisco, Calif.: Transport Workers' Union of America, 1981.

Reviewed a number of studies of occupational health and safety and concluded that a growing body of epidemiological literature in the health and safety field indicates that worker absenteeism (including transit operator absenteeism) is due to occupationally induced stress and strain and not to workers taking undue advantage of sick leave or to the inherent nature of the workers themselves.

The authors identified nine stressors which are of particular concern for the transit operator: too fast a pace, confinement to the work area, rigid work rules, threat of physical violence, unsafe or unhealthy working conditions, little job satisfaction, little positive support, perceived lack of job security, and monotonous tasks. They isolated two variables as being of particular importance: (1) increasing levels of violence and physical assaults on transit systems and (2) unrealistically tight schedules.

Washington Metropolitan Area Transit Authority. (Study on absenteeism) among represented employees in the Department of Transit Services. Washington, D.C.: Washington Metropolitan Area Transit Authority, 1980.

Examined absenteeism and workers' compensation claims within the Washington Metropolitan Area Transit Authority (WMATA) to recommend a reasonable and realistic level of absenteeism, analyze the factors that influence employee attendance, and recommend appropriate changes to WMATA policy. Absenteeism and workers' compensation claims were also compared to those reported by Baker & Schueftan (1980) and the Southern California Rapid Transit District (Leahy et al., 1979). The analysis was guided by the "Attitudinal Formation Toward Attendance Model" developed by WMATA which hypothesized absenteeism as the result of the complex interaction between an employee's personal and professional experiences. Data for the study were obtained from a review of the transit literature, analysis of WMATA policies and procedures, collection and analysis of data from the personnel records of 600 employees, and informal meetings with operating and management personnel. Analysis revealed that employee absences accounted for approximately \$32 million in WMATA's FY 1981 budget, with \$21,311,000 attributable to the cost of the extraboard and \$9,050,000 to workers' compensation. While less than the national average, WMATA bus operators lost an average of 20.17 workdays in 1979; days lost to workers' compensation were three times the national average and increasing.

A number of factors believed to underlie the absenteeism problem were isolated through informal meetings with affected personnel. These included: an inability to take time off for single days when a need arose, lack of recognition by management, difficult interaction with passengers, and inadequacy of facility maintenance. Considerable concern was expressed about abuses of the workers' compensation system, with two groups interviewed expressing the opinion that only 20%-30% of the claims that were filed were valid. A number of factors believed to contribute to this abuse were isolated, including provisions in various labor contracts and internal WMATA procedures. It was also noted that workers' compensation claims within WMATA are seasonal, with certain times of the year (Christmas, hunting season, summer, etc.) producing a predictable number of absences. Analysis of data on absenteeism and workers' compensation claims within WMATA revealed that much of the problem was related to high absenteeism/claims of a few employees, with approximately 25 percent of the employees causing the majority of the problem. The report concludes with suggestions for improvements to WMATA policy, including changes in extraboard allocation, designed to decrease absenteeism and reduce costs.

B. THE TRANSIT EXTRABOARD AND MANPOWER OPTIMIZATION

Brown, Barbara. Building an operator availability program: San Francisco Municipal Railway. Paper presented at the Annual Meeting of the American Public Transit Association, Chicago, Illinois, October 1981. San Francisco, Calif.: San Francisco Municipal Railway, 1981.

Describes the San Francisco Municipal Railway's Operator Availability Program, a coordinated effort to determine optimum extraboard size; rationalize extraboard scheduling; and examine the interrelationships between the work environment, employee stress, absenteeism and productivity. This program was based on the premise that attainment and maintenance of an optimally sized extraboard would reduce costs and improve performance. Optimum extraboard size was calculated for MUNI using a formula developed by Peat, Marwick, Mitchell & Co. This formula defined the optimally sized extraboard as one in which the costs of non-scheduled driver overtime are balanced against the costs of guarantee pay for unutilized extraboard operators. Using historical absence data and projections of future vacation demand, the optimum extraboard size was calculated for summer (when vacations are at their peak), the January-April period (when vacations are sparse) and the medium-level autumn period. Further refinement, using weekly driver counts, yielded optimum extraboard figure by day of the week, so that extra operators would be available on the days when most needed (Mondays and Fridays) and given days off when least needed. This total analysis resulted in the recommendation that MUNI increase its extraboard to 300 drivers. Comparison of the cost of operation in a test period revealed that the additional operators would result in a saving of \$24,502 per pay period, or \$637,066 per year, largely the result of eliminating the need to pay overtime pay to regular drivers. Other modifications to MUNI operations were proposed as a result of this analysis, including the establishment of a 'non-driving driver' division to isolate those operators unavailable for runs due to special leaves, long-term sick leave, workers' compensation leave, etc., so that an accurate count of available personnel could be made.

