# The Health Impact of Urban Mass Transportation Work in New York City

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## Executive Summary

The mass public transportation system in New York City is of critical importance and astonishing magnitude. The economy, the environment and the overall welfare of New York and its businesses and residents depend upon the subways and buses. These subways and buses carry over 7,000,000 passengers per day. To do so, New York City Transit operates nearly 6,500 subway cars, which travel 685 track miles, and 4,500 buses, which traverse over 2,000 route miles. In 2003, New York City Transit had an operating budget of $4.9 billion and employed 48,110 workers. These many workers are essential to the efficiency and safety of the public transit system, which, in turn, relies upon the safety and well-being of transit workers in the performance of their jobs. These concerns have special poignancy in view of the heightened emphasis on the security of public transport.

Transit workers develop important, common diseases and injuries to which their work is likely to be a causal or contributing factor. Such injuries and diseases have been identified by a substantial body of scientific research, including epidemiologic and mechanism-based studies. The major health outcomes of concern are cardiovascular diseases, which include hypertension, heart disease, and stroke; lung and bladder cancer and possibly other cancers; emphysema and asthma; post-traumatic stress disorder and other stress-related psychological disturbances; and low back pain and other musculoskeletal disorders. Most available studies address the risk of disease among bus drivers; comparable studies among subway, maintenance and other transit workers are few.

Occupational hazards of New York City transit workers are uncommonly diverse and encompass much of the spectrum of occupational health. They include chemical, safety, ergonomic, physical, psychological, and biologic hazards. These exposures are matched to important, sometimes life-threatening, outcomes, such as asbestos exposure and lung cancer; hypertension and heart disease; traumatic death and post-traumatic stress disorder; live electricity and electrocution; and vibration and disabling back injuries.

Such diversity of hazards and associated diseases and injuries in a single industry is highly unusual in occupational health and presents an extraordinary opportunity for synergy in causing ill health. The bus driver experiences both job-related hypertension and exposure to air pollutants such as fine particulates and carbon monoxide, which work in concert to damage the heart. Similarly, the subway worker has the stress of keeping to tight time schedules, serving a demanding public, and suffering frequent loud noise, all of which contribute to high blood pressure. This diversity also presents a considerable challenge to develop and apply appropriate policies and practices of prevention and control.

Indeed, few other single industries encompass as large a part of the National Occupational Research Agenda established the National Institute for Occupational Safety and Health as does the urban mass transit industry in New York City and other metropolitan areas.

Current knowledge about the nature and extent of occupational disease, disability and injury experienced by New York City transit workers is limited, principally due to the lack of a coherent, comprehensive, integrated system to capture that information. Sufficient information exists at present to warrant a re-examination of health and welfare policies and practices to maximize the health protection of transit workers and to alleviate the deleterious impacts of transit work on health. At the same time, development of a research and surveillance program that better measures the impact of transit work on health is critically needed. Such a program would be vital to assess the effectiveness of future interventions to limit the negative impact of transit worker on health.

Creation of a university-based Center of Excellence of Occupational Health and Safety of Transit Workers in New York City would provide an excellent mechanism for overcoming the current knowledge deficit and for ensuring the development of a program of research and surveillance that is responsive to labor and management of the New York City transit industry. The goals of such a Center will be to assemble a multi-disciplinary research team; to develop a unified research database; to create a hazard, illness and injury surveillance system; to conduct epidemiologic analyses of transit worker health; to support pilot research studies; and to develop and provide appropriate methods of participation of labor and management in Center direction and activities. Such a Center would give direction and coherence to future transit research. It would serve as an incubator for new inquiries into the nature and extent of health and safety problems of transit work and would provide a mechanism for the rapid translation of new scientific advances into practice in the transit industry.

It is a propitious moment to make progress in transit worker safety and health. The threat of terrorism to public transport systems has prompted the general public to have an acute understanding of the importance of a healthy and vigilant transit workforce to help prevent and respond to emergencies. Both union and management have a mutual interest and show evidence of recent cooperation (i.e. – development of safety dispute resolution process; joint walk-around inspection policy). Ready sources of data, especially health and job title data, exist, providing the research community with a rich and accessible resource. New York City has an active, highly regarded occupational health and safety research community located among its universities to assist in this endeavor. There are a large number of transit workers in New York City, which will enhance the scientific validity of relevant research and make the impact of that research meaningful to many people. Finally, the transit industry has enormous economic and environmental importance to New York City. It is, thus, an excellent window of time to intensify current efforts to protect the health of New York City transit workers and to acquire additional knowledge about relevant hazards in order to improve strategies to prevent avoidable death and disability among transit workers.

## Preface

This report was written by several researchers and practitioners of occupational safety and health in the New York metropolitan area. Funding was provided through a grant from the New York State Legislature administered by the New York State Department of Health to the Transport Workers Union Local 100.

We benefited greatly from comments and advice provided by an external review committee of nationally-renowned occupational health scientists and professionals working principally in New York. The members are listed on the following page. While all reviewers were positive in their comments on a draft version of this report, the listing of their names as members of the External Review Committee in this document does not constitute their endorsement of every statement in this report. The authors made diligent efforts to modify the report in response to the comments provided by this Committee. Indeed, the report was greatly strengthened by the reviews. The authors are grateful for their comments and suggestions.

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# Chapter 1 Introduction

Steven Markowitz, MD

Occupational diseases and injuries encompass a broad range of human ill health. They include lung cancer and mesothelioma in asbestos workers; leukemia in workers exposed to benzene; chronic bronchitis in workers exposed to dusts; chronic disease of the musculoskeletal system in workers who suffer repetitive trauma; hypertension in workers subject to high stress; chronic kidney disease in workers exposed to lead and solvents; heart disease in workers exposed to carbon monoxide; workplace violence in jobs with public access where money is handled; and traumatic death due to construction cave-ins. Such illnesses and injuries afflict many thousands of workers in the United States.

Occupational diseases and injuries are highly preventable. Because they arise from man-made conditions, they can be prevented through alteration of those conditions. *Primary prevention* of occupational disease requires only the elimination or reduction of hazardous exposures. *Secondary prevention*, i.e., early detection of occupational disease in the pre-symptomatic stages when it can still be controlled or cured, is also feasible. It depends on the ability to efficiently and effectively identify and screen workers at high risk for occupational disease. Finally, *tertiary prevention*, the prevention of complications and disability from already existing illness, depends on the development and wide application of appropriate diagnostic and treatment strategies. Prevention on all three levels requires a solid information base on the effects of specific occupational exposures and data on where and by whom hazardous substances are used.

Occupational diseases and injuries are public health problems. They are not rare; they are not restricted to a limited number of factory workers exposed to exotic hazards under unusual working conditions. Their occurrence has enormous significance for other members of the public. When a worker is disabled from work, his or her family is immediately impacted by loss of income, household services, and a fully functioning member of the family. Co-workers too are impacted, because they may experience the same set of exposures and risks that felled their co-worker. Like the communicable diseases, by indicating that others are likely to be at risk, occupational diseases and injuries provide a signal that can be used by a perceptive public health system to act to prevent others from being injured or made ill. As a consequence, public health techniques of recognizing sentinel health events, of identifying persons at risk and of intervening to prevent or to control disease may be effectively applied in the workplace and thereby save workers, their families, their employers, and their co-workers needless suffering and costs.

## Burden and Costs of Occupational Disease and Injuries

However diverse and longstanding work-related diseases and injuries are, it is only recently that research has addressed the totality of such illness and injury in terms of the number of workers affected and the costs of such ill health in the United States. Given the extraordinary variety of jobs, exposures, and associated health problems, it is not easy to calculate the numbers of people and dollars that are involved. It is nonetheless important, because it will focus our attention and enable us to compare occupational health to other public health problems such as AIDS and cancer.

In 1997, Leigh, Markowitz and colleagues estimated that occupational diseases caused between 47,000 and 74,000 deaths per year in the United States in 1992 (1). This is in addition to the 6,500 traumatic deaths that occurred on the job in 1992. Further, they calculated that the wage loss, medical care and other costs associated with these disease-induced and injury-related deaths were approximately $171 billion. They achieved these estimates by reviewing available epidemiologic research to determine what fraction of cancer, heart disease and stroke, respiratory disorders, and nervous system and kidney disease were cause by work and combining these data with health care costs and average wages. They compared these cost estimates with other categories of disease and noted that the estimated 1992 costs was $30 billion for AIDS; $164 billion for circulatory disease (heart disease and stroke), $171 billion for cancer.

Steenland and colleagues of the National Institute for Occupational Safety and Health re-visited this issue using 1997 data (2). They used a similar approach, assigned proportions of broad disease categories to occupational causation, though they were more selective in the diseases that they chose compared to the work of Leigh, Markowitz and colleagues. Their results were, nonetheless, similar to the previous study. They concluded that approximately 49,000 deaths (26,000 – 72,000) in the U.S. in 1997 were due to occupational diseases with an additional 6,200 deaths due to injuries on the job. No economic costs were estimated. They also reported that occupational mortality (49,000 deaths in 1997) was the 8$^{th}$ leading cause of death in the U.S. and was ahead, for example, of suicide (30,575 deaths in 1997) and motor vehicle deaths (43,500 deaths in 1997).

**The Problem of Recognizing Occupational Injuries and Illnesses**

If occupational disease and associated mortality is so common, why is this not generally better recognized?

First and foremost, many occupational diseases are also diseases of everyday life. That is, many of the diseases caused by occupational exposures are also caused by non-occupational factors or occur even in the absence of an identified cause. For example, chronic obstructive lung disease, or emphysema, is principally caused by cigarette smoking but also may be caused by occupational exposures and/or genetic factors. In fact, most diseases, whether occupational or otherwise, have multiple causes, which act in concert to cause disease in an individual or population. It is the rule then, not the exception, that multiple causes play a significant role in contributing to an individual's illness. Consider, for example when a hypertensive, diabetic, cigarette smoker with a stressful job has a heart attack: all of these known cardiovascular risk factors contributed to the heart attack. While the web of causation for most diseases, including occupational diseases, is complex, considerable progress in understanding the role of occupational factors in disease has been made in the past 30 years.

There are distinctive, even unique, occupational diseases that are highly visible and universally recognized. These include the dust diseases of the lungs (pneumoconioses), such as asbestosis and silicosis; selected cancers, such as mesothelioma (cancer of the pleura caused by asbestos) and liver angiosarcoma (caused by vinyl chloride); and heavy metal poisoning. These diseases, though distinctive, usually have features that are similar to other diseases, a fact that sometimes obscures their nature. Regardless, it is the minority of occupational diseases and of people afflicted with occupational diseases who have this characteristic subset of occupational diseases.

The second reason that occupational diseases are not better recognized is that the central tasks of health care and its providers are the diagnosis and treatment of disease. Disease causation is not the mainstay of what doctors consider and act upon. This has changed somewhat in recent years, particularly in heart disease prevention, as reduction in known cardiovascular risk factors such as hypertension and elevated serum cholesterol has received more attention. Notably, this increased attention to disease causation has occurred when there is medical treatment of the risk factor. Non-medical causes of illness such as workplace exposures still provoke little concern of health care providers. The result is that the occupational contribution to illnesses remains obscured.

Thirdly, there exist substantial disincentives to recognizing diseases as having an occupational origin (Azaroff et al., 2002; Pransky et al., 1999). Workers may fear job loss or harassment if their occupational disease is known. They may also have difficulty receiving health care under workers' compensation, either because physicians frequently do not accept workers' compensation, or because insurance companies routinely dispute occupational disease claims. Workers often do not know their legal rights to and the advantages of receiving medical care under workers' compensation (Tuminaro, 2005). Employers strive to reduce workers' compensation costs and to defer the attention of government workplace inspectors. Doctors are averse to serving as medical arbiters in legal and administrative proceedings (e.g. - workers' compensation) and dislike the payments delays and uncertainties that are typical of workers' compensation. These factors, in addition to the general lack of interest of physicians in disease causation, interact to ensure that much occupational disease remains hidden.

**Consequences of Limited Recognition of Occupational Disease**

The consequences of the limited recognition of occupational diseases are multi-dimensional. For the individual, proper compensation, medical care, and reduction in further workplace exposures are eliminated. For co-workers and employers, the opportunities to reduce workplace exposures and to screen for early detection of occupational diseases are missed. For public health authorities and policy-makers, a full accounting of occupational diseases is precluded when such diseases are not specified as occupational. For the general public, the shifting of financial costs of occupational diseases from employers to private and public insurance inflates medical costs and insurance for the full population. In short, the failure to recognize occupational diseases obstructs all steps that concerned parties might take to rectify the causes and consequences of occupational disease.

Leigh and Robbins recently compared national workers' compensation data with the estimates of occupational disease and injury mortality reviewed above (Leigh and Robbins, 2004). They found that 15 states that accounted for 36% of the total U.S. population had a total annual average of 279 deaths per year due to occupational diseases, according to the workers' compensation systems. This total represented less than 1% of the 46,405 to 94,024 deaths due to occupational disease in 1999 in the U.S. identified through the epidemiologic estimates cited in a previous section.

Focusing on medical costs of occupational diseases alone, Leigh and Robbins cited that the 46,405 to 94,024 occupational deaths were associated with $9.5 to $24.7 billion in medical costs in 1999. But total medical costs for all occupational illnesses paid by workers' compensation was less than $2 billion in the United States in 1999 (Leigh and Robbins, 2004). Furthermore, most of these medical costs were paid in relation to non-fatal illnesses, such as musculoskeletal and skin disorders. Clearly, workers compensation pays few of the medical costs associated with occupational diseases, especially fatal ones. Who pays? We all do, because private and public insurance presumably pays for most of the medical care of occupational diseases. Workers especially pay, because they also bear the deductibles, co-insurance and other shared expenses of medical care that are not covered by insurance (Leigh and Robbins, 2004).

Tuminaro rightly points out that the degree of such cost-shifting is generally not known for specific industries, including the New York City transit industry (Tuminaro, 2005).

**Application to Transit Workers**

In this report, we provide a broad overview of occupational hazards, injuries and illnesses experienced by transit workers, especially with relevance to New York City transit workers. The health and safety problems of these workers in New York City have generally been subject to little systematic study. The hazards that they face are diverse, and the resultant diseases and injuries for which they are risk are equally varied. Many of the health problems that transit workers have overlap with diseases of every day life, making the occupational component difficult to delineate.

Our aim in this report is to characterize, to the extent that information is readily available, the work-related health problems that such workers have, or are likely to have, and the associated job hazards. Much of this report reflects the contents of the currently published medical literature and our broad experience in the field of occupational health, including transit work. We have not had the time or resources in preparation of this report to undertake original, primary research, and there are undoubtedly additional data and studies that are relevant the health and safety of transit workers, which were not included in this report due to these same limitations. Readers are welcome to inform us of additional relevant information or studies that were not included in this report, as we try to frame what next steps need to be taken in order to advance the health and safety of transit workers in New York City and elsewhere.

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## Chapter 2 Illnesses and Injuries among Transit Workers

Steven Markowitz MD


**Summary**

Transit workers develop important common diseases and injuries to which their work is likely to be causal or contributing factors. Such injuries and diseases have been identified as a result of a large body of epidemiologic studies. Their causal relation to work is enhanced in plausibility by a more limited set of mechanistic studies. The major health outcomes of concern are cardiovascular diseases, which includes hypertension, heart disease, and stroke; lung and bladder cancer and possibly other cancers; emphysema and asthma; post-traumatic stress disorder and other stress-related psychological disturbances; and low back pain and other musculoskeletal pain syndromes. Most available studies address the risk of disease in bus drivers; few studies exist for subway workers.