To assess the effectiveness of the Operator Availability Program, a performance monitoring program was implemented to collect data in the following areas: (1) unscheduled overtime, (2) missed service hours due to no operator, (3) guarantee pay hours, (4) absenteeism, and (5) percent of optimum extraboard achieved. The last measure is the chief performance measure for the Operator Availability Program, with all other performance measures tracked against the percent of optimum extraboard achieved. Statistically significant improvements in these areas were achieved, with at least \$500,000 in savings attributed to impacts of the program.

Brown, Barbara. Report on operator availability. San Francisco, Calif.: San Francisco Municipal Railway, 1979. (Mimeo).

Analyzed operator availability and absenteeism in the San Francisco Municipal Railway (MUNI) for 1978-79. Data were provided for absenteeism rates by category (industrial injury, sick leave, vacation, etc.) and by bi-weekly pay period. The

average operator absenteeism rate was 20%, with a median rate of 17.65%. Absenteeism due to industrial injury averaged 33.5 drivers per day, or 2 percent of the total workforce. Delays in filling new operator requisitions and operator 'passes' (drivers unavailable to complete runs due to industrial injury, illness or leave) reduced the extraboard to 18% of the total number of operators, short of MUNI's desired level of 29% and the industry standard of 30%. To gather additional information on the extraboard/absenteeism relationship, a questionnaire was distributed to other transit agencies to determine current industry standards for the extraboard, absentee rates, and strategies used to correct or reduce driver unavailability. A copy of the survey instrument is appended to the report, although the results are not included. Several short-term strategies for reducing MUNI's absence rate were proposed, including improvements in filling open requisitions and more effective scheduling of training sessions. Long-term strategies, based on the assumption that sickness and absence are a function of the workplace, were also explored.

Chomitz, Kenneth M., & Lave, Charles A. Part-time labor, work rules, and transit costs. Prepared for the U.S. Department of Transportation under contract #UMTA-CA-11-0018-81. Irvine, Calif.: University of California, Institute of Transportation Studies and School of Social Sciences, 1981. (NTIS #PB 81-180556).

Explored the impact of labor union work rules on transit operating costs and the magnitude of cost savings that could be expected from the use of part-time drivers. Appendix C ("The Cost of Trippers") and Appendix D ("Analysis of Absenteeism") examined several issues related to extraboard operation including costs and benefits of assigning trippers to the extraboard, extraboard sizing in relation to trippers, and absenteeism of extraboard versus regular drivers. Results of a normative analysis of extraboard operation indicated that the cost of assigning trippers to the extraboard varied according to a number of factors including the effectiveness of combining traditional extraboard functions with trippers, the maximum spread time permitted on the extraboard, and the pattern and predictability of absenteeism and special runs within the property. To determine the way in which transit properties actually relate the size of the extraboard to the number of trippers, a questionnaire survey was conducted of twenty-three large U.S. and Canadian properties. The questionnaire sought quantitative data concerning the extraboard work assignment procedure. Response rate was 87%. Statistical analysis was applied to the data to construct a mathematical model of the extraboard size/extraboard tripper relationship. Results of normative versus positive analysis of this relationship revealed the potential need for utilizing the extraboard more efficiently.

Inglis, John M. Improved labor productivity through a comprehensive management approach. Paper presented at the Annual Meeting of the American Public Transit Association, Boston, Massachusetts, October 1982. Salt Lake City, Utah: Utah Transit Authority, 1982.

Reports the results of a program initiated in response to a number of operational problems associated with UTA's previously high ratio of extraboard to regular drivers. These problems included uneven daily labor demand; high rates of customer complaints of operator no-shows, off-route, etc.; high operator turnover and unrest; high accident rates; low labor productivity related to high overtime; low service reliability and poor on-time performance. The manpower optimization program, implemented in 1980, increased the allowable spread time from 11 to 14 hours, reduced the number of extraboard operators from approximately 200 full-time to 54 part-time employees, and made a number of improvements in maintenance, scheduling, and operator/supervisor relations.

Significant improvements in system productivity were achieved. Service reliability was increased, voluntary turnover and accidents were reduced, and labor productivity (payroll/platform ratio) increased dramatically. In 1979, between 450 and 475 operators were required to provide service in the UTA service area. 1982 requirements called for approximately 390 operators—a reduction in labor force of 17 percent. This reduction occurred over a period of time in which actual service was reduced less than 7 percent. In addition, the reduction in labor that took place between 1980 and 1982 was made without any layoffs and was accommodated through attrition.

The most dramatic improvement was in the area of absenteeism. Through 1978 and 1979, operator absenteeism due to illness averaged between 1.8 and 2 days per employee per month. With the initiation of the experimental labor scheduling in 1980, the absence rate dropped immediately and continued to drop to the present rate of approximately 0.4 to 0.6 days per employee per month. This has resulted in substantial productivity gains and has further reduced the need for an extraboard.

Jennings, Kenneth M., Smith, Jay A., & Traynham, Earle C., Jr. Study of unions, management rights, and the public interest in mass transit. Final report #DOT-OS-50116. Jacksonville, Fla.: University of North Florida, August 1976.

Documented the results of an empirical study of transit labor relations in a nine-state southeastern U.S. region. Labor agreements from forty-five transit properties were analyzed on a provision-by-provision basis utilizing a list of 249 variables in eight major categories. Three characteristics of extraboard operation were analyzed: scope, provisions for rotation, and payment for administrative error. Considerable variation existed in contract language regarding the scope and operation of the extraboard. Approximately 25 percent of the contracts restricted the extraboard solely to extraboard operators. Over 30 percent of the contracts required regular operators to report to the extraboard under certain circumstances, e.g., after a lose out or after being released from jury duty, and 14 percent specified that regular operators were eligible for the extraboard on their time off. Contract

provisions for rotation of the extraboard were highly individualized. Approximately 50 percent of the contracts provided for daily rotation of extra operators on the basis of assignment, with nine of the contracts specifying a minimum number of hours for rotation. Four of the contracts provided for rotation on a first-in, first-out basis, while three contracts provided for rotation on the basis of seniority.

The uniqueness and informality that often characterizes the operation of the extraboard was evidenced by the fact that 22 percent of the contracts had no specific provision for rotation of the extraboard. Similarly, policy for dealing with refusal of assignments by extra operators was generally dealt with informally, with over 60 percent of the contracts having no reference to penalty for refusal. Forty percent of the contracts had provisions for payment of administrative error in connection with the operation of the extraboard. Most of these provided for differential payment or credit for the amount of the run-around. Only four contracts provided for full payment or credit. The full survey instrument used in this study is included as an appendix to the report.

Koffman, David. A survey of Municipal Railway operators in the Presidio and Metro Divisions. Prepared for the San Francisco Municipal Railway. Menlo Park, Calif.: Crain & Associates, July 10, 1981.

Administered an attitudinal questionnaire to coach operators in two divisions of the San Francisco Municipal Railway (MUNI). The questionnaire was designed to help MUNI evaluate the effectiveness of its Transit Line Coordinator (TLC) program which replaced the traditional line inspector program. One hundred thirty-five questionnaires were completed and returned, with 17 percent of this group extraboard drivers. Responses were solicited on a variety of issues including TLC/operator relationships, perceived quality of communication within MUNI, and problems with passengers. Statistical cross tabulation of responses was conducted to determine if responses differed according to operating division, whether operators were regular or extraboard, started in the AM or PM, or according to operators' length of employment at MUNI. The report includes a copy of the survey instrument and verbatim transcription of operators' responses to open-ended questions.