*Note for readers: For those who are not familiar with public health research, explanation of a few terms might be useful in reading this chapter. In epidemiology studies, the disease or injury rate in the group of interest (bus drivers and/or subway workers) is compared with the rate of the same disease or injury in a second group, either workers in other industries or people in the general population. These two rates are compared by making a ratio of the two, putting the rate of the transit workers in the numerator and then dividing it by the rate of the comparison group, which is the denominator. The resulting ratio indicates whether the disease rate in transit workers is greater than, less than, or equal to the rate in the comparison group. A ratio of 1.5 (or 150) indicates that transit workers have a 50% increase in rate or risk of disease more than the compared group. There are different types of ratios (relative risk ratios, odds ratios, etc), but they are all interpreted in the same manner. These ratios are usually accompanied by a confidence interval, which expresses the likelihood that this ratio occurred by chance. The confidence interval gives a range of values around the ratio, which expresses alternative ratios that are compatible with the study results. If the first number of the confidence interval range is greater than or equal to 1, then the observed difference between the disease or injury rate of the transit workers versus the compared group likely did not occur by chance. We say that this difference is statistically significant.*

## I. Cardiovascular Disease

Transit workers experience a variety of adverse cardiovascular outcomes, including myocardial infarctions and other manifestations of coronary artery disease, hypertension, and stroke. The role of occupational exposures – broadly defined – in causing an excess of cardiovascular disease is multi-factorial. While the relative importance of various occupational risk factors and their interaction with non-occupational risk factors may not be entirely delineated, the fact of excess cardiovascular disease risk in transit workers is well established. Furthermore, the observed cardiovascular disease excess may represent an underestimate of the true risk of such disease for transit workers, due to factors such as hypertension and other cardiovascular risk factors that serve to select out people from entering or remaining in transit work.

### A. Hypertension

An important series of studies have been undertaken over the past two decades by research scientists in relation to the San Francisco municipal bus drivers. These are among the most prominent studies of bus drivers undertaken in the U.S.

In 1987, Ragland et al. studied the prevalence of hypertension in 1,500 San Francisco municipal bus drivers (Ragland et al., 1987). The source of data was the medical records of the occupational health clinic that conducted routine medical examinations of the drivers. The bus drivers were compared to similar data from a national and local health survey and from pre-employment bus driver physical examinations. Ragland et al. found that bus drivers had higher rates of hypertension compared to the three comparison groups after adjustment for age and race. As importantly, this excess was most visible for bus drivers over age 50, regardless of race. Furthermore, hypertension was clearly related to the number of years driving a bus.

Other earlier studies in Scandinavia showed similar findings (Pikus et al., 1975; Hartvig et al., 1983. as cited in Evans, 1994). They found a higher rate of hypertension in bus drivers than in comparison groups, and this differential increased with added duration of work as a bus driver.

In a follow-up study, Albright and others examined the issue of hypertension and stress as measured by a common job strain and demand/decision latitude model among 1,396 San Francisco bus drivers (Albright et al., 1992). They found no relation between stress and hypertension within the study group when accounting for multiple relevant variables. This study did not compare bus drivers to other occupational groups and used only a single model to assess stress.

More recently, Greiner and colleagues used multiple methods to measure stress among San Francisco bus drivers and its relation to hypertension (Greiner, 2004). Notably, hypertension was positively related to age and years of driving even after each variable was controlled for the other. 39% of drivers aged 50 and over were hypertensive, as were 36% of drivers who were bus drivers for more than 20 years. The more objective measure of stress, which had been previously developed by the authors through an observational interview (Greiner, 1997), included the presence of work barriers and time pressure. This measure was positively related to hypertension. Translated into time units, the presence of work barriers or time pressure increased the prevalence of hypertension by two-fold for an hour-equivalent of work barriers or time pressure. The authors concluded that relatively simple interventions in the organizational and technical design of task and traffic environment could significantly reduce hypertension among bus drivers.

**B. Heart Attacks and Cardiac Mortality**

In 1991, Michaels and Zoloth published a study of the causes of death of 376 New York City bus drivers. A proportionate mortality analysis demonstrated a significant excess due to ischemic heart disease in both races combined (proportionate mortality ratio, PMR = 1.2, 95% confidence interval (CI): 1.0-1.5), and among the 58 non-white drivers (PMR = 1.7, 95% CI: 1.0-2.7). The authors concluded that these findings were consistent with the scientific literature linking job strain with cardiovascular disease among bus drivers.

In an important and well-perfomed study of heart disease prevention in Sweden, Rosengran et al. (1991) studied the incidence of coronary heart disease in 103 bus and tram drivers, using 6,596 men in other occupational groups as a reference group. Over the 11-year study period, one in five (18.4%) bus and tram drivers had a coronary artery disease event, compared to only 6.4% rate in the comparison group. The odds ratio (OR) was 3.3 (95% CI: 2.0-5.5). The only other group with an increase in risk of similar magnitude was taxi drivers with OR 3.1 (95% CI: 1.6-6.2). The authors then performed an analysis that allowed a simultaneous examination of most other risk factors for coronary heart disease (multivariate logistic regression analysis), including age, serum cholesterol, blood pressure, smoking, body mass index, diabetes, marital state, family history of coronary heart disease, alcohol abuse, socioeconomic status, leisure time physical activity, physical activity at work, psychological stress and bus and tram driving. Among bus and tram drivers, the OR remained elevated at 3.0 (95% CI: 1.8-5.2) after adjustment for these other risk factors, but was no longer significant for taxi drivers.

Tuchsen et al. studied ischemic heart disease identified through hospital admissions and deaths among all people in Denmark aged 20-59 years from 1981 to 1985 (Tuchsen et al., 1992). These data were unusual, because they permitted calculation of rates of hospitalization by occupation and industry for all workers (and non-workers). Previously identified non-occupational associations for ischemic heart disease were replicated, enhancing study validity. They used a measure called the standardized hospitalization ratio (SHR), which is the age-standardized rate of hospital admissions for the group of interest compared to (divided by) the age-standardized rate of hospital admissions for all other people in the study. All (urban and rural) male bus drivers had a standardized hospitalization ratio (SHR) of 136, which increased to a SHR = 143 for male urban bus drivers. Male taxi drivers also had an elevated SHR (168).

In 1993, Alfredsson et al. reported on two linked studies of myocardial infarction (heart attacks) among bus drivers in Sweden (Alfredsson et al., 1993). In the first study, the mortality from myocardial infarctions among 9,446 male bus drivers was compared to that of other employed men over a 15-year period. A 50% increase in mortality from myocardial infarction was observed among drivers in Stockholm and the two Swedish counties with large cities. This effect was limited to urban bus drivers, as no excess mortality from myocardial infarction was observed in mostly rural areas. In a second study, the incidence of MI among male bus drivers was compared to other employed men, using a case control approach. An increased incidence of first myocardial infarction was observed for bus drivers in Stockholm county (relative risk, RR = 1.6, 95% CI: 1.1-1.9). The authors suggested that among the factors that might contribute to observed excess risk are job strain, irregular working hours, a sedentary job, automobile exhaust fumes, and noise (Alfredsson et al., 1993).

Netterstrom and Suadicani (1993) studied ischemic heart disease (IHD) occurring over a 10-year period among all male full-time bus drivers in three major cities in Denmark. They tested the question whether bus drivers who report job strain and job dissatisfaction have an excess risk of subsequent death due to IHD. They first assessed psychosocial well-being and work conditions via questionnaire among 2,045 bus drivers in 1978 and then observed mortality from 1978 to 1988 through the Danish Register of Causes of Death. They found a significantly increased risk of IHD in bus drivers working in a high traffic intensity area: relative risk (RR) = 1.6. 59 of the 212 drivers who died during the follow-up period died from IHD. Contrary to expectation, drivers who reported a high degree of job satisfaction as measured in different ways had an increased risk of IHD. The authors recommended that a refinement of the measure of stress exposure might resolve some of the inconsistencies regarding stress and IHD in the literature (Netterstrom and Suadicani**,** 1993).

Gustavsson et al. used a population-based case control approach to study the risk of fatal and non-fatal heart attacks among bus, taxi, and truck drivers in Sweden (Gustavsson et al., 1996). Information on tobacco smoking and obesity was used to control for known non-occupational risk factors. The incidence of myocardial infarction was increased among bus drivers in Stockholm (relative risk, RR = 1.5, 95% CI: 1.2-2.1), and among taxi drivers both in Stockholm (RR 1.65, 95% CI: 1.3-2.1) and in rural areas (RR 1.8, 95% CI: 1.2-2.8). Most (> 80%) urban bus drivers in the study reported a combination of high psychological demands and low control at work. The investigators concluded that urban bus drivers were at an increased risk of myocardial infarction, which was unlikely due to other cardiovascular risk factors, and which might be due to psychosocial work factors.

In Denmark in 2001, Hannerz and Tuchsen followed up their previous study by evaluating causes of hospital admissions among male professional drivers aged 20-59 years, including drivers of goods vehicles and drivers of passenger transport (bus and taxi drivers) (Hannerz et al., 2001). They calculated age-standardized hospital admission ratios (SHRs) and time trends (1981-97) for various diseases. SHRs for most disease categories were higher among professional drivers compared to the general male population. For ischemic heart disease, the SHR ranged from 1.44 to 1.83, depending on the time period; all elevations in risk were statistically significant. When comparing drivers of passenger transport to drivers of goods vehicles, the former had significantly higher SHRs due to diseases of the circulatory system (30%) and also infectious and parasitic diseases (86%) and diseases of the respiratory system (26%). Drivers of passenger transport also showed an increasing SHR for chronic obstructive pulmonary disease over time.

Tuchsen and Endahl extended this analysis to examine if risk of heart disease among bus drivers had changed over time (Tuchsen and Endahl, 1999). In fact, the risk of ischemic heart disease increased among bus drivers from a SHR of 1.4 (95% CI: 1.2-1.7) between 1981-1985 to a SHR of 1.89 (95% CI: 1.6-2.3) in 1991-1993. This increase was among the highest seen in any occupational group.

In the most recent study from Sweden, Bigert et al. identified all first heart attacks among men aged 45-70 years in Stockholm County in 1992 and 1993. They used a case control study design, selecting 1,482 controls randomly from the population, compared to 1,067 cases of men with heart attacks. They obtained occupational exposure and other relevant risk factor information from questionnaires. The crude (unadjusted) odds ratio (OR) among bus drivers was 2.1 (95% CI: 1.3-3.4), decreasing to 1.5 (95% CI: 0.9-2.5) after adjustment for potential confounders, including socioeconomic status, tobacco smoking, alcohol drinking, physical inactivity at leisure time, overweight status, diabetes and hypertension. They also found similar findings among other vehicle drivers. The ORs among taxi drivers and truck drivers were 1.88 (1.19-2.98) and 1.66 (1.22-2.26), respectively, reducing to OR's of 1.34 (0.8-2.2) and 1.1 (0.8-1.5), respectively, after adjustment. Adjustment for job strain produced only a modest decrease in the ORs. An exposure-response pattern, as measured by duration of work, was found for bus and taxi drivers (Bigert et al., 2003).

### C. Stroke

Given the similarity of disease processes and underlying risk factors between coronary artery disease and stroke, the question of stroke risk among transit workers is of interest. Few studies, however, are available.

In Sweden, Tuchsen studied the risk of stroke among professional drivers, including bus, truck, and taxi drivers, between 1981 and 1990. He used a cohort study design and included all employed male and female Danes who were between the ages of 20 and 59 years. The outcome measure, as described above, was the Standardized Hospitalization Ratio, or SHR, for stroke between occupational groups. Nearly all groups of male drivers showed an elevated risk of stroke. The SHR for city bus drivers was approximately 160, which represented a statistically significant excess. Among women city bus drivers, the SHR was approximately 185, which was not statistically significant, but the number of women studied was smaller than men. For longer-term city bus drivers, the risk of stroke increased. Longer-term male city bus drivers had nearly three times the risk of stroke compared to shorter-term city bus drivers (RR = 2.65; 95% CI: 1.02-5.76). Longer-term female city bus drivers also had a higher risk of stroke than shorter-term drivers. The authors concluded that professional driving was associated with an increased risk of stroke. Selection factors likely resulted in underestimates of the true excess risks associated with bus driving (Tuchsen, 1997).

### D. Mechanisms of Cardiovascular Disease

The mechanisms of elevated cardiovascular disease rates among bus drivers have been the subject of considerable study and are beyond the scope of this review (Tuchsen 1997). Among important factors may be stress and their physiological correlates; noise and its contribution to hypertension; irregular working hours; air pollution, including carbon monoxide, particulate air pollution, diesel exhaust, and other ambient air pollutants; poor diet; and absence of physical exercise.

### E. Cardiovascular Intervention Studies

Hedberg et al. (1998) evaluated a lifestyle intervention program aimed at reducing the risk of heart disease among professional drivers. There were 102 participants, equally divided into two groups; one-fourth of participants were bus drivers. A health profile assessment intervention provided risk-factor education on an individual and group basis. The reference group received a health examination. Outcomes included blood pressure, serum lipid levels, body mass index, estimated maximal oxygen uptake, and a questionnaire assessment of lifestyle habits, which were measured at the beginning of the study and at 6 and 18 months. Study results indicated fewer positive results in the intervention group compared to the reference group. The former experienced increased maximal oxygen uptake, improved exercise habits, and intention to improve diet. The reference group experienced increased maximal oxygen uptake, decreased serum total cholesterol, and decline in perception of stress and isolation. Participants cited variable working hours as the most common obstacle to changing a health habit. The authors concluded that both groups obtained benefit in some heart disease risk factors and noted a high degree of enthusiasm and participation in the study.

## II. Cancer

As reviewed above, Michaels and Zoloth published a study of the causes of death of 376 New York City bus drivers in 1991. For all drivers, PMRs for all malignant neoplasms (PMR = 1.3, 95% CI: 1.1-1.5) and for cancer of the esophagus (PMR = 2.5, 95% CI: 1.0-5.2) were significantly elevated. No cancer sites were significantly elevated in the proportionate mortality analyses by race.

Alfredsson et al. compared the mortality of all male bus drivers in Sweden (n= 9,446) to that of other employed men over a 15-year period. No increased mortality from lung cancer, all cancer sites combined, or from all causes combined was observed for these drivers (Alfredsson et al., 1993).

Jakobsson et al. (1997) completed a more detailed study of the risk of lung cancer in different subgroups of professional drivers in urban and rural areas of Sweden. They linked occupational and geographical data from the Swedish census of 1970 with lung cancer incidence from the National Swedish Cancer Registry for the period, 1971 to 1984. Professional drivers were divided into bus, taxi, and long and short distance truck drivers. The relative risks (RR) for bus drivers were not increased in any area of the country. Taxi drivers and long and short distance truck drivers in Stockholm County showed increased RR's for lung cancer. The highest risk was among short distance truck drivers (RR = 2.0, 95% CI; 1.5 to 2.6). The effect was urban: drivers in rural areas showed no increased RRs for any category of driver. The authors concluded that an environmental factor such as motor exhaust probably played a role in the excess of lung cancer among short distance urban truck drivers in Sweden.

Hansen et al. (1998) studied the risk of lung cancer among different groups of professional drivers in Denmark. They performed a national case-control study between 1971 and 1989, including 28,744 employed men with primary lung cancer and an equal number of matched controls. Nationwide pension data were used to re-construct employment histories back to 1964. Historical information on tobacco smoking habits was available. They found an elevated risk of lung cancer among bus and truck drivers. The odds ratio was 1.3 (95% CI; 1.2 to 1.5) for bus and truck drivers combined. They also found an odds ratio of lung of 1.6 (95% CI; 1.2 to 2.2) among taxi drivers. This was a large study, including a total of 2,251 male lung cancer cases that had been employed as bus, truck, taxi, or unspecified drivers. No significant difference in tobacco smoking was found between professional male Danish drivers and the total employed population and could not explain the observed elevations in lung cancer risk. The adjusted risk of lung cancer increased significantly with added duration of employment as a driver. The authors concluded that occupational exposure to vehicle exhaust was likely to play an important role in the risk of lung cancer among professional drivers.