Leahy, Arthur T., & Thomason, Jim. Method for determining optimal bus operator staffing levels. Prepared for the Southern California Rapid Transit District, Los Angeles, California, 1981. (Mimeo)

Conducted a study to determine the optimal (i.e., most economical) bus operator staffing level for the Southern California Rapid Transit District. The study was based on the hypothesis that both a shortage and an excess of operating personnel would be associated with higher operating costs. This hypothesis was supported. The lowest labor costs per assignment were achieved when the system had a modest excess of operators; while a ratio of 1.30 operators per assignment was considered to be 'full' staffing, the least expensive operating costs occurred with

the actual operator ratio between 1.31 and 1.32. With a system of approximately 3350 work runs or assignments, a 'surplus' of about 70 operators, or 1.5%, was most cost efficient. When the operator ratio fell below 1.30 or climbed above 1.32, there was an increase in the cost per assignment. This result is consistent with the hypothesis that lower operator levels contribute to higher overtime costs. The increase in costs above the 1.32 operator ratio level suggests that, in fact, any declines in overtime were more than offset by fixed and variable costs for additional operators.

At the outset, the impact of increasing staffing levels to the optimal ratio appeared to have a beneficial effect on SCRTD's absenteeism rate. The corresponding reduction in the amount of available overtime appeared to reduce the motivation for employees to take unscheduled days off. The authors caution, however, that an absenteeism discipline rule which went into effect at the same time the study began may also have accounted for a portion of this decline.

MacDorman, Littleton C., & MacDorman, John C. The transit extraboard: some opportunities for cost saving. Paper presented at the Annual Meeting of the American Public Transit Association, Boston, Massachusetts, October 1982. Arlington, Va.: MacDorman & MacDorman Consultants, 1982.

Developed a methodology for determining the optimal, least-cost arrangement for sizing the extraboard to accommodate both unanticipated absenteeism and scheduled trippers. This model can also be refined to size the extraboard based on known daily or seasonal patterns of absence. (See also Brown 1981 for a similar application of this methodology.)

The objective of the model is to determine the extraboard size where the sum of the probable unscheduled guarantee pay, fixed fringe benefits and unscheduled premium are minimized. The formula used is:

$$p(x) = \frac{\text{Premium pay} - \text{fixed cost}}{\text{Guarantee pay} + \text{premium pay}}$$

This formula says that the optimal number of extraboard operators is attained at the point at which the probable cost of the xth extraboard operator equals the premium cost savings attributable to the xth extraboard operator. The basic premise of the model is that as the actual operator workforce deviates from the optimal, additional costs are incurred.

To test this model, a questionnaire was distributed to all U.S. transit properties operating over 100 vehicles to obtain information that could be used to determine optimal extraboard sizes. Replies were received from 21 properties, or 25% of the sample. The purpose of this survey was to identify the magnitude of cost savings that might be possible among the larger U.S. properties if improved extraboard sizing techniques were used. The estimates of cost savings were based solely on the information received from the properties, including reported absenteeism, wage rates, fringe benefits, and provisions of the labor agreement affecting the operators' work procedures.

Analysis revealed evidence that many properties were incurring significant levels of scheduled guarantee, i.e., guarantee paid as a result of routinely using extraboard operators on many trippers when the operator's workhours were far less than either the daily or weekly guarantee provided for in the labor agreement. The most apparent trend in the survey analysis was a general oversizing of the full-time operator workforce. On the average, properties utilized 7.3 percent more full-time operators than would be required under the optimal cost condition. In contrast, two properties were found to be undersized, and five properties closely matched the optimal number of full-time operators.

The study further found that the use of part-time operators can have a significant impact in reducing the cost of the tripper schedule. Not only can such manpower provide a savings in guarantee and premium pay, but since the associated wage rates and/or fixed fringe benefits are generally less than those for full-time operators, additional savings may be contained in these differentials.

Using the sample properties responding to their questionnaire as a basis for projection, the authors estimated that there could be a \$50 million annual cost savings to the U.S. transit industry through improved procedures for manpower planning and extraboard sizing. Many properties have, however, argued for retaining their present extraboard sizes because of labor agreement constraints, the reluctance of operators to work overtime, and increased potential for poorer performance in the areas of attendance and safety. The authors urge those properties which are oversized and which have labor agreement constraints that may inhibit the reduction of the workforce to begin a reduction process through normal attrition. As the extraboard size becomes smaller, information should be monitored that would indicate any adverse impacts in other areas such as accident rates and costs, missed runs and trips due to operator unavailability, absence rates and customer complaints.

As part of the survey process, data were obtained on absence rates for all properties sampled. This revealed a wide variation in absenteeism among these U.S. properties. Absenteeism rates ranged from a low of 7.6 average annual absences per operator to a high of 68.8, with a mean of 24.7. The authors conclude by noting that absenteeism is still very high in the transit industry, is the primary factor which influences extraboard size, and is an issue of paramount importance in reducing or increasing the marginal costs of scheduled service.

Richardson, Reed S. The locomotive engineer, 1863-1963: A century of railway labor relations and work rules. Ann Arbor, Mich.: University of Michigan, Graduate School of Business Administration, Bureau of Industrial Relations, 1963.

Traces the history and development of railway labor work rules. The practice of maintaining an extraboard in contemporary transit organizations can be traced to railroad work rules developed in the period from 1830-1886. Irregular operations, resulting from increased volume of traffic and seasonal fluctuations, required that engineers be held in reserve in case it was necessary to make unscheduled runs or replace other engineers. This brought about the establishment of the early form of what is now called the 'extra board.'

Smith, Judith, Kiffe, Donna L., & Lee, David A. An approach to ideal manpower planning. Transit Journal, Fall 1980, 6(4), 61-67.

Implemented an innovative manpower planning approach designed to improve service reliability, reduce absenteeism, reduce overtime, and mediate an apparent shortage of operators at the Metropolitan Transportation Commission (Minneapolis/St. Paul, Minn.). In 1979, the MTC began to experience an increasing cycle of apparent operator shortage, missed trips, overtime costs and absenteeism. In addition, because the driver labor budget was directly linked to an assumed manpower level, increasing overtime to maintain regular service resulted in payroll cost overruns of nearly 3%.

To mediate this situation, an innovative manpower planning approach designed to calculate an 'ideal' number of drivers to meet quarterly service requirements was introduced at one of MTC's four operating divisions. During an experimental period, missed trips at this division were reduced by 98% and the payroll/platform ratio declined from 1.23 to 1.19. This approach was subsequently introduced into the system as a whole with equally positive performance results.

Yet anticipated effects on absenteeism did not occur. Theoretically, observed the authors, absenteeism should be reduced since it is assumed that the routine availability of overtime pay provides a cushion for drivers absent from their regular shifts. In fact, absenteeism at the MTC was not reduced through attainment of ideal manpower levels, suggesting that the loss of a day's pay and the reduced potential to make up lost pay through overtime work was a less salient deterrent to driver absenteeism than previously believed. This suggested the need for additional mechanisms to control absenteeism through direct measures, rather than through the manpower planning process.

C. ADVANCES IN OPERATOR SCHEDULING AND RUNCUTTING

Ball, Michael O., Bodin, Lawrence D., & Dial, Robert. Experimentation with a computerized system for scheduling mass transit vehicles and crews. In Wren, Anthony, ed. Computer scheduling of public transport: Urban passenger vehicle and crew scheduling. Amsterdam: North-Holland and Publishing Co., 1981, pp. 313-334.

Developed a sophisticated interactive model for the simultaneous solution of the vehicle and driver scheduling problem. The system uses an optimization algorithm to generate a low cost set of crew and vehicle schedules. The interactive approach was chosen to allow the scheduler to make rapid changes based on seasonal variations, route changes, or changes in demand patterns; to enable planners to quickly determine the sensitivity of crew and vehicle costs to changes in work rules or service profiles; and to improve upon the relative inflexibility of systems such as RUCUS. The algorithm differs from more traditional approaches by concentrating on the crew scheduling component as the initial input variable, because of the relative dominance of crew costs over vehicle costs in the economics of the problem. A non-interactive version of this model was tested and refined using data from the Baltimore RTA. Results approximated those from manual scheduling. Development is currently underway on the interactive portion of the system.

Blais, J.-Y., & Rousseau, J.-M. HASTUS: A model for the economic evaluation of drivers' collective agreements in transit companies. (Publication #163). Montreal, Quebec, Canada: Universite de Montreal, Centre de Recherche sur les Transports, March 1980.

Illustrates the application of the HASTUS-micro scheduling model to union contract negotiations in two Canadian urban transit properties. The model uses linear programming to assess the current and projected cost consequences of a variety of scheduling/work rule/wage combinations including changes in maximum spread time, number and duration of runs, guarantee pay hours, number and length of trippers, and premium pay. The model uses natural language, requires minimal computer time, gives relatively precise cost estimates of contract modifications, and can be easily adapted to the needs of individual transit properties.