Soll-Johanning et al. (Soll-Johanning et al., 1998) of the National Institute of Occupational Health of Denmark conducted a retrospective cohort study of 18,174 bus drivers or tramway employees in Copenhagen during the period 1900-94. Bus drivers or tramway employees had an increased risk of all malignant cancers (standardized incidence ratio (SIR) = 1.2, 95% CI: 1.2 to 1.3). This increased risk was observed for both men and women (male SIR = 1.24, 95% CI: 1.2 to 1.3; and female SIR = 1.3, 95% CI: 1.1 to 1.5, respectively). Males who were employed for > 3 months showed statistically significant elevations in risk at a number of cancer sites: lung cancer (SIR = 1.6, 95% CI: 1.5 to 1.8), laryngeal cancer (SIR = 1.4, 95% CI; 1.0 to 1.9), kidney cancer (SIR = 1.6, 95% CI; 1.3 to 2.0), bladder cancer (SIR = 1.4, 95% CI: 1.2 to 1.6), skin cancer (SIR = 1.1, 95% CI: 1.0 to 1.2), pharyngeal cancer (SIR = 1.9, 95% CI; 1.2 to 2.8), rectal cancer (SIR = 1.2, 95% CI: 1.0 to 1.5) and liver cancer (SIR = 1.6, 95% CI: 1.2 to 2.2). For women employed for > 3 months the risk of lung cancer was significantly increased (SIR = 2.6, 95% CI: 1.5 to 4.3). Soll-Johanning and colleagues concluded that Danish bus drivers and tramway workers had elevated risks of several types of cancer.

Bruske-Hohlfeld and colleagues conducted two case-control studies on lung cancer in Germany. The study included 3,498 males with lung cancer and 3,541 male population controls. Information about lifelong occupational and smoking history was obtained by questionnaire. Drivers of buses, taxis, trucks, diesel locomotives and heavy equipment were considered as exposed to diesel exhaust. All odds ratios were adjusted for smoking and asbestos exposure. The lung cancer risk for all jobs with diesel exhaust exposure combined was elevated with OR=1.43 (95% CI: 1.23-1.67). Professional drivers (buses, trucks, and taxis) showed an increased risk in West Germany (OR=1.44, 95% CI: 1.18-1.76), but not in East Germany (OR=0.83, 95% CI: 0.60-1.14). The odds ratio for lung cancer among professional drivers remained elevated after control for smoking and asbestos exposure. The authors concluded that the study results support the association between occupational diesel exhaust exposure and lung cancer (Bruske-Hohlfeld et al., 1999).

Soll-Johanning et al. (2003) specifically studied lung and bladder cancer risk among bus drivers and tramway employees in Denmark. This was a more detailed analysis of data reported previously (see above) using a nested case–control study of 153 lung and 84 bladder cancer cases compared with 606 controls selected from the group of 18,174 bus drivers or tram workers employed in Copenhagen. Information on smoking, occupational and residential history was collected. An air pollution exposure index based on which routes the bus drivers had mainly driven was established. The analysis showed decreasing risk for lung cancer with increasing years of employment as a bus driver (RR = 0.97 for each added year, 95% confidence interval = 0.96–0.99). There was no relation between air pollution index and lung or bladder cancer risk.

**III. Respiratory Disease**

In 1988, Balarajan and McDowall published the results of a prospective mortality study of 3,392 professional drivers in London. There were significantly fewer deaths than expected from all causes (SMR = 91, $p < 0.05$), circulatory disease (SMR = 75, $p < 0.05$), and accidents (SMR = 61, $p < 0.05$). Truck drivers showed excess deaths from bronchitis, emphysema, and asthma (SMR = 143, $p < 0.05$), stomach cancer (SMR = 141, $p < 0.05$), lung cancer (SMR = 159, $p < 0.05$), a pattern not evident among taxi drivers. Taxi drivers experienced increased mortality from bladder cancers, leukemia, and other lymphatic cancers, but the results were not statistically significant (Balarajan and McDowall, 1988).

Torén and Hörte examined asthma mortality by occupation in Sweden (Torén and Hörte, 1997). They linked occupational information from the National Census in 1980 with national mortality between 1981 and 1992. Information about smoking habits was obtained from smoking surveys carried between 1977 and 1979. The measure of risk was the smoking-adjusted standardized mortality ratio (SMR). Significantly increased mortality from asthma was found only among two male occupational groups, professional drivers and farmers, and one female occupational group, hairdressers. The smoking-adjusted SMR for asthma among male professional drivers was 144 (95% CI = 101-209) based on 43 deaths. The authors considered that the increased mortality among the professional drivers may be a random occurrence.

Tuchsen and Hannerz studied social and occupational differences in chronic obstructive lung disease in high-risk industries in Denmark. They formed cohorts of all employed Danes between the ages of 20 and 59 years in the years 1981, 1986, and 1991. They compared standardized hospitalization ratios (SHR) and time trends (1981-1993). For male bus and taxi drivers, they found a SHR for chronic obstructive pulmonary disease (COPD) of 142 ($p < .05$), which decreased to 117 ($p > .05$) when adjusted for social group. Among women professional drivers, the SHR for COPD was approximately 185 ($p < .05$), and it decreased to 1.5 ($p < .05$) after adjustment. When different calendar periods were compared, there was an increasing SHR for taxi and bus drivers over time, peaking in 1991-1993, when an adjusted SHR = 174 (95% CI: 125-235) was observed (Tuchsen and Hannerz, 2000).

In Denmark, Hannerz et al. studied causes of hospital admissions among male professional drivers aged 20-59 years, including drivers of goods vehicles and drivers of passenger transport (Hannerz et al., 2001) They calculated age-standardized hospital admission ratios (SHRs) and time trends for various diseases between 1981 and 1997. SHRs for most disease categories were higher among professional drivers compared to the general male population. When comparing drivers of passenger transport to drivers of goods vehicles, the former had significantly high SHRs due to diseases of the respiratory system, diseases of the circulatory system and also infectious and parasitic diseases. Drivers of passenger transport also showed an increasing SHR for chronic obstructive pulmonary disease over the time period of the study.

**IV. Musculoskeletal Disorders**

Back pain, especially low back pain, is a common disorder in the general population, but more so in transit workers, including subway workers and bus drivers. The general relationship between driving motor vehicles – trucks, tractors, or buses – and various back conditions has been well established for at least three decades (Kelsey et al., 1975; Troup, 1978; Kelsey et al., 1980; Frymoyer et al., 1980; Backman, 1983; Ragland et al., 1996).

Johanning, noting that New York City subway operators had a high prevalence of back problems, evaluated whole-body vibration among subway workers (Johanning, 1991). He measured subway car vibrations by placing vibration transducers in triaxial orientation directly on the subway operator's seat. He found high lateral and vertical accelerations providing whole-body vibration at levels above the international standard, and he concluded that such exposure might contribute to musculoskeletal symptoms.

To assess the prevalence of back pain among subway train operators, Johanning and colleagues (Johanning et al., 1991) applied a self-administered questionnaire survey among subway train operators (n = 492) and a similar reference group (n = 92). They found that train operators had a higher prevalence of all types of back problems, especially cervical and lower back pain, than did the reference group. In a multiple logistic regression model, the odds ratio for sciatic pain among subway train operators was 3.9 (95% CI: 1.7-8.6); the operators also had a higher risk of hearing-related problems (odds ratio = 3.2, 95% CI: 0.6-17.4) The authors concluded that the back problems identified among subway train operators were likely to be related to exposure to whole-body vibration and inadequate ergonomic conditions.

Anderson studied spinal symptoms among a stratified random sample of 195 members of an urban transit union in California (Anderson, 1992). Two-thirds of the study group was bus operators, and the remaining formed a non-driving comparison group. He obtained information from an orthopedic medical history and physical examination. 80.5% of drivers reported current back or neck pain, compared to 50.7% of non-drivers. Most pain was mild (53.9% of bus drivers and 29.9% of non-drivers). Both groups reported an equal prevalence of severe pain. The author recommended ergonomic and scheduling changes in bus operation to relieve back ill health.

Magnusson and colleagues studied the role of mechanical and psychosocial factors in back, neck, and shoulder pain and work loss among bus and truck drivers in Sweden and the United States. Drivers were compared to sedentary workers. They measured vibration levels directly during representative driving conditions and obtained other information about health and occupation, including the physical and psychosocial aspects of the work environment, through questionnaires. U.S. bus drivers reported the following symptoms more often than sedentary workers: low back pain: 81% vs. 42% ($p < .0006$); neck pain: 53% vs. 38% ($p < .002$); and shoulder pain: 42% vs. 15% ($p < .01$). These differences were greater among the U.S. versus Swedish bus drivers and greater among the U.S. bus versus truck drivers. The highest risk factors for back and neck pain were long-term vibration exposure and heavy and frequent lifting. The highest risk of low back pain was associated with the combination of long-term vibration exposure and frequent lifting. Work loss from low back pain increased with perceived job stress. The authors concluded that driving-related vibration and lifting cause back, neck, and shoulder pain (Magnusson et al., 1996).

In 1997, Krause and colleagues published a study of physical workload, ergonomic factors, and the prevalence of back and neck pain among 1,449 urban transit drivers in San Francisco (Krause et al., 1997). They defined physical workload as duration of driving and used self-reported ergonomic factors, vehicle type, height, weight, age, and gender in a multivariate analysis of the relative importance of these factors in relation to back and neck pain. Driving for 10 years was associated with an odds ratio of 3.4 for back and neck pain, which decreased to 2.6 when adjusted for ergonomic factors. The risk of back and neck pain rose continuously with increasing years of driving and with weekly hours of current driving. Female drivers had back and neck pain twice as frequently as male drivers (OR = 2.1, 95% CI; 1.3–3.4). Self-reported difficulty in seat adjustment raised the risk of back and neck pain nearly four-fold (odds ratio = 3.9, 95% CI; 2.4-6.3). Most (6 of 7) ergonomic factors were significantly related to the prevalence of back and neck pain after adjustment for other variables. The authors concluded that both physical workload and ergonomic factors were important factors in the development of back and neck pain among urban transit drivers, suggesting that the problem of back and neck pain in these workers might be partly alleviated or prevented by ergonomic changes in transit vehicles (Krause et al., 1997).

In 1998, Krause and colleagues reported on the results of a 5-year prospective cohort study on psychosocial job factors and physical workload in predicting work-related spinal injuries among 1,449 urban transit operators (Krause et al., 1998). The study goal was to separate the effects of these two causal factors, which had previously been shown to affect back pain in transit operators. Information sources included questionnaires, workers' compensation records, and company records. Logistic regression permitted adjustment for multiple variables. During the 5 years of follow-up, 320 drivers reported a first spinal injury. The following factors were predictive of spinal injury: psychological job demands (OR = 1.50; 95% CI, 1.33-1.95); job dissatisfaction (OR = 1.56; 95% CI; 1.09-2.23); frequency of job problems (OR = 1.52; 95% CI, 1.02-2.26), and low supervisor support (OR = 1.30; 95% CI; 0.99-1.72). Female gender also raised the risk of spinal injury (OR = 1.49; 95% CI; 0.95-2.32). Part-time work lowered the risk of spinal injury by two-thirds, compared with full-time work (OR = 0.37; 95% CI; 0.15-0.93). Krause et al. concluded that psychosocial job factors and physical workload independently predicted spinal injury in transit vehicle operators (Krause et al., 1998).

### A. Musculoskeletal Intervention Studies

Johanning et al., 1996 conducted a prospective physical and psychological health intervention study for 125 transit operators aged > 45 years with > 15 years of job seniority. The one-year intervention included physical exercise, relaxation, back school, work-related stress management and diet counseling. A control group of 26 transit non-operators was used for comparison. WHO cardiovascular risk survey methods, ergometry, Minnesota ECG coding, standardized low-back tests, blood lipids, lead, and carboxyhemoglobin were measured. The intervention did not significantly lower cardiovascular risk beyond that of the control group. The prevalence and intensity of back problems decreased after intervention: 55.4% of participants with low back pain reported substantial improvement. The authors concluded that a multidisciplinary intervention program improved musculoskeletal disorders but not cardiovascular disease risk.

## V. Mental Health

In 1991, Michaels and Zoloth published a study of the causes of death of 376 New York City bus drivers. Proportionate mortality analyses found a significant excess in risk of death from mental, psychoneurotic and personality disorders (ICDA Ninth Revision 290-319, which includes alcoholism and narcotics abuse) in the combined (white and African-American) group (PMR = 2.7, 95% CI: 1.2-5.3), and among white drivers (PMR = 3.1, 95% CI: 1.1-6.7).

Cothereau et al. studied the mental health impact and related somatic health symptoms among 202 French train drivers having experienced a "person under train" accident (Cothereau et al., 2004). The train drivers were evaluated several times: immediately after the event, three months later, and one, two, and three years later and were compared with 186 train drivers who did not experience such an event. The exposed train drivers had a prevalence of post-traumatic stress of 4% at the first evaluation versus 0% for the comparison group. The exposed drivers also showed a variety of psychological symptoms, especially somatic symptoms, anxiety, insomnia, and social dysfunction as measured with a standardized questionnaire. Differences between exposed and unexposed drivers disappeared by the end of the first year. The authors identified the situation where a lone driver drives the train away following the event as a “vulnerability factor” for psychological sequelae. Most (>95%) exposed drivers had no short, medium, or long-term occupational impairment. The authors concluded that viewing a traumatic accident is a work-related risk and that providing psychological support to drivers after an accident increases recovery from such traumatic events.

**Appendix: Chapter 2: Workers' Compensation Data**

Limited data are available from private sources (e.g. – workers' compensation law firm and medical practice) providing services to transit workers in New York City. These data represent case series, i.e. – non-randomly selected individuals who voluntarily choose specified sources of legal and medical services. While they may provide useful information, their experience may or may not be representative of the experience of larger numbers of transit workers. These data are collected for the purposes of providing specific services for clients or patients and are not collected for research purposes. All data analyses were performed by the parties providing the data.

**A. Analysis of Workers' Compensation Claims of NYCTA Workers in 2003 by Grey & Grey, LLP.**

Source: Robert E. Grey (Grey & Grey, LLP):

Method: Grey reviewed all of his firm's workers' compensation claims associated with NYCTA employees in 2003. He identified and reviewed 136 such claims and identified the occupational title and cause of the injuries associated with these claims.

**Transit Workers' Workers Compensation Claims**
**By Cause and Job Title According to Grey & Grey LLC., 2003**

| Cause | Bus operators | Cleaners | Maintenance | Station agents | Track workers | Train operators | Total |
|---|---|---|---|---|---|---|---|
| **Assault** | 8 | - | - | 2 | - | 1 | **11** |
| **Environment** | - | - | - | - | - | 2 | **2** |
| **Equipment** | 10 | 5 | 8 | 6 | 5 | 15 | **49** |
| **Inhalation** | - | 1 | - | 3 | - | - | **4** |
| **Lifting** | - | 6 | 5 | 1 | 3 | - | **15** |
| **Occupational disease** | - | - | 1 | 3 | - | 2 | **6** |
| **Slip/Trip** | 3 | 11 | 4 | 3 | 3 | 9 | **33** |
| **Motor vehicle accident** | 5 | - | - | - | - | - | **5** |
| **12/9 (body on tracks)** | 1 | - | - | - | 1 | 9 | **11** |
| **Total** | **27** | **23** | **18** | **18** | **12** | **38** | **136** |

Comments (per R. Grey):

1. Bus operators: "Assault" generally involves physical or verbal attack of bus operator by passengers. "Equipment" refers to seats and interlocks.

2. Cleaners: All lifting incidents were associated with back injuries. Slip and fall incidents often involved stairs. Equipment issues include lack of adequate equipment and failure or defect in equipment provided.

3. Maintenance: This category includes maintenance-type occupations in all NYCTA operations. The causes of injury were similar to those of cleaners.