Blais, J.-Y., Laporte, G., Lessard, R., Rousseau, J.-M., & Soumis, F. The problem of assigning drivers to buses in an urban transit system. (Publication #44). Montreal, Quebec, Canada: Universite de Montreal, Centre de Recherche sur les Transports, August 1976.

Examined the problem of assigning bus drivers to vehicles given the constraints of transit labor work rules and the peaked nature of transit demand. The primary goal was to develop a set of techniques to assist transit properties to more efficiently assign runs, reduce operating costs, and reduce the number of trippers. The proposed approach attempts to go beyond the RUCUS technique, which

essentially improves upon an initial solution provided by the user, by generating a set of optimal solution algorithms which are then followed by a number of heuristic steps which refine the solution search. The proposed technique consists of two interrelated models: a 'macro' model, which uses linear programming to relate the number of straight runs, work days and trippers in a given period to a number of constraints such as labor provisions; and a 'micro' model, which builds upon data from the initial phase to generate a list of bus driver assignments. This two-phase approach was tested on data from one operating division of the Montreal Urban Community Transport Commission (MUCTC) and was found to achieve better results than those achieved by manual methods.

Hildyard, Peter M., & Wallis, Hugh V. Advances in computer-assisted runcutting in North America. In Wren, Anthony, ed. Computer scheduling of public transport: Urban passenger vehicle and crew scheduling. Amsterdam: North-Holland Publishing Co., 1981., pp. 183-192.

Traces the development of the RUCUS automated runcutting system and briefly assesses the system's current status and potential. Extensive discussion is devoted to the problem of gaining transit industry acceptance of the RUCUS package. Early versions of RUCUS had no provision for user feedback, unwieldy input routines and extremely complex commands which made many schedulers uncomfortable and unwilling to use the system even when cost savings were demonstrated. Recent improvements to the RUCUS system have simplified its use and enabled more flexible man-machine interaction. The authors stress the importance of making any automated scheduling system interactive, simple to use, and equipped with manual capabilities which simulate the "pencil and paper" approach traditionally used by schedulers. They conclude that advances in microcomputer technology and the growing professionalism of transit planners and schedulers will encourage the adoption of systems such as RUCUS.

Landis, Mark. A perspective on automated bus operator scheduling--Five years' experience in Portland, Oregon. In Wren, Anthony, ed. Computer scheduling of public transport: Urban passenger vehicle and crew scheduling. Amsterdam: North-Holland Publishing Co., 1981, pp. 61-67.

Describes the implementation and use of the RUCUS automated scheduling package by the Tri-County Metropolitan Transit District, a medium-sized operator serving the Portland, Oregon metropolitan area. Tri-Met's computerized scheduling system uses the basic RUCUS package supplemented by a battery of customized routines and sub-programs which enable the district to generate a wide variety of data on system costs and performance. Additionally, the RUCUS system has been used to plan and evaluate service changes, facilitate labor negotiations, and test the impact of proposed schedule and work rule changes on operational and cost parameters. It is estimated that the first computer run-cut generated in 1975 resulted in a savings in driver pay of over \$100,000 annually. The author concludes that the Portland experience with RUCUS demonstrates that it is well within the

ability of a traditional transit organization to adapt to automated scheduling; that it is possible to use automation to produce schedules that are more timely, accurate and effective than their manual counterparts and that result in significant labor cost savings; and that automated scheduling techniques can be extended to the areas of service planning, financial analysis, and labor negotiation.

Lessard, Rejean, Rousseau, Jean-Marc, & Dupuis, Daniel. HASTUS I: A mathematical programming approach to the bus driver scheduling problem. In Wren, Anthony, ed. Computer scheduling of public transport: Urban passenger vehicle and crew scheduling. Amsterdam: North-Holland Publishing Co., 1981, pp. 251-267.

Developed a heuristic mathematical programming approach to schedule bus drivers and vehicles, taking into account constraints imposed by the labor contract. Additional algorithms have been developed to account for situations unique to individual properties such as a workday with three pieces of work or workdays without a break. Trial application of this model to transit properties in Quebec City and Montreal yielded solutions comparable to, or better than, manual solutions. The HASTUS system was implemented by the Quebec City Transit Authority in March 1979 and is routinely used to generate the assignment of drivers for all schedules and to generate a series of printouts used directly by drivers to sign up for their assignments. Application of HASTUS in Quebec City has resulted in a continuing reduction of premium pay paid to drivers and an estimated annual savings of \$125,000 to the property. The system is currently being refined for use within the Montreal Urban Community Transport Commission with the goal of developing a set of interactive routines which allow schedulers to specify additional constraints and modify the solutions produced.