4. Station agents: Assaults were perpetrated by patrons. All of the slip/fall injuries occurred on stairs. Two equipment failures were attributable to defective chairs; two others were associated with defects in premises (including a ceiling collapse). Three inhalational injuries were caused by vapor exposure (e.g. - cleaning fluid in two cases).

5. Track workers: The lifting and equipment injuries resulted from absence of proper equipment or devices to accomplish assigned tasks.

6. Train operators: 40% of train operator injuries resulted from faulty equipment, including stuck windows, torn seats, defective brakes, and others. Many trip/fall incidents occurred while walking through or between trains or from trains to platforms.

7. Most claims (119 of 136) were not contested by the employer.

## B. Analysis of Work-Related Injuries of NYCTA in 2003 by Central Medical Services of Westrock, P.C.

Source: Michael Hearns, M.D., Msc., CENTRAL MEDICAL SERVICES OF WESTROCK, P.C, New York City.

Method: Hearns and colleagues abstracted data from all medical visits of MTA employees to this practice in 2003.

Results: 231 MTA workers were seen in 2003, principally in Brooklyn (45%), Queens (45%), and Long Island (10%). Mean age was 48 years (range: 22 to 77 years). There were 85 females and 46 males. The mean length of time for approval of authorization for treatment and/or diagnostic testing was 7 months (range: 2 days to 25 months).

Detailed information is currently available for the 74 MTA bus operators who were treated in 2003. There were 40 males and 34 females. The mean age for both genders was 42 years (range: 24-64). The group consisted of 72 workers compensation cases and 2 major medical cases. Medical conditions included musculoskeletal conditions, psychological disorders, exposure incidents, and miscellaneous conditions.

*Medical conditions*

1. Musculoskeletal conditions: 51 cases

   a. Head/face cases (n=5): typical diagnosis was contusion/laceration.
   b. Neck/back cases (n=17): typical diagnosis was herniated disc.
   c. Shoulder cases (n=7): typical diagnosis was impingement syndrome.
   d. Wrist/hands cases (n=10): typical diagnosis was carpal tunnel syndrome.
   e. Knee cases (n=7): typical diagnosis was knee contusion.
   f. Ankle/foot cases (n=5): typical diagnosis was sprain/strain.

2. Psychological conditions: 9 cases; typical diagnosis was PTSD.

3. Exposure incidents: 4; typical diagnosis was body fluid exposure

4. Miscellaneous cases 10.

*Causes of injury*

- Assaults by passengers 15 cases
- Slip/trip/falls 11 cases
- Repetitive injuries 10 cases
- Psychological (excl. assaults) 9 cases
- MVA 6 cases
- Potholes 5 cases
- Exposures 4 cases
- Miscellaneous 4 cases
- Physical 3 cases

References – Chapter 2 Illnesses and Injuries among Transit Workers


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## Chapter 3 Occupational Safety and Health Hazards in Urban Mass Transit

David M. Newman, M.A., M.S.

**Summary**

Transit workers in New York City face an extraordinary variety of hazards that typically characterize a broad range of industries, including construction, manufacturing, service, public administration, and even mining. These hazards derive from chemical, biological, physical, safety, ergonomic, and psychologically stressful exposures. While these hazards vary greatly by occupation within the transit industry, most occupational titles in transit experience multiple hazards, often simultaneously. Moreover, since the work of transit is literally mobile or otherwise performed frequently in the field (e.g. – on the subway tracks), control of hazards in the transit industry is especially challenging. Special problems such as dealing with deaths on the tracks, workplace violence, and performing track work in a train system that never shuts down adds to the challenge. At present, limited systematic and quantitative information about both the current degree of hazards and exposures as well as the efficacy of hazard controls exist in the New York City Transit system.

**Chapter 3 Table of Contents**

## I. Introduction

It is not well understood, except by transit workers themselves, that employees in the mass transit industry labor under conditions that are frequently as unhealthy or as dangerous as those encountered in industries more widely recognized as hazardous, such as mining. Although urban mass transit, like other dangerous industries, is characterized by the use of heavy industrial and construction equipment, large rail and road vehicles, multiple chemical substances, and manual labor, it has received relatively little attention in the scientific literature. Similarly, many of the occupational hazards faced by urban transit workers are not regulated or addressed by provisions of the federal Occupational Safety and Health Act (OSHA) or by safety requirements enforced by the Federal Railroad Administration (FRA).

Professional industrial hygiene practice postulates a universally acknowledged framework for effectively addressing occupational risks - anticipation of hazards before they occur, recognition of hazards when they occur, evaluation of hazards to determine level of risk, and elimination or control of hazards to prevent or reduce injury, illness, or death. This paper broadly characterizes the occupational safety and health hazards in New York City's mass transit system. Due to the scope and diversity of its operations, it is likely the New York City transit system is representative of virtually all of the occupational hazards that may be found in mass transit systems in other North American cities.

It is hoped that this chapter will contribute to further examination of workplace hazards in urban mass transit systems by the industrial hygiene and regulatory communities, and more importantly, that it will be of use to operating system management and labor unions in establishing workplaces that are healthful and safe.

## II. New York City Transit System

New York City's mass transit system is one of the largest in the world, carrying close to one billion riders each year and encompassing 722 miles of below-grade, surface, and elevated railroad track, and additional hundreds of miles of bus routes. Because of restrictions imposed by the city's geography and geology, the system utilizes elevated tracks, subsurface tracks, roadways, open cuts, bridges, and tunnels, beneath both land and water.

Since buses and trains are operational 24 hours a day, 7 days a week, there is no down time for maintenance or repair. Consequently, subway maintenance and repair activities are conducted while the 600-volt third rail is live and as trains continue to operate on tracks where work activities are occurring.

These are high-hazard work operations that have a long history of multiple fatalities. Five workers have been killed in the three years since July 2001 and 22 since 1980, all from third rail electrocution or from being struck by trains while performing maintenance of way. There have been 132 worker fatalities since 1946.

The extent of chronic illness, if any, among New York City transit workers from workplace exposure to chemical agents such as solvents, lead, and asbestos or to physical agents such as vibration, has not been investigated and is largely undocumented.

The collective bargaining agreement between New York City Transit (NYCT) and Transport Workers Union (TWU) Local 100 establishes more than 200 job titles. Major types of work in the system include: operation, maintenance, and repair of trains and buses; maintenance and repair of the railroad bed ("maintenance of way"); maintenance and repair of infrastructure, including buildings, tunnels, elevated structures, signals, power, telecommunications, lighting, drainage, and ventilation; construction of pre-fabricated track panels; production and sale of Metro cards; cleaning operations in buses, trains, stations, buildings, and on tracks; and clerical support for these efforts. There are approximately 26,000 employees engaged in subway operations and 12,000 in bus operations.

Although the U.S. Department of Transportation's Federal Railroad Administration is the government agency with primary responsibility for promulgating and enforcing railway safety rules and requirements, it lacks jurisdiction over "intra-city" urban mass transit systems such as New York City's railway and bus operations. While the general industry and construction standards of the federal Occupational and Safety Act are applicable to New York City Transit, they do not address issues specific to railroad operations, such as flagging and track safety. Because NYCT is a government authority and its employees are public sector workers, the government agency responsible for enforcing OSHA standards is the Public Employee Safety and Health Bureau (PESH) of the New York State Department of Labor, and not the federal Occupational Safety and Health Administration.

## III. Chemical Hazards

There are several primary sources of potential chemical exposure to workers in the New York City transit system: 1) chemical products deliberately introduced into the work environment for use in maintenance and repair operations (for example, solvents and degreasers); 2) chemical substances inadvertently released into the work environment from deterioration or disturbance of in-place materials (for example, lead and asbestos); chemical byproducts from work operations (for example, diesel emissions and hazardous wastes); and 3) chemicals that originate in external sources (for example, methane from gas lines or hydrogen sulfide from decomposing organic matter).

Primary routes of entry into the body for workplace chemicals include inhalation, ingestion, skin absorption (contact with intact skin), and puncture. Of these, inhalation is the most common route of entry into the body and thus of foremost concern. Inadvertent ingestion can occur when airborne contaminants settle out onto food or beverages in the workplace. Dose (amount of the chemical substance entering the body) is dependent upon frequency and duration of exposure and upon concentration of the chemical(s). In general, health risk is determined by dose and toxicity.

Identification of chemical hazards in this chapter is based on observations and descriptions of work practices and of chemicals present at work sites of the New York City transit system. Determination of level of risk from chemical exposure to workers in the New York City transit system is beyond the scope of this chapter. Risk level is dependent upon intensity (toxicity and concentration) and frequency and duration of the exposure. These types of chemical exposure data either do not exist or are not available for examination. Assessment of the adequacy of general and local exhaust ventilation and of respiratory protection and personal protective equipment is also beyond the scope of this chapter. Similar limitations apply to other types of hazards identified in this chapter.

### A. Asbestos

Asbestos is a generic name for a group of six naturally occurring fibrous silicate minerals, including chrysotile, actinolite, amosite, anthophyllite, crocidolite, and tremolite. Asbestos fibers have great tensile strength, exhibit minimal electrical conductivity, are fire- and heat-resistant, and have the ability to be woven. As a result, asbestos has been used, and continues to be used, in a wide variety of commercial and industrial applications. It is commonly, and incorrectly, assumed that asbestos-containing products are prohibited. In fact, in 1989 EPA promulgated the Asbestos Ban and Phase out Rule (40 CFR 763, Sec. 762.160 - 763.179), which was ultimately overturned by the U.S. Fifth Circuit Court of Appeals in 1991. Thus, the original 1989 EPA ban on the U.S. manufacture, importation, processing, or distribution in commerce of many categories of asbestos-containing products was set aside and did not take effect. Asbestos continues to be used in textiles, electrical and thermal insulation, various types of filters, asbestos-cement pipes and sheeting, clutch facings, brake linings, pipe covering, gaskets, plastics, floor and ceiling tiles, roofing felts and shingles, and other products.

Asbestos and all commercial forms of asbestos have been classified as “known human carcinogens” by the International Agency for Research on Cancer (IARC) of the World Health Organization. Occupational exposures have been associated with asbestosis and with lung, gastrointestinal, and laryngeal cancers, and mesotheliomas. Exposure to cigarette smoke coupled with occupational exposure to asbestos fibers is known to have a multiplicative effect on the risk of lung cancer.

Asbestos-containing materials (ACM) that remain in intact condition are not of immediate concern. Deterioration or disturbance of ACM that permits release of asbestos fibers into the work environment presents exposure risks via the inhalation and ingestion routes. Asbestos fibers may remain suspended in air and available for inhalation for hours or days, and may settle out and then be re-suspended by air currents produced by weather, human activities, or vehicular traffic.

Asbestos-containing materials are ubiquitous in the New York City transit system. Asbestos is present in sprayed-on fireproofing in subway tunnels and under subway cars, in cable and pipe insulation, in brakes, and in the transite boxes that enclose hand switches along subway tracks. These materials are subject to disturbance in regular work operations by power and cable maintainers, track workers, ventilation and drainage maintainers, telecommunications maintainers, bus mechanics, and painters, plumbers, masons, and carpenters. Because asbestos-containing materials at the work site are generally not labeled as such, the presence or absence of asbestos may be unknown to the workers involved in the disturbance activities. Consequently, exposure may be difficult to avoid. In addition, age and vibration may cause additional asbestos fibers to be released from deteriorated ACM and distributed throughout tunnels and buildings. Asbestos fibers may also become embedded in the grease and grit that adheres to the undersides of subways trains and is disturbed and released later during inspection, repair, or overhaul activities.

### B. Carbon Monoxide

Carbon monoxide is a colorless, odorless, tasteless gas that is a byproduct of the incomplete combustion of any carbon-containing material, such as gasoline, natural gas, oil, propane, coal or wood. Sources include furnaces, fires, and most commonly in the transit workplace, internal combustion engines such as those in some buses, forklifts, and compressors.

Carbon monoxide is a chemical asphyxiant that exerts its toxic effects by combining with the hemoglobin of the blood, decreasing the amount of oxygen delivered to tissues. Initial symptoms of carbon monoxide poisoning may include headache, dizziness, drowsiness, nausea, impaired judgment, and deterioration of muscular coordination. Symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Ultimately, permanent damage to the heart and brain, coma, and death may occur.

Transit workers are primarily exposed to carbon monoxide via vehicle emissions in bus depots. Bus operators, bus shifters, fuelers, bus maintainers, and mechanics work in and around idling buses, without respiratory protection. Typically, at the end of a work shift, bus operators line their vehicles up in one or more refueling lines, with the engines idling. Bus shifters take over to jockey the vehicles to the pumps and then to a wash area. There may be a dozen or more buses idling near the pumps or the wash area at one time. Shifters and fuelers work in an indoor environment in which multiple vehicle engines are operating simultaneously. Similarly, at the start of a shift, multiple buses are starting and idling while awaiting exit from a depot. Productivity measures that result in increases in the number of buses idling are not accompanied by concomitant improvements in mechanical supply and exhaust of air. In fact, general exhaust ventilation is often inadequate to effectively capture and exhaust vehicle emissions to the exterior. Garages are equipped with local exhaust ventilation (tail pipe exhaust hoses) only at repair bays in certain depots. Bus drivers are also exposed to carbon monoxide over the course of their driving day as they travel and idle in traffic. Also exposed are maintenance workers in subway tunnels where mobile generators or compressors are operational but not vented to the exterior.

### C. Coal Tar Creosote

Coal tar creosote is used as a wood preservative and wood treatment pesticide. It is composed of at least 75% polycyclic aromatic hydrocarbons (PAHs), with the balance largely PAH derivatives. Occupational exposure occurs primarily via the dermal and inhalation routes from contact with coal tar creosote-treated wood products, such as railroad ties.

Health effects include increased cancer risk and adverse respiratory and dermal effects. Both IARC and EPA classify coal tar creosote as a probable human carcinogen. Occupational exposure has been associated with increased cancer risk of the respiratory tract, skin, lung, pancreas, kidney, scrotum, prostate, rectum, bladder, and central nervous system. Dermal effects are generally limited to unprotected areas such as the hands, face, and neck, including the posterior part of neck. Dermal irritation, burning, erythema, dry peeling skin, and folliculitis have been reported in workers handling creosote-treated wood. Symptoms appear to worsen on sunny days, suggesting a phototoxic effect.

New York City Transit manufactures its own pre-fabricated track panels for use on elevated tracks. These are 39-foot lengths of rail attached on site to wooden rail ties. The fabrication process requires drilling approximately 120 holes per panel into coal tar creosote-treated oak. Respiratory protection is not provided. Overhead exhaust fans pull coal tar creosote vapors as well as coal tar contaminated particulates produced by drilling across workers' breathing zones, increasing the likelihood of inhalation exposure. The cotton work gloves that are provided to protect against cuts and abrasions when manually handling coal tar creosote-treated ties do not provide adequate protection against dermal exposure. As separate lockers are not provided, coal tar creosote-contaminated work clothes are stored in the same lockers as personal clothing, possibly resulting in secondary contamination of personal clothing.

### D. Confined Spaces

A confined space, by definition, is a space that is large enough and so configured that an employee can bodily enter and perform assigned work, has limited or restricted means for entry or exit, and is not designed for continuous employee occupancy. Examples include manholes, storage tanks, vaults, shafts, pipes, and pipe galleries. Transit workers such as power, telecommunications, and ventilation and drainage maintainers often must enter and work in subterranean utility vaults and in pits in pump rooms.

Under the OSHA/PESH Permit Required Confined Space standard (29 CFR 1910.146), a permit required confined space is a confined space that also has the potential to contain a hazardous atmosphere, or the potential for engulfing an entrant, or an internal configuration that could trap an entrant with inwardly converging walls or a floor that slopes downward and tapers to a smaller cross-section, or any other recognized serious safety or health hazard. Most confined space deaths and injuries are the result of atmospheric hazards. These fall into three categories - oxygen deficiency or enrichment, toxic gases such as carbon monoxide or hydrogen sulfide, and flammable or explosive gases such as methane.

A confined space atmosphere that contains less than 19.5% oxygen is inadequate for an entrant's respiratory needs, even if the space contains no toxic materials. OSHA defines an atmosphere with less than 19.5% oxygen as an oxygen-deficient atmosphere. An atmosphere with less than 19% oxygen will begin to cause impaired coordination, one with less than 14% oxygen will cause impaired perception and judgment, one with less than 10% oxygen will result in fainting and unconsciousness, and one with less than 8% oxygen can be fatal. There are many potential causes of oxygen-deficient atmospheres. Work activities such as welding, brazing, or cutting of metal can deplete oxygen in confined spaces. Exhaust from gasoline- or diesel-powered equipment in or around a confined space can displace oxygen. Organic materials such as leaves can decompose and produce gases such as hydrogen sulfide, which can displace oxygen. A confined space with greater than 23.5% oxygen is considered to be oxygen-enriched. The risk of fire increases with increases in percentage of oxygen present. An oxygen-enriched atmosphere may be created by the inadvertent pumping of pure oxygen into a space.

A second category of atmospheric hazards is toxic atmospheres, which are created by the presence of gases, vapors, or fumes that have toxic (poisonous) properties. The toxic effect is independent of the oxygen concentration. The most commonly encountered toxic gases in confined spaces are carbon monoxide and hydrogen sulfide. Carbon monoxide, a chemical asphyxiant, is a colorless, odorless, tasteless gas that is a byproduct of the incomplete combustion of any carbon-containing material, such as gasoline, natural gas, oil, propane, coal or wood. Sources include fires and vehicle or equipment emissions. Initial symptoms of carbon monoxide poisoning may include headache, dizziness, drowsiness, nausea, impaired judgment, and deterioration of muscular coordination. Symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Ultimately, permanent damage to the heart and brain, coma, and death may occur.

Hydrogen sulfide, a colorless flammable gas, is commonly known as sewer gas and has the characteristic pungent odor of rotten eggs. It is produced by bacterial breakdown of organic matter. Despite the distinctive odor, reliance on odor detection as indication of overexposure is unreliable, as rapid desensitization to the odor occurs. Inhalation at concentrations of 500 parts per million (a relatively low concentration) can be fatal with just one or two breaths, yet odors are frequently not perceived at concentrations above 100 parts per million. Exposure at low concentrations may result in eye and nasal irritation, sore throat, cough, nausea, headache, shortness of breath, and fluid in the lungs. Bronchial obstruction has been observed in asthmatics exposed to just 2 parts per million for 30 minutes. Neurological effects may include delirium, disturbed equilibrium, memory loss, olfactory paralysis, irritability, tremors, and convulsions. Most fatal cases associated with exposure have occurred in confined spaces such as sewers. Death results from respiratory distress and cyanosis.

The third category of atmospheric hazards in confined spaces is flammable or explosive atmospheres. If there is a buildup of a flammable vapor in a confined space, a fire or explosion can occur in the presence of a source of ignition. Methane (natural gas) is the explosive gas most frequently found in confined spaces.

Some chemical substances present multiple atmospheric hazards, depending on their concentration. Methane, for example, is nontoxic and is harmless at some concentrations. However, it can displace all or part of the atmosphere in a confined space and the hazards presented by such displacement can vary greatly. With only 10 percent displacement, methane produces an atmosphere that, while adequate for respiration, can explode violently. By contrast, with 90 percent displacement, methane will not burn or explode, but it will asphyxiate an unprotected worker in about 5 minutes.

### E. Diesel Emissions

Diesel exhaust is a complex mixture of hundreds of organic and inorganic compounds. Diesel exhaust includes both a vapor phase and a particle phase. More than 100 carcinogenic or potentially carcinogenic compounds have been identified in diesel exhaust. Diesel exhaust includes more than 40 substances listed as hazardous air pollutants by EPA.

Diesel engines exhaust particulate matter at a rate 20 times greater than comparable gasoline engines. In dry weather, diesel particulate matter can remain suspended in the air for about 10 days. Greater than 90% of the mass of diesel particulate matter are smaller than 2.5 microns in diameter and are easily inhaled into the bronchial and alveolar regions of the lungs. Many of the toxic organics and metals that comprise diesel exhaust are attached (adsorbed) to diesel particulate matter and are therefore available for inhalation.

Both IARC and EPA have classified diesel exhaust as “probably carcinogenic to humans.” Exposed workers are at increased risk for malignancies of the lung, bladder, lymphatic tissue, testicles, gastrointestinal tract, and prostate. Diesel exhaust contains genotoxic compounds in both the vapor phase and the particle phase. Diesel particulate matter is mutagenic in mammalian cell systems and can induce adverse chromosomal changes.

Long term (chronic) inhalation exposure is also associated with non-carcinogenic adverse health effects such as decline in pulmonary function, deficits in neurological behavior, increased allergic hypersensitivity, development of airway inflammation and disease, increased risk for cardiovascular mortality, onset or exacerbation of occupational asthma, and eye, throat, and nasal irritation and increased incidence of cough, phlegm, and wheezing. Short-term (acute) exposures may result in reversible irritation and inflammatory symptoms, including exacerbation of allergies and asthma.

Transit workers are primarily exposed to diesel exhaust via vehicle emissions in bus depots. Bus operators, bus shifters, fuelers, bus maintainers, and mechanics work in and around idling buses, without respiratory protection. Typically, at the end of a work shift, bus operators line their vehicles up in one or more refueling lines, with the engines idling. Bus shifters take over to jockey the vehicles to the pumps and then to a wash area. There may be a dozen or more buses idling near the pumps or the wash area at one time. Shifters and fuelers work in an indoor environment in which multiple vehicle engines are operating simultaneously. Similarly, at the start of a shift, multiple buses are starting and idling while awaiting exit from the depots.

Productivity measures that result in increases in the number of buses idling are not accompanied by concomitant improvements in mechanical supply and exhaust of air. In fact, general exhaust ventilation is often inadequate to effectively capture and exhaust the vehicle emissions to the exterior and may not be operational. Garages are equipped with local exhaust ventilation (tail pipe exhaust hoses) only at repair bays, not at lines for fueling or washing, where they are most likely to idle. An industrial hygiene investigation by New York City Transit’s Office of System Safety of a bus depot found “a haze ... (that) was the result of a buildup of diesel exhaust emissions.” Further investigation determined that the OSHA/PESH Short Term Exposure Limit (STEL) for nitrogen dioxide ($NO_2$), a component of diesel exhaust, was exceeded, by as much as 3 times the legal limit, on all 6 days of the investigation. Bus drivers are also exposed to diesel exhaust over the course of their driving day as they travel and idle in traffic. Also exposed are maintenance workers in subway tunnels where mobile generators or compressors are operational but not vented to the exterior, and train operators (yard) who drive diesel engines to move supplies and equipment.

**F. Hazardous Waste**

New York City Transit’s maintenance and repair operations result in the system-wide generation of large quantities of hazardous wastes that are regulated under EPA’s Resource Conservation and Recovery Act (RCRA). Multiple New York City Transit work sites are licensed by EPA as large quantity generators of hazardous waste (producing greater than 1,000 kilograms [2,200 pounds] per month). Additional numerous New York City Transit work sites are licensed by EPA as small quantity generators of hazardous waste (producing greater than 100 kilograms [220 pounds] per month).

Among the generated hazardous wastes identified in New York City Transit's Hazardous Waste Policy Instruction Manual are polychlorinated biphenyls (PCBs), mercury, lead, solvents, and corrosives. PCBs are characterized by IARC as "probably carcinogenic to humans." Occupational exposure to metallic (elemental) mercury may affect the central nervous system and kidneys, resulting in irritability, emotional instability, tremor, mental and memory disturbances, or speech disorders. Occupational exposure to lead may adversely impact the blood, bone marrow, central nervous system, and peripheral nervous system and kidneys, resulting in anemia, encephalopathy (e.g., convulsions), peripheral nerve disease, abdominal cramps and kidney impairment. Occupational exposure to organic solvents may lead to central nervous system depression, psychomotor impairment, and narcosis, with a spectrum of intermediate symptoms that include drowsiness, headache, dizziness, dyspepsia, and nausea. Corrosives are defined by the OSHA/PESH Hazard Communication Standard (29 CFR 1910.1200) as "chemicals that cause visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact."

Transit employees who work in train and bus operation, maintenance, and repair, maintenance and repair of the railroad bed, maintenance and repair of infrastructure, production of Metro cards, and cleaning operations in buses, trains, stations, buildings and on tracks, may have responsibility for, and exposure to, hazardous wastes in the course of their regular work activities. These responsibilities may include accumulation of hazardous wastes as they are generated, transport of hazardous wastes to temporary on-site storage areas, and inspection of hazardous waste storage areas. Workers are also responsible for response to and clean up of chemical spills and leaks to prevent environmental damage and to protect human health. Spill response efforts, particularly at large quantity generation sites, present the greatest risk.

### G. Lead

Sources of lead exposure in occupational settings include work with batteries, paint, metal products (solder, brass, bronze pipes), and steel welding & cutting operations. Occupational exposure usually occurs via inhalation, although ingestion also occurs from lead dust settled onto hands, food, and drink. Health effects are identical regardless of route of entry into the body.

The main target for lead in the body is the central nervous system. Occupational exposure has been associated with lead encephalopathy (a general term for diseases that affect brain function). Results of lead neurotoxicity include reductions in sensory motor reaction time, impaired memory and learning ability, deficits in postural balance, and general malaise, forgetfulness, irritability, lethargy, headache, fatigue, impotence, decreased libido, dizziness, and weakness. Cardiovascular effects include increases in heart rate and blood pressure, and hypertension. Gastrointestinal symptoms include abdominal pain, constipation, cramps, nausea, vomiting, anorexia, and weight loss. Occupational exposure to lead is also associated with liver and kidney dysfunction. Exposure to lead may adversely impact both male and female human reproductive functions and result in increases in frequency of spontaneous abortion, decreases in male fertility, and increases in chromosomal aberrations. Chronic occupational exposure to lead has been associated with increased mortality.

Until recently, all paint used for all purposes within the New York transit system was lead-based. Lead-based paint continues to be used for some purposes. As a result, any work operation that includes application of paint or disturbance of painted surfaces involves potential lead exposure. Such work operations are very common and are performed on frequent basis by structural ironworkers, painters, track workers, cleaners, masons, power maintainers, welders, plant engineers, and others. Work tasks that involve known or presumed exposure to lead include use of a vibrating tool, needle gunning, use of an impact wrench on structural steel components, use of a pneumatic rivet buster on structural steel components, manual scraping, manual demolition of painted structures, manual sanding of painted surfaces, use of a heat gun on painted surfaces, grinding of painted surfaces, welding or torch burning of painted steel, power cable splicing, scarifying of ceramic tiles, soldering with lead solder, power drilling on painted steel and concrete, and spray painting with lead-based paint. There is also the potential for lead exposure by workers who work with lead acid batteries.

### H. Man-Made Vitreous Fibers

Man-made (synthetic) vitreous fibers are a group of fibrous, inorganic materials made from rock, clay, slag, or glass. They differ from naturally occurring mineral fibers such as asbestos in that they do not have a crystalline form. There are three categories of synthetic vitreous fibers – glass fibers, mineral wool, and refractory ceramic fibers. Man-made vitreous fibers are finding increased use in commercial and industrial applications as an alternative to asbestos. Glass fibers (including "fiberglass") and mineral wool are commonly used in household and commercial insulation. Refractory ceramic fibers are commonly used in furnace insulation. In New York's transit system, man-made mineral fibers are used in a variety of applications, including as insulation under subway seats, where car maintainers frequently come into contact with them.

Exposure to synthetic vitreous fibers via the dermal and inhalation routes can result in persistent irritation of the skin, eyes, and upper respiratory tract. In some cases, exposure to glass wool has been found to produce DNA damage and chromosomal and nuclear aberrations. Refractory ceramic fibers, unlike other man-made vitreous fibers, can induce pleural plaques in humans. IARC has classified refractory ceramic fibers as a "probable human carcinogen" Glass fibers and mineral wool have not been classified as carcinogens.

### I. Mercury

Power and cable maintainers may be exposed to elemental (metallic) mercury in the course of maintenance and repair activities on rectifiers and related equipment such as vacuum pumps.

Vapors released from elemental mercury and inhaled are readily absorbed through the lungs. Inhalation of sufficient levels of metallic mercury vapor has been associated with systemic toxicity in humans. Major target organs are the kidneys and the central nervous system, although respiratory, cardiovascular, and gastrointestinal effects also occur. Symptoms may include irritability, emotional instability, tremor, mental and memory disturbances, speech disorders, chronic cough, dyspnea, tremor, muscle pain, and tightness or burning pains in the chest. Occupational exposure has been associated with persistent impairment of pulmonary function, increases in heart rate and blood pressure, and abdominal pain and difficulty swallowing. Dermal effects can include skin rash and peeling skin. Neurological effects include a wide variety of cognitive, personality, sensory, and motor deficits.

### J. Pesticides

Insecticides, herbicides, and rodenticides are used in train and bus facilities and on track beds. Organophosphates, the insecticides in most general use, are neurotoxins that are efficiently absorbed via inhalation, ingestion, and skin penetration. Chlorophenoxy herbicides are skin, eye, and respiratory irritants and liver, kidney, and central nervous system toxicants.

Because rodenticides target mammals, they pose special risk to humans. The primary route of entry for warfarin and related compounds is ingestion, as it is for convulsants such as crimidine, sodium fluoroacetate, and strychnine. Ingestion can occur from skin or clothing contact and subsequent transfer to mouth or to food and drink. Lack of attention to personal hygiene or lack of access to sanitary facilities may contribute to exposure. Some inorganic rodenticides such as thallium sulfate are easily absorbed through the skin. Other inorganic rodenticides such as yellow or white phosphorus are corrosive and damage all tissues with which they come into contact. Inhalation of the dust of another inorganic rodenticide, zinc phosphide, can cause pulmonary edema.

Chronic exposure of transit workers to pesticides is the most likely exposure scenario; acute exposure is not likely, although possible if workers are present during application of pesticides or are present in the vicinity of a spill. All transit workers, at all work locations, have the potential to come into contact with pesticides.

### K. Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are a group of complex synthetic mixtures of chlorinated biphenyls of differing degrees of chlorination. PCBs are not known to exist in nature.
PCBs have chemical stability, high boiling point, low volatility, electrical insulating capabilities, and fire resistance, which make them commercially attractive. PCBs have been used in hundreds of industrial and commercial applications including in electrical, heat transfer, and hydraulic equipment, as plasticizers in paints, plastics and rubber products, and in pigments, dyes and carbonless copy paper.

Production of PCB-containing products was halted in the mid-1970s due to evidence of toxicity and of environmental persistence and harm. Since 1974, PCB use in the U.S. has been restricted to closed systems such as electrical capacitors, transformers, and vacuum pumps. Although PCBs are no longer used in new products, significant quantities continue in current industrial use. The widespread use of PCBs as dielectrics, coolants, and lubricants in electrical transformers and other equipment means that PCB fluids, unless replaced, are present in many older transformers, fluorescent lighting fixtures, and other electrical devices and appliances that remain in use. These are vulnerable to release into the work environment, as older components deteriorate and leak or are disturbed by work activities.

In the transit system, power and cable maintainers, in particular, work with transformers that contain PCBs unless they have been replaced. Occupational exposure, when it occurs, is via the inhalation and dermal routes. Workplace exposure to PCBs can occur during repair and maintenance of PCB transformers, during fires or spills involving PCB transformers, and during disposal of PCB-containing materials.