Schmidt, James W., & Fennessey, R. James. Automating extraboard assignments and coach operator timekeeping. In Wren, Anthony, ed. Computer scheduling of public transport: Urban passenger vehicle and crew scheduling. Amsterdam: North-Holland Publishing Co., 1981, pp. 345-352.

Describes the SAGE Extra Board Roster and Dispatch System, an on-line interactive program which can be used to improve the efficiency of extraboard operations and reduce the errors associated with manual extraboard rostering and dispatching. The system is equipped with a video display screen which allows on-line access to extraboard work assignments, payroll data, operator personnel data, labor utilization data and route cost data. The daily time records are accumulated in a history file and can be restored for retroactive pay, absenteeism studies, labor negotiation analysis and other projects. The system consists of three separate but interactive modules: Bidding, Timekeeping, and Daily Rostering and Dispatching.

Ward, Richard E., Durant, Philip A., & Hallman, A. B. A problem decomposition approach to scheduling the drivers and crews of mass transit systems. In Wren, Anthony, ed. Computer scheduling of public transport: Urban passenger vehicle and crew scheduling. Amsterdam: North-Holland Publishing Co., 1981, pp. 297-312.

Developed a mathematical programming approach to bus operator scheduling which decomposes the total scheduling problem into a number of smaller problems which are solved individually. This is said to more closely approximate the technique traditionally used by manual schedulers and to take into account the peaked nature of transit service and the constraints imposed by transit labor work rules. In this approach, the entire schedule is segmented by duty-type (i.e., early straights, middle straights, owl runs, extra pieces) into six distinct categories of work. A subroutine is used to minimize total pay hours for each duty type. In the initial phase of the research, attention was directed toward solving the problem for the late and middle duties. The approach was tested using data from three case study properties, all of which had already experimented with some form of automated runcutting. Analysis was conducted for the evening peak only. Results of the analysis were encouraging, comparing favorably with results from both manual and other computer analysis.

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PART II: DESCRIPTION OF RELATED RESEARCH IN PROGRESS

This section provides summaries of two recently initiated U.S. research projects which are exploring the interrelationships between transit operator stress, operator hypertension/illness, and operator performance.

PROJECT TITLE: "Stress and Hypertension Among Transit Bus Operators"

FUNDING AGENCY: U.S. Department of Transportation, Urban Mass Transportation Administration

PROJECT NUMBER: UMTA-CA-06-0160

RESEARCH AGENCY: Center for the Municipal Occupational Safety and Health, San Francisco General Hospital; and University of California, San Francisco

PRINCIPAL INVESTIGATOR: June M. Fisher, M.D.

PROJECT START DATE: September 1981

PROJECT STATUS: Ongoing

In 1981, the U.S. Department of Transportation's Urban Mass Transportation Administration awarded a \$150,000 planning grant to the University of California, San Francisco, for a study of stress and hypertension among bus drivers in the San Francisco Municipal Railway (MUNI). This initial study has been expanded to a three-year project and involves the cooperative efforts of researchers from the University of California, San Francisco School of Medicine; the University of California, Berkeley School of Public Health; the University of California, Berkeley Institute for the Study of Social Change; the San Francisco General Hospital; the San Francisco Department of Health; as well as representatives of MUNI and the Transport Workers Union.

The goal of this study is to determine the relationship between job stress, hypertension, and other medically-related conditions in MUNI drivers. Based on their findings, researchers will attempt to identify those areas where changes in work practice, administrative function, medical evaluation, intervention, and engineering controls might reduce the negative outcomes of driver stress.

The project will consist of five distinct components: (1) a physiological component, which will develop quantitative objective physiological measures of work-related stress in MUNI bus drivers through cardiovascular and hormonal monitoring of a sample of drivers, both at work and at home, (2) a social-epidemiological component, which will determine the health status of MUNI bus drivers and the impact that health status has on work variables, such as absenteeism, turnover, accidents, performance and early retirement, (3) an environmental component, which will identify the degree of driver exposure to carbon monoxide, lead and noise and how these toxins affect driver performance,

(4) a bibehavioral component, which will identify and test practical and acceptable interventions to decrease elevated blood pressure in drivers already identified as hypertensive, and (5) an anthropological component, which will assess the effect of social and cultural factors in driver perception of stress. Field testing of a pilot sample of MUNI drivers is underway.