Occupational exposure to PCBs is associated with a wide range of adverse health effects. IARC has classified PCBs as a "probable human carcinogen." Studies of occupationally exposed workers found excess incidence of numerous types of cancers, including skin cancers (malignant melanomas) and rare cancers of the liver and intestines. Exposure to PCB's has also been linked to respiratory, liver, dermal, reproductive, ocular, thyroid, and neurologic effects.

**L. Solvents And Cleaning Products**

Numerous solvents are in use throughout the transit system. Uses include degreasers, general cleaning agents, stainless steel cleaners, contact cleaners, graffiti removal products, adhesives, and pigment carriers in paints and inks.

Occupational exposure to organic solvents may lead to irritant responses and to central nervous system depression, psychomotor impairment, and narcosis, with a spectrum of intermediate symptoms that include drowsiness, headache, dizziness, dyspepsia, and nausea. Inhalation is the primary route of exposure as many organic solvents have relatively high vapor pressures and evaporate readily. Many industrial solvents are irritants and can cause dermatitis and defatting of the skin. Exposure to solvents is a leading cause of occupational skin disease. Two of the many solvents frequently used in transit workplaces are methyl ethyl ketone and stoddard solvent.

Methyl ethyl ketone (MEK) solvent is a primary component in the production of Metro cards, the disposable plastic computerized fare cards that have replaced subway tokens in the New York system. MEK is efficiently absorbed into the body via the inhalation and dermal routes. Short-term exposure is associated with nose, throat, and eye irritation. Long-term exposure to MEK in the workplace may result in neurological impairment.

Stoddard solvent (also known as mineral spirits, white spirits, or naphtha), is used to clean or degrease machine parts. Stoddard solvent is a mixture of numerous hydrocarbons, including alkanes (paraffins), cycloalkanes (napthenes), and aromatic hydrocarbons, which is derived by refining crude oil. Short-term exposure may result in eye, skin, and throat irritation, dizziness, and headaches. Long-term exposure may result in largely reversible neurological dysfunction, including headaches, fatigue, memory deficits, decreased coordination and subtle changes in color vision.

Cleaning operations utilize various chemical products. Bus cleaners use harsh cleaners in bus washes and for graffiti removal, resulting in constant inhalation and skin contact. Station cleaners clean, by hand, token booths inside and out with ammonia and water, station floors with bleach and water, and crew rooms with bleach, water, and bowl cleaner. Ventilation is not provided for any of these work operations.

**M. Spray Painting**

New York City bus maintainers are responsible for bodywork and spray painting of buses, including mechanical sanding prior to each operation. Unless provided with appropriate mechanical ventilation, respiratory protection, and skin protection, exposure to mists and vapors from paints, solvents, thinners, and epoxies can be harmful, depending upon the toxicity of the substance and the type and duration of exposure.

Hazardous components of paint spray include diisocyanates, liquid organic solvents, and metals such as lead and chromium. Diisocyanates are comprised of low molecular weight aromatic and aliphatic compounds, most frequently toluene diisocyanate (TDI), methylene bisphenyl isocyanate (MDI), and hexamethylene diisocyanate (HDI). Diisocyanates are strong eye, dermal, gastrointestinal, and respiratory irritants. Acute exposure to high concentrations may result in chemical bronchitis, severe bronchospasm, nocturnal wakening, and, rarely, pulmonary edema, and death.

The most common adverse health outcomes associated with diisocyanate exposure are increased airway sensitization and obstruction (asthma) and, less commonly, hypersensitivity pneumonitis. Initial symptoms of diisocyanate sensitization are those typical of acute airway obstruction, including coughing, wheezing, and shortness of breath. The exposed worker may develop an asthmatic reaction immediately or only after months or years of exposure. After sensitization, even low exposure may produce an immediate or delayed asthmatic response, which can be fatal. Sensitized workers may retain persistent asthma symptoms even after years of no additional exposure. Hypersensitivity pneumonitis produces flu-like symptoms are such as fever, headache, and muscle ache. Additional symptoms may include a chest tightness, difficulty breathing, and dry cough. Chronic hypersensitivity pneumonitis may result in fatigue, weight loss, and progressively increased breathing difficulty.

TDI has been classified by IARC as “possibly carcinogenic to humans” and by OSHA and NIOSH as a “potential occupational carcinogen.”

**N. Steel Dust**

Virtually all subway workers, including train operators, conductors, cleaners, and maintainers are exposed to steel dust regularly over the course of their working day. Occupational exposure can occur directly through inhalation unrelated to work activities and indirectly via inhalation during work activities, such as car cleaning or undercarriage maintenance, which disturb and re-suspend settled dust.

Steel dust is produced by the friction between steel wheels and steel tracks and by the wear of brakes on steel wheels. Manganese and chromium are found in significant concentrations in many types of steel and have been identified as major components of the steel dust existent in the “microenvironment” of “subway air” in the New York City transit system.

Exposure to hexavalent chromium, a common component of steel products, has been associated with numerous adverse health conditions. Inhalation can result in nasal irritation, nosebleeds, ulcers, and holes in the nasal septum. High exposures have caused asthma attacks in people allergic to chromium. Long-term exposure is known to cause lung cancer. Hexavalent chromium has been classified by IARC as a “known human carcinogen.” Ingestion of large amounts of hexavalent chromium has resulted in ulcers, kidney and liver damage, convulsions, and death. Workers handling liquids or solids with hexavalent chromium content have developed skin ulcers.

Occupational exposure to manganese has been associated with pulmonary inflammation. Symptoms of lung irritation or injury may include cough, bronchitis, pneumonitis, and minor reductions in pulmonary function. Manganese is classically associated with the disabling syndrome of neurological effects referred to as “manganism.” Manganism approximates Parkinson’s disease. It is a progressive condition that involves tremor; halting, clumsy movement of the limbs; dull and emotionless facial expression, and personality changes, including irritability, aggressiveness, and bizarre compulsive acts.

### O. Sulfuric Acid

Transit workers may have respiratory exposure to acid in vapor or liquid form from lead acid batteries, which often contain sulfuric acid. Inhalation of sulfuric acid vapors can irritate the lungs and can result in reduction of pulmonary function; inhalation of high concentrations can cause pulmonary edema and may be fatal. Contact can severely burn the skin and eyes. Repeat exposure can cause erosion and pitting of the teeth, stomach upset, nose bleeds, tearing of the eyes, emphysema, and bronchitis.

### P. Welding

Welding is the process of joining pieces of metal by the use of heat, pressure, or both. Related operations include brazing or soldering, which uses a filler material with a lower melting point than the metal pieces being joined, and metal cutting, which heats the metal with a flame and directs a stream of pure oxygen along the line to be cut.

Welding smoke is a toxic mixture of particles, fumes, and gases. The chemical composition of the smoke mixture is determined by the base material being welded or the filler material that is used, by the coatings and paints on the metal being welded and the coatings covering the welding electrode, by the shielding gases supplied from the compressed gas cylinders, by the chemical reactions produced by the heat and by the arc’s ultraviolet light, by the process and consumables used, and by any contaminants in the air from nearby work operations.

The following partial list of chemical agents released by the welding process is taken from OSHA training materials:

> **Zinc** - Zinc is used in large quantities in the manufacture of brass, galvanized metals, and various other alloys. Inhalation of zinc oxide fumes can occur when welding or cutting on zinc-coated metals. Exposure to these fumes is known to cause metal fume fever. Symptoms of metal fume fever are very similar to those of common influenza. They include fever, chills, nausea, dryness of the throat, cough, fatigue, and general weakness and aching of the head and body.

**Cadmium** - Cadmium is used frequently as a rust-preventive coating on steel and also as an alloying element. Acute exposures to high concentrations or cadmium fumes can produce severe lung irritation, pulmonary edema, and in some cases, death. Long-term exposure to low levels of cadmium in air can result in emphysema (a disease affecting the ability of the lung to absorb oxygen) and can damage the kidneys. Cadmium is classified by OSHA, NIOSH, and EPA as a potential human carcinogen.

**Iron Oxide** - Iron is the principal alloying element in steel manufacture. During the welding process, iron oxide fumes arise from both the base metal and the electrode.
The primary acute effect of this exposure is irritation of nasal passages, throat, and lungs.

**Mercury** - Mercury compounds are used to coat metals to prevent rust. Under the intense heat of the arc or gas flame, mercury vapors will be produced. Exposure to these vapors may produce stomach pain, diarrhea, kidney damage, or respiratory failure. Long-term exposure may produce tremors, emotional instability, and hearing damage.

**Lead** - The welding and cutting of lead-bearing alloys or metals whose surfaces have been painted with lead-based paint can generate lead oxide fumes. Inhalation and ingestion of lead oxide fumes and other lead compounds will cause lead poisoning. Symptoms include metallic taste in the mouth, loss of appetite, nausea, abdominal cramps, and insomnia. In time, anemia and general weakness, chiefly in the muscles
of the wrists, develop. Lead adversely affects the brain, central nervous system, circulatory system, reproductive system, kidneys, and muscles.

**Fluorides** - Fluoride compounds are found in the coatings of several types of fluxes used in welding. Exposure to these fluxes may irritate the eyes, nose, and throat. Repeated exposure to high concentrations of fluorides in air over a long period may cause pulmonary edema (fluid in the lungs) and bone damage. Exposure to fluoride dusts and fumes has also produced skin rashes.

**Chlorinated Hydrocarbon Solvents** - Various chlorinated hydrocarbons are used in degreasing or other cleaning operations. The vapors of these solvents are a concern in welding and cutting because the heat and ultraviolet radiation from the arc will decompose the vapors and form highly toxic and irritating phosgene gas.

**Phosgene** - Phosgene is formed by decomposition of chlorinated hydrocarbon solvents by ultraviolet radiation. It reacts with moisture in the lungs to produce hydrogen chloride, which in turn destroys lung tissue. For this reason, any use of chlorinated solvents should be well away from welding operations or any operation in which ultraviolet radiation or intense heat is generated.

**Carbon Monoxide** - Carbon monoxide is a gas usually formed by the incomplete combustion of various fuels. Welding and cutting may produce significant amounts of carbon monoxide. In addition, welding operations that use carbon dioxide as the inert

gas shield may produce hazardous concentrations of carbon monoxide in poorly ventilated areas. This is caused by a "breakdown" of shielding gas. Carbon monoxide is odorless, colorless and tasteless and cannot be readily detected by the senses.
Common symptoms of overexposure include pounding of the heart, a dull headache, flashes before the eyes, dizziness, ringing in the ears, and nausea.

**Ozone** - Ozone is produced by ultraviolet light from the welding arc. Ozone is produced in greater quantities by gas metal arc welding, gas tungsten arc welding, and plasma arc cutting. Ozone is a highly active form of oxygen and can cause great irritation to all mucous membranes. Symptoms of ozone exposure include headache and chest pain. Excessive exposure can cause fluid in the lungs (pulmonary edema). Both nitrogen dioxide and ozone are thought to have long-term effects on the lungs.

**Nitrogen Oxides** - The ultraviolet light of the arc can produce nitrogen oxides, from the nitrogen and oxygen in the air. Nitrogen oxides are produced by gas metal arc welding, gas tungsten arc welding, and plasma arc cutting. Even greater quantities are formed if the shielding gas contains nitrogen. Nitrogen dioxide, one of the oxides formed, has the greatest health effect. This gas is irritating to the eyes, nose and throat but dangerous concentrations can be inhaled without any immediate discomfort. High concentrations can cause shortness of breath, chest pain, and fluid in the lungs (pulmonary edema).

Transit system plumbers, painters, masons, carpenters, tinsmiths, iron workers, and other structural maintainers and mechanics may perform or be exposed to welding operations, often in small or confined spaces, and often without respiratory protection or mechanical ventilation.

## IV. Biological Hazards

### A. Avian Feces

The nesting of pigeons and the presence of pigeon droppings is ubiquitous in train yards, bus depots, train stations, and on tracks. Transit workers work around and under pigeons and disturb pigeon droppings in the course of their work. In addition, cleaners are responsible for removal of pigeon droppings from transit property.

Histoplasmosis is the most common adverse health effect associated with exposure to pigeon droppings and other bird excrement. Histoplasmosis results from inhalation of the spores of the fungus *Histoplasma capsulatum*. Old and accumulated droppings, and soil that is contaminated with droppings, may contain the H. capsulatum fungus. Spores of the fungus can become airborne, and thus inhaled, when the material is disturbed.

Histoplasmosis primarily affects the lungs. Most infected people are asymptomatic (display no symptoms) or experience symptoms that are so mild that they do not seek medical attention. Often they do not realize they are infected and are not diagnosed. If symptoms occur, they do so within a few days to two weeks after exposure. Histoplasmosis can appear as a mild, flu-like respiratory illness with a variety of symptoms, including malaise, fever, chest pain, dry or non-productive cough, headache, loss of appetite, shortness of breath, joint and muscle pain, chills, and hoarseness.

Histoplasmosis can cause chronic lung disease, which may worsen over months or years, and can, in unusual circumstances, be fatal.

Persons working at a job or present near activities where material contaminated with H. capsulatum becomes airborne can develop histoplasmosis if enough spores are inhaled. The number of inhaled spores needed to cause disease is unknown.

Cryptococcosis is another fungal disease associated with exposure to roosts and soil contaminated with decaying pigeon droppings. Even when old and dry, bird droppings can be a significant source of infection. Exposure is via the respiratory route. Like histoplasmosis, most cryptococcal infections are mild and occur without symptoms. The generalized form of cryptococcosis begins with a lung infection and spreads to other areas of the body, particularly the central nervous system, and is usually fatal if left untreated. The cutaneous (skin) form is characterized by acne-like skin eruptions or ulcers with nodules just under the skin.

### B. Bloodborne Pathogens

Occupational exposure to blood and other bodily fluids from infected individuals carries the risk of infection by pathogenic bloodborne microorganisms. Workers who may be exposed to blood or other potentially infectious materials in the course of their regular work activities may be infected with these bloodborne pathogens and may develop disabling or fatal disease. Infected individuals may also transmit the pathogens to others. In the occupational setting, the most significant bloodborne pathogens are the hepatitis B virus, the hepatitis C virus, and the human immunodeficiency virus (HIV).

Hepatitis B virus (HBV) infection (inflammation of the liver) is the most significant bloodborne occupational hazard. In the workplace, HBV is spread via direct inoculation of infectious blood, such as might occur during a puncture from a sharp instrument. Blood and some body fluids potentially contain the highest quantities of virus and are the most likely vehicles for transmission of HBV. Body fluids such as saliva, semen, urine, and feces may also contain infectious virus but at lower concentrations, unless they are visibly contaminated with blood. Puncture is not the sole route of entry for infectious blood. Potentially serious exposures may occur through scabs, cuts, scratches, burns, or dermatitis, or from splashes of blood or serum into the eye or mouth. Hepatitis B is a resilient virus and can remain viable for at least a week in dried blood at room temperature. Infection may also occur from indirect contact with infected materials, such clothing or work surfaces contaminated with the blood of a person with hepatitis B and then touching one's eyes, mouth, nose, or an open wound.

One-third of HBV-infected individuals have no symptoms, one-third have a mild flu-like illness which is usually not diagnosed as hepatitis, and one-third have a severe symptoms and illness with jaundice, fatigue, anorexia, nausea, abdominal pain, joint pain, rash, and fever. One-fifth of jaundice cases require hospitalization. Both hospitalized and non-hospitalized patients typically incur lost work time in the range of weeks to months. Although only a small percentage of those infected with HBV develop chronic hepatitis B, they can still infect others and are at increased risk of premature death from liver disease, such as cirrhosis and cancer. Although the majority of persons with chronic hepatitis B do not exhibit symptoms, the virus may still be damaging to the liver. Infected persons that do not show any signs or symptoms of disease are referred to as "carriers."

Hepatitis C is a potentially fatal infection of the liver caused by the hepatitis C virus (HCV). Like hepatitis B, hepatitis C is a bloodborne disease. Bloodborne viruses may be present in any body fluid that contains blood.

Infection with HCV can result in no or mild symptoms, acute (short-term) liver disease, and/or chronic (long-term) illness. Acute hepatitis C symptoms include jaundice, fatigue, loss of appetite, nausea, and vomiting. Symptoms may not present for 2 to 3 months after exposure. Chronic hepatitis C is a condition that results when the infection lasts for several months. Chronic infection develops in 75-80% of patients. Active liver disease develops in 70% of those with chronic infection. Of those with active liver disease, 10-20% develop cirrhosis and 1-5% develop liver cancer.

Acquired Immune Deficiency Syndrome, or AIDS, is a disease that is caused by the Human Immune-deficiency Virus (HIV). HIV adversely affects the immune system, rendering the infected individual vulnerable (immunocompromised) to a wide range of illnesses. These conditions, some of which tend to recur, can be aggressive, rapidly progressive, difficult to treat, and unresponsive to traditional modes of treatment.

HIV is a member of a group of viruses known as human retroviruses. Like HVB and HVC, HIV is a bloodborne pathogen. HIV lives in blood and can also live in any body fluid that contains blood. These include semen and vaginal/cervical fluids. The virus is also found in internal body fluids that surround the heart, the lungs, and bone joints, as well as in spinal fluid. HIV is not normally found in urine, feces or saliva. However, because of injury or illness, these substances may be contaminated with blood.

HIV infection initially produces no symptoms. Once the immune system becomes damaged, the individual is likely to experience weight loss, persistent low-grade fever, night sweats and flu-like symptoms. As the individual's immune/defense system becomes less able to ward off diseases, the infected person will likely come down with respiratory infections, intestinal disorders, and fungal infections. An HIV-positive person is given a diagnosis of "AIDS" after developing an opportunistic infection.

The primary mode of HIV transmission in an occupational setting is mucous membrane or non-intact skin contact with HIV-infected blood, blood components or blood products. Five of first 65 (8%) case reports of (healthcare) workers whose HIV infections were associated with occupational exposure involved blood contamination of mucous membranes or non-intact skin.

Many transit work activities present opportunities for contact with human blood and/or potentially contaminated sharps. Train, bus, and station cleaners and track workers routinely encounter blood and bodily fluids, vomit, excrement, urine, knives, hypodermic needles, diapers, razor blades, and even human tissue and body parts. Station cleaners must lift full plastic trash bags out of garbage cans with no protection against skin puncture from sharps that are frequently in the trash. Conductors and train operators are “first responders” to accidental or intentional deaths on the subway tracks. All of these situations offer potential exposure to bloodborne pathogens.

V. **Physical Hazards**

## A. Electricity (High Voltage)

Subway maintenance and repair activities are routinely conducted while the 600-volt third rail is live and as trains continue to operate on tracks where work activities are occurring. Transit employees performing operations or maintenance work on or near electric power generation, transmission, or distribution installations encounter higher electrical loads under significantly more hazardous conditions than do most other workers.

The level of risk from electrical shock is dependent upon the amount of current that enters the body, the duration of the exposure, and the path of the current through the body. The major categories of electrical injuries include electrocution and electric shock, burns, and falls caused as a result of contact with electrical energy.

Electrical shock or electrocution (death from electrical shock) occurs when a person becomes part of an active electrical circuit that has a current capable of over stimulating the nervous system or causing damage to internal organs. The presence of moisture from environmental conditions such as standing water, wet clothing, high humidity, or perspiration increases the possibility of shock or electrocution. High-voltage electrical energy quickly breaks down human skin, reducing the body's natural resistance. Once the skin is punctured, the lowered resistance results in massive current flow, which can cause cardiac arrest and damage to internal organs. The most common non-fatal injuries resulting from human contact with electricity are burns. Electrical burns result from direct contact with current and are usually serious. Arc blasts occur when high voltages travel in air across a gap between conductors. Arc blasts can produce thermal radiation of up to 35,000$^{o}$F., causing burns. A high voltage arc is also capable of producing a significant pressure wave blast. For example, a person about two feet away from a 25,000 amp arc will receive approximately 480 pounds of force on the body, possibly resulting in physical injury, hearing damage, and memory loss. A high voltage arc can also create and propel drops of molten metal, causing burns or fires at a distance. Thermal burns may occur when electricity ignites flammable vapors in the air. Contact with electrical current may cause a muscular contraction or a startle reaction that could be hazardous if it leads to a fall from elevation or contact with dangerous equipment.

Operating voltage in the New York subway system ranges from 550 to 34,000 volts; the third rail maintained at 600 volts. Since trains are operational 24 hours a day, 7 days a week, there is no down time for maintenance or repair. Consequently, subway maintenance and repair work exposes employees to energized parts of the power system. Power and cable maintainers frequently come into contact with live high voltage circuits. Virtually all track workers "hump rail" 22 inches away from a live third rail, often in dark tunnels and under wet or slippery conditions. Train operators may work in cabs with weather leaks, forcing them to stand in wet conditions in close proximity to the 600 volt circuit breakers located in the cramped cab. Train operators often must "lay up trains" (park their trains between stations or in yards), requiring travel by foot, alone, in tunnels and over live third rails, sometimes under wet conditions. Ventilation and drainage maintainers work in pump rooms, with water conditions, in close proximity to sources of high voltage electricity.

Subway car barns use 600 volt DC Stingers to supply temporary power to trains entering and leaving the barn. These bugs are always live. The bugs are manually held in contact at the side of the train by workers in the aisles, who walk or run alongside each moving train to ensure a continuous supply of power. Moving the train fully in or out of the barn requires the worker to connect and disconnect several bugs in sequence, one at a time. Aisles between tracks are narrow, permitting a maximum of 20 inches clearance from either side of each live bug to an adjacent train. This arrangement is conducive to inadvertent contact by a worker with a live bug, particularly if the worker is transporting tools or equipment. This may result in electrical shock or electrocution, or it may result in the bug being set into a swinging motion where its live lead could hit another worker or an adjacent train. This hazardous situation is further exacerbated where bugs are located in the aisle on the opposite side of the train operator's cab. In these cases, it is impossible for the train operator to remain in visual or verbal contact with the worker running alongside the train with the bug.

### B. Explosions and Fire

Routine operations often provide the potential for explosive atmospheres or conditions. Storage locations that charge lead acid batteries may contain liberated gases that are highly explosive. In 1998, three maintenance of way employees were burned in two separate incidents when the third rail grounded to the running rail, resulting in explosions. The 600-volt "stingers'" used to power non-energized trains into and out of car maintenance shops sometimes come into accidental contact with train bodies, causing arcing and explosions.

The primary sources of explosion and fire threat within the transit system are: flammable and explosive chemicals used in work processes and stored on-site as raw materials and hazardous wastes; vehicle and equipment fuels such as gasoline and acetylene; inadvertent sources of ignition such as unprotected access to high voltage energy and high temperatures generated by equipment operation, including welding work and hot surfaces on undercarriages of subway trains; and external sources of flammable atmospheres in confined spaces. Explosion and fire hazards are in many cases compounded by failure to provide fire extinguishers and unobstructed access to fire hydrants, to engage in fire drills, and to provide unobstructed access to clearly marked emergency exits. An additional explosion and fire threat has emerged since September 11, 2001, as it is believed that mass transit systems now constitute a priority target for terrorist actions.

### C. Noise

Train and bus operators, conductors, road car inspectors, bus and car maintainers, and other transit workers who operate, service, or maintain vehicles, equipment, or facilities are routinely exposed to high levels of noise. Noise is defined as unwanted sound. Maintenance and repair operations use loud machinery such as motors, grinders, saws, presses, and pneumatic equipment. Some hand held power tools also produce excessive noise. Working aboard or in proximity to passing rail or road vehicles exposes workers to high levels of noise. Noise intensity may be magnified within enclosed spaces such as tunnels.

Loudness is measured in decibels (dB). The decibel system is logarithmic, rather than arithmetic. Sound intensity (loudness, or "sound pressure level") doubles every 3 dB, increases tenfold per 10 dB, and increases 100-fold per 20 dB. This means that 88 dB is twice as loud as 85 dB, that 95 dB is ten times as loud as 85 dB, and that 105 dB is one hundred times as loud as 85 dB. According to the National Institute for Occupational Safety and Health (NIOSH), exposure to sound intensities of 85 dB and greater may result in hearing loss.

Noise produced by the scraping of subway train floors with air chisels reportedly exceeds 105 dB. The train operator’s horn reportedly exceeds 110 dB. Power substations continually produce high-pitched whines from transformers. The periodic release of air at 100 pounds per square inch (psi) of pressure from pneumatic brakes during idling and maintenance or their sudden release when thrown into emergency reportedly measures greater than 100 dB. Noise produced by subway trains in motion is presumed to average 90 dB (at some distance from the train).

Health risk from exposure to excessive levels of occupational noise is determined by the loudness, duration of exposure, type (i.e., continuous noise or impulse or intermittent noise), and the pitch, or frequency, of the noise. Exposure to occupational noise can result in two types of noise-induced hearing loss (NIHL). Temporary (conductive) hearing loss occurs when sound vibrations are blocked from reaching the inner ear. This may be due to wax buildup, an infection of the middle ear, or explosive sounds, which damage the ear drum or middle ear. This type of hearing loss is reversible - the ear may recover on its own or it may be surgically corrected. Permanent (sensorineural) hearing loss occurs when cells and nerves in the inner ear are damaged. Permanent hearing loss occurs gradually, without awareness on the part of the affected individual, and is irreversible. Exposure to excessive occupational noise also causes increases in levels of stress, which may raise blood pressure. High noise levels can also cause insomnia, fatigue, irritability, and decreased job performance. Excessive occupational noise also increases the risk of incidents of injury or death because high noise levels make it more difficult to hear other workers, to hear warnings or approaching vehicles, or to be heard by other workers. A common dilemma of subway workers is that, though their work environment is noisy enough to require hearing protective devices, the safety threat from constant movement of trains often precludes its use.

## VI. Safety Hazards

### A. Falls

Approximately 60 per cent of falls in the workplace result from slips and trips and do not involve working aloft. The remaining 40 percent are falls from elevation. Slips are caused be insufficient friction or traction between the footwear and the walking surface. Common causes of slips include wet or oily surfaces, spills, weather-related conditions, loose rugs or mats, and walking surfaces that do not have same degree of traction in all areas. Trips are caused by the unintentional collision of the foot with an object, resulting a loss of balance and ultimately a fall. Common causes of tripping include obstructed view, poor lighting, obstacles in the footpath, and uneven walking surfaces. Most non-fatal injuries in the New York transit system are caused by slips and trips.

Many work operations in New York City’s transit system are conducted from aloft. Track workers who lay rail on elevated structures forty feet above the street must jump from tie to tie. Ties may be 18 to 24 inches apart with no decking or fall protection. Structural maintainers, including iron workers, painters, plumbers, masons, carpenters, and tinsmiths, may work aloft on elevated tracks, on scaffolds, or in bucket trucks. In many instances, no barriers, guardrails, kick boards, or fall protection systems are available.

### B. Flagging

Many mass transit systems cease carrying passengers during late night and/or early morning hours, in part to allow for safe maintenance and repair of equipment and tracks. New York City Transit is one of the few systems that transports passengers 24 hours a day, every day. All rail maintenance and repair is performed adjacent to live 600 volt third rails, with trains running normally ("under traffic"), at up to 40 miles per hour. In the absence of modern means of communication and modern signaling equipment, it is the job of flaggers to signal oncoming trains and direct them to slow down or stop while work proceeds, just as they have for the last hundred years or more.

The sole mechanical device used to supplement flagging is the "tripper," which is put in place 150 feet up the track from the beginning of the job to activate an approaching train's tripcock and put its brakes into emergency mode if the train operator does not see or disregards the flagger. However, this distance is not sufficient to halt the train before it enters the work area.

Flaggers are the most vulnerable subway workers. Between July 2001 and November 2002, four NYCT employees were killed while conducting flagging operations. One report states "the philosophy of flagmen considers it better to place a small number in harm's way, placing one or two flagmen at risk, rather than the entire crew."

Fatalities and near misses are frequent. In May 2000, a work crew in a tunnel narrowly avoided injury or death when a train came into the work site from the wrong direction, known as "wrong railing." As permitted by NYCT policies, flaggers had been placed only in the direction from which trains were expected to appear.

In addition to track maintenance crews, track and tile cleaners enter the roadbed with flaggers. Train operators and structural maintainers often must traverse track beds alone and without the benefit of flaggers.

### C. Hazardous Energy

Maintenance and repair operations can expose workers to hazardous energy sources. Energy in any form is hazardous when it builds to a level (potential energy) or when it is released in a quantity (kinetic energy) that could harm a worker. Turning off or de-energizing machinery or equipment during servicing does not fully protect the worker against the hazards of unexpected activation, re-energizing, or release of stored energy in equipment, tools, or power sources. Despite the shutoff, it is still possible to be injured from unexpected movement of materials or parts. Forms of hazardous energy include mechanical, electrical, pneumatic, chemical, hydraulic, and thermal.

Effective protection against exposure to hazardous energy requires releasing or minimizing any residual or potential energy in the system, utilizing a restraining device to prevent movement, and/or physically preventing re-energizing. This may require, for example, moving components so that springs are no longer under tension, ensuring that liquids or gases return to approximate atmospheric pressure, or preventing further movement of material or components or relocating them in a stable position.

Even when the device is shut off and energy dissipated, injury can still occur should there be inadvertent re-activation of the machine or equipment, either by the affected worker or by another person. For example, the maintenance worker may inadvertently restart equipment by accidentally short-circuiting switches or activating control buttons or levers. In another scenario, another worker may re-energize the device without knowing that someone is working on it.

Effective control of hazardous energy requires ensuring that it is not capable of being transmitted from its source to the equipment that it powers. This can be accomplished in the workplace by identifying the source of hazardous energy, de-energizing the equipment by isolating its energy source, dissipating any stored (potential) energy that could affect the equipment, and locking out the energy-isolating device.

Transit maintenance workers are exposed to pneumatic and electromechanical stored energy when they work on or around pneumatic (air) brakes. Mechanical energy may be released from hand brake springs under tension.

Car inspectors typically work under a train while the car is energized. The system being checked is de-energized but can be reactivated by a second worker who cannot see the worker under the car. There is no provision for lockout/tagout safety precautions.

### D. Traffic Work Zone Hazards

Transit workers in construction, repair, or maintenance work zones that are located on, above, or adjacent to streets with vehicular traffic are exposed to risk of injury from the movement of construction vehicles and equipment within the work zones and from passing motor vehicle traffic. Flaggers and other workers on foot are exposed to the risk of being struck by traffic vehicles or construction equipment. Workers who operate construction vehicles or equipment risk injury due to overturn, collision, or being caught in running equipment. All workers in these zones, regardless of their assigned tasks, work in conditions of low lighting, low visibility, and inclement weather, and may work in congested areas with exposure to high traffic volume and speed.

### E. Trenching And Excavation

An excavation is any man-made cut, cavity, trench, or depression in the earth’s surface formed by removal of earth. A trench is narrow excavation below the surface of the ground in which the depth is greater than the width and the width does not exceed 15 feet. Trenching and excavation operations occur at various transit system work sites. In fact, most subway tunnels are actually excavations that have been covered over.

The most common significant hazard of trenching and excavation is death or serious injury resulting from a cave in. A cave-in is a collapse of the walls of an excavation. Wall failures often occur suddenly, with little or no time for a worker to react. The weight of the soil crushes and twists the body causing death or serious injury in a matter of minutes, or even seconds.

Cave-ins may have one or more causes. Vibration from construction equipment or traffic can adversely impact soil cohesion. The weight of equipment or excavated material (spoil) that is too close to the edge of the trench can cause a collapse. Soils that do not hold together, such as sandy soils, are more likely to collapse. Soil that has been dug before is not as stable as earth that has not been previously disturbed. Changes in weather conditions can result in changes in soil conditions.