This study was initiated as a result of bi-annual medical examinations of MUNI drivers conducted at the San Francisco General Hospital's Center for Municipal Occupational Safety and Health (CMOSH) from 1978-1980. These examinations are required by the State of California as a condition for bus drivers' license renewal and include cardiovascular assessment. A review of the medical records of the first 1200 drivers seen by CMOSH revealed an excessively high incidence of elevated blood pressure in this group. Forty-five percent of all drivers tested were found to have borderline or elevated blood pressure levels (> 140/90) at the time of examination. This incidence of elevated blood pressure is far greater than normal compared to the general population matched for age and sex and held for both black and white bus drivers. Significantly, younger drivers had lower than average blood pressure, making the sharp rise in their middle-aged counterparts even more striking. Equally significant was the finding that while white bus drivers had lower blood pressure readings than their black counterparts, the incidence for hypertension for white bus drivers was significantly higher than for the general white population.

While the factors which cause this apparent high cardiovascular risk have not been clearly delineated, project researchers have hypothesized that a number of factors may be involved, including occupational stress and organization of work, shift changes, social isolation, environmental factors, personality factors and individual health behavior.

PROJECT TITLE:	"Transit Bus Operator Selection and Training for Dealing with Stress"
FUNDING AGENCY:	Transportation Research Board, National Cooperative Transit Research & Development Program
PROJECT NUMBER:	33-1
RESEARCH AGENCY:	Group Associated Management Services, Inc.
PRINCIPAL INVESTIGATOR:	Brownlee Elliott
PROJECT START DATE:	October 1981
PROJECT STATUS:	Ongoing

This project is an investigation of the interrelationships between bus drivers' individual characteristics, characteristics of their work environment, and stress-related behaviors including illness and absenteeism. The goal of this study is

to develop a valid screening device that will reliably predict an individual's susceptibility to those forms of stress that are likely to affect job performance. The research will also provide two training modules: one designed to help newly hired operators anticipate and deal with typical stressful situations, and one designed to help supervisors recognize stress symptoms displayed by operators and provide guidance on appropriate courses of action.

A preliminary review of the literature led researchers to conclude that the occupational stress of bus drivers results from an interactive process: some stress is the result of the personal characteristics of bus drivers, some can be attributed to the working environment, but most stress is the result of an interaction between the personal characteristics of bus drivers and their working environment.

Further, the interaction between the personal characteristics of bus drivers and their working environment involves some inherent inconsistencies. The personal characteristics that contribute to the successful operation of the vehicle interfere, to some extent, with successful dealings with passengers; and the personal characteristics that contribute to successful dealings with passengers interfere, to some extent, with the successful operation of the vehicle.

The researchers anticipate that their instrument will divide bus operator applicants into four major groups: (1) those subject to stress from dealings with passengers, (2) those subject to stress from dealings with the vehicle itself, (3) those subject to stress from both sources, and (4) those not subject to stress at all. They hypothesize that groups one and two will be relatively large, while groups three and four will be relatively small.

In the current phase of the project, researchers are administering a questionnaire based on these variables to 1200 drivers in five U.S. transit organizations and supplementing this analysis with in-depth interviews with management personnel. The refined questionnaire, administered in conjunction with three standardized survey instruments (the State Trait Anxiety Index, the Jenkins Activities Survey and a shortened version of the Holland Vocational Preference Test) will comprise the final stress tolerance measurement device. This battery of tests will enable transit managers to identify bus driver applicants who may be at particular risk for job-related stress.

For additional information on this project see:

Group Associated Management Services Inc., & Performance Technologies Corporation. Identification of stress factors and job characteristics. Interim report on NCTRP Project #33-1. Washington, D.C.: Transportation Research Board, National Cooperative Transit Research & Development Program, 1982.

Transportation Research Board. Review of literature related to bus operator stress. (NCTRP Digest No. 1) Washington, D.C.: Transportation Research Board, National Cooperative Transit Research & Development Program, 1982.

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