## VII. Ergonomic Hazards

Ergonomics is the science of fitting workplace conditions and job demands to the capabilities of the worker, rather than making the worker fit the job. Since people come in all shapes and sizes, this means designing or redesigning tools, equipment, workstations, and job tasks to prevent discomfort or injury. Many employers have successfully used ergonomics programs as a cost-effective way to prevent or reduce work-related musculoskeletal disorders, keep workers on the job, and boost productivity and workplace morale. Additional detail about ergonomic hazards of transit workers can be found in Chapter 4.

### A. Illumination

Proper illumination is essential for effective and safe performance of job tasks. Humans receive about 85 percent of their information through their sense of sight. Illumination of appropriate quality and quantity, without glare or shadows, helps prevent or reduce eye fatigue and headaches and serves to highlight moving machinery and other safety hazards. Inadequate illumination can adversely affect overall productivity and work quality, particularly in tasks where precision is required. Inadequate illumination can be a safety hazard, causing injuries from misjudgment of the position, shape or speed of an object. Momentary blindness resulting from sudden drastic changes in light intensity from bright to dark or vice versa can increase the potential for accident and injury.

Working with too much or too little illumination commonly results in symptoms such as eyestrain, eye irritation, blurred vision, dry burning eyes, and headaches. Poor lighting affects not only the ocular system but also contributes to musculoskeletal disorders, which can occur when workers adopt poor or awkward postures while performing job tasks under inadequate lighting conditions.

The amount of light necessary for safe and effective job performance varies and is dependent on the type of task being done (such as need for speed or precision), type of surfaces (whether they reflect or absorb light), conditions in the general work area, and the vision of the individual worker. Regulatory and professional standards call for illumination of 5 to 10 footcandles in work spaces where visual tasks are performed only occasionally, 20 to 50 footcandles for performance of visual tasks of high contrast or large size, and 50 to 100 footcandles for performance of visual tasks of medium contrast or small size. In general, workers engaged in maintenance and repair tasks should be provided with at least 20 footcandles of illumination.

Transit job sites often lack working or adequate illumination. Measurement of light intensity at work positions in work pits under trains being repaired at a New York City Transit maintenance barn yielded results of 0.0 to 0.2 footcandles when workers' headlamps were turned off. With headlamps on, the range of illumination at the point of work improved to only 0.6 to 4.2 footcandles.

Subway tunnels are typically illuminated with 36-watt incandescent bulbs installed at intervals of 15 to 40 feet. This arrangement, even if all bulbs are working, which is frequently not the case, provides insufficient light in which to walk or work safely or be seen by oncoming trains. The flashlights carried by transit workers in tunnels are often incapable of penetrating the tunnel gloom or being seen by train operators in emergency situations. Train operators are subject to sudden drastic changes in light intensity as they move under speed from tunnel to station and tunnel to outdoors, or vice versa.

### B. Musculoskeletal Disorders

Many transit workers are at risk for work-related musculoskeletal injuries, including train and bus operators, machine operators, users of hand tools, materials handlers, maintenance workers, and clerical workers.

The term work-related musculoskeletal disorders (MSDs) describes a type of injury which affects and results from or is exacerbated by occupational overuse or misuse of muscles, nerves, tendons, ligaments, joints, cartilage, or spinal discs. Other names for work-related MSDs include repetitive strain injuries (RSIs) and cumulative trauma disorders (CTDs). As these names imply, MSDs develop over time, unlike strains and sprains, which usually result from a single incident. Work-related musculoskeletal disorders most often occur in the fingers, hands, wrists, elbows, arms, shoulders, back, and neck.

Some MSDs have high incidence rates and are well known. Carpal tunnel syndrome is an inflammation of the nerves in the wrist, hand, and fingers, caused by repeated bending of the wrist, holding tools or material tightly, or constantly pressing the wrist against a hard object, thus compressing the nerve. Raynaud's syndrome is a disorder of the blood vessels, usually in the fingers or hands, often caused by use of vibrating hand tools. Tendinitis is an inflammation of a tendon or the sheath that surrounds a tendon, caused by repeated movement of a joint. Thoracic outlet syndrome is a disorder of the nerves and blood vessels in the shoulder, caused by overhead work or by carrying heavy items with the arms straight down.

MSDs are caused by exposure to risk factors. Exposure to any single risk factor may result in pain or injury. Jobs or working conditions that present multiple risk factors have a higher probability of causing a musculoskeletal injury. Risk level depends on intensity, frequency, and duration of the exposure. Work-related MSDs may be caused by one or more of the following risk factors:

- *Repetition* - performing the same motions over and over
- *Awkward or fixed posture* - working in an awkward position or holding the same position for a long time (for example, sitting in a small, nonadjustable driver's seat)
- *Forceful movement* - exerting excessive force while lifting, pulling, pushing, twisting, or gripping a tool or object
- *Vibration* - from power or pneumatic tools or equipment or from vehicle movement
- *Contact pressure* - direct pressure on the soft tissues of the body

- *Insufficient recovery time* - working for long periods without adequate rest breaks
- *Working in cold environments*
- *Job stress* - fast work pace, lack of control over work

Symptoms of musculoskeletal disorders may include pain, tenderness, swelling, numbness, tingling, spasm, weakness, loss of joint mobility, and loss of coordination.
These symptoms can occur during work, at the end of the work shift, or hours or days later. Generally, the more frequent and intense the symptoms, the more serious the injury is likely to be. Symptoms may be mild or may be so intense that they interfere with the ability to perform routine tasks such as fastening a button or turning a doorknob. In advanced cases, MSDs can cause severe pain and permanent disability.

Ergonomic hazards are plentiful in transit workplaces. Bus and train operators and conductors work with equipment where insufficient attention has been paid to ergonomic design. Train maintainers engage in overhead work in pits that lack artificial illumination. Computer workstations lack adjustable desks and seats.

Bus maintainers engage in heavy lifting and handling of cumbersome objects, such bus wheels, which weigh 300 pounds. All repair of bus undercarriages is overhead work.

An ergonomic assessment of the cockpit of NYCT buses found that “primitive seat and cab design...typically result in awkward body posture of operators (no lumbar support available)” and that “effective vibration attenuation (suspension) seats have not been installed in currently used equipment.”

Station cleaners responsible for emptying trash receptacles lift heavy bags of garbage to shoulder height, use carts to move bags to the refuse room, and then lift again to unload.

Track and tile cleaners engage in repetitive up and down motions all day, every day, to clean tiles on track walls.

Track workers engaged in rail replacement (“humping rail”) hand-carry 39-foot lengths of rail weighing 1300 pounds in gangs of 16 workers, using grappling (“rail”) hooks. Sledgehammers or 5-foot clawbars weighing 40 pounds are used to dislodge track clips. The old 1300-pound rail is then lifted and moved out of the way and is replaced with the a new 1300-pound rail which must be lifted waist-high and carried over the drainage trough and secured. Where track is embedded in concrete rather than in ballast (gravel), the concrete is broken up with a jackhammer. (Rail replacement is conducted “under traffic” with the third rail live.)

Train operators who work in train yards must pull themselves up onto trains from ground level, as opposed to from platform level, around ten times per day. They apply and release hand brakes in each of the 8 or more cars in a train, working on multiple trains each shift. They pull and release heavy, taut safety chains between cars and set coupler adjustments, which are often not greased. These are heavy physical operations.

Train operators must work in a cramped operating position in the tiny cab of the train. Many train operators are too big to sit in the space provided and must stand for the entire shift as they operate the train. Train operators must apply continual pressure to the train controller or the train will go into emergency braking mode. Application of this pressure places the operator in an awkward, stooping position.

Airbrake maintainers work in pits and engage in overhead work. Sometimes there are no pits and they must lie down on the tracks and work overhead with only two to three feet of clearance between the road bed and the undercarriage.

### C. Vibration

Vibration exposure occurs whenever a worker comes in contact with vibrating vehicles, machinery, or equipment. Contact with a vibration source transfers vibration energy to a person's body through a supporting system such as a seat or platform. Hand-arm vibration (HAV) exposure occurs when a worker operates hand-held equipment such as a chain saw or jackhammer. Whole-body vibration (WBV) exposure occurs when a worker sits or stands on a vibrating floor or seat. Risk of injury depends on intensity of the vibration, duration of exposure, and which part of the body receives the vibration energy. Risk can also be affected by the frequency of the vibration. Bodily organs tend to have their own resonant frequencies. If exposure occurs at or near a resonant frequency, adverse effects may be compounded.

The nature of the exposure determines whether there is an impact upon a major part of the worker's body or only on a particular organ. Segmental vibration exposure affects an organ, part, or "segment" of the body. For example, hand-arm vibration affects operators of chain saws, chipping tools, jackhammers, drills, grinders and other hand-held vibrating tools. On the other hand, groups of workers exposed to whole body vibration from vibrating floors and seats include truck, bus, and train operators and conductors.

Hand-arm vibration can damage blood vessels, tendons, muscles, bones, joints, and nerves in the fingers, resulting in conditions known as white finger disease (Raynaud's phenomenon) and hand-arm vibration syndrome (HAVS). Symptoms include whitening of one or more fingers when exposed to cold, tingling and loss of sensation in the fingers, pain, loss of grip strength, and cysts in fingers and wrists. Symptoms are aggravated by exposure of hands to cold temperatures.

Whole-body vibration can cause fatigue, insomnia, and headache during or shortly after exposure. Exposure to WBV has been associated with back disorders. Whole-body vibration can cause acute physiologic changes, including increases in heart rate, oxygen uptake and respiratory rate. Decreased performance has been reported in workers exposed to whole-body vibration.

Transit workers exposed to HAV include maintainers who use grinders, jackhammers, and sawzalls. Transit workers exposed to WBV include bus and train operators and conductors.

## VIII. Stressors

### A. Stress

The National Institute for Occupational Safety and Health (NIOSH) defines job stress as "the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources, or needs of the worker" and job stressors as "stressful working conditions."

Job stress can have adverse health outcomes and can cause injury. Examples of problems that are caused by or related to exposure to job stressors include mood swings, sleep disturbances, upset stomach and headache, and deteriorating relationships with family and friends. There is mounting evidence that work stress can be an important factor in the occurrence and severity of some chronic health problems, including cardiovascular disease, musculoskeletal disorders, psychological disorders, cancers, ulcers, and impaired immune function.

The scientific literature suggests a commonality of types of working conditions that a majority of people are likely to find stressful. According to NIOSH, these include:

- *Design of tasks* - Heavy workload, infrequent rest breaks, long work hours and shiftwork; hectic and routine tasks that have little inherent meaning, do not utilize workers' skills, and provide little sense of control.
- *Management style* - Lack of participation by workers in decision- making, poor communication in the organization, lack of family-friendly policies.
- *Interpersonal relationship* - Poor social environment and lack of support or help from coworkers and supervisors.
- *Work roles* - Conflicting or uncertain job expectations, too much responsibility, too many "hats to wear."
- *Career concerns* - Job insecurity and lack of opportunity for growth, advancement, or promotion; rapid changes for which workers are unprepared.
- *Environmental conditions* - Unpleasant or dangerous physical conditions such as crowding, noise, air pollution, or ergonomic problems.

Many of these factors are present in the working conditions encountered by transit workers. Major occupational stressors in urban mass transit include violence, scheduling, interaction with passengers, traffic, lack of supervisory support, shift work, long hours, oppressive environmental conditions, lack of autonomy, adversarial labor-management relations, and lack of adequate recovery or break time.

Bus and train operators must undergo surprise physical examinations, the medical results of which might at any time result in their disqualification for continuation in their jobs and in termination of employment. There is little supervisory support for bus and train operators who must deal with equipment breakdowns or delays caused by traffic or construction or difficulties with passengers.

Bathroom relief is often not available to bus and train operators. Bathroom facilities are not accessible during or at the end of some bus routes. Lack of bathroom access for train operators sometimes forces them to urinate in their cabs and then continue to work the remainder of their tour in the urine-soaked cab.

Station agents work alone and must constantly contend with the potential for verbal abuse or violence.

Transit workers are often placed in impossible “Catch 22" situations, without effective supervisory response. Operators of rear wheel drive articulated buses know that their buses tend to jackknife in inclement weather, lose traction, and swerve, yet drivers must continue to operate buses under these conditions. Although NYCT rules prohibit backing up a bus without a guide in the street and some bus routes require backing up as part of a broken U-turn, NYCT provides does not provide a guide. No matter what the bus operator does in a situation like this, s/he is in a dangerous situation and is breaking the rules.

Train operators are responsible for the safe operation of 10-car trains carrying thousands of passengers. Train operators must always be on the lookout for “jumpers,” or people forced off crowded platforms into the path of their moving trains, and then must act as first responders, descending onto the tracks to be the first to investigate the death and/or dismemberment.

Conductors must always be alert for subway draggings - incidents where passengers are caught in closing doors and dragged, sometimes to their deaths, until the conductor can bring the train to an emergency stop. According to TWU 100, there are 123 curved subway stations where the conductor’s line of vision is obstructed.

A study of 66 workers’ compensation cases of NYCT employees found that 13 were involved in a trauma while at work which resulted in need for psychological consultation and treatment. These included being exposed to toxic substances, being involved in an anthrax scare, being lost or abandoned in a subway tunnel, and being involved in “death cases” or near miss situations, including running over civilians or seeing co-workers shot to death.

Regarding the anxiety of constantly working under traffic and in close proximity to the live 600-volt third rail, track workers speak of the ability to “internalize the stress” as a requirement for the job.

Bus operators are under constant pressure to adhere to schedules, regardless of traffic conditions. To comply, bus operators sometimes feel compelled to shorten their 32-minute lunch break. If the end of the bus operator’s shift occurs before reaching the end of the route being driven, s/he may be relieved at that time. S/he must then proceed back to the depot “on her/his own time,” i.e., without pay.

Bus mechanics must sometimes use hydraulic lifts under faulty mechanical conditions, for example, to lift a bus that is heavier than the rated capability of the lift. The mechanic must then work under the lifted bus. Ventilation and drainage maintainers sometimes are not provided with a hoist necessary to lift and repair a ventilation fan, in which case to get the job done they must improperly improvise a hoist, possibly endangering themselves and breaking the rules in the process.

### B. Workplace Violence

Work-related assaults and other acts of violence and abuse comprise some of the leading causes of workplace injuries and fatalities. As crime and violence have increased in urban environments, there have been corresponding increases in urban mass transit systems, with transit workers often the targets or witnesses of such incidents. Factors that place workers at risk for violence in the workplace include interaction with the public, exchange of money, provision of services, late night or early morning work, working alone, guarding valuable goods or property, and the potential for encountering violent people or volatile situations. To workers at risk, the potential for workplace violence may constitute a significant occupational stressor.

There are four categories or types of workplace violence. Criminal intent violence (type 1) involves verbal threats, threatening behavior, or physical assault by a perpetrator who has no legitimate relationship to the business or its employees. The violence is usually associated with the act committing a crime. Customer/client violence (type 2) involves verbal threats, threatening behavior, or physical assault by a perpetrator, such as a passenger or customer, who has a legitimate relationship to the business and becomes violent while receiving services at the workplace. Worker-victims tend to be in service-providing jobs, such as bus or train operators or station agents. Customer/client violence may be "situationally" provoked by frustration with bus or train delays or fare costs or by perceived discourteous treatment. Worker-on-worker violence (type 3) involves verbal threats, threatening behavior, or physical assault by a perpetrator who is an employee or past employee who attacks or threatens one or more current or past employees. The threat or assault may be a result of perceived unfair treatment. Personal relationship violence (type 4) involves verbal threats, threatening behavior, or physical assault by a perpetrator who usually does not have a relationship with the business but has a personal relationship with the intended victim. The assailant's actions are motivated by perceived difficulties in the relationship or by psycho-social factors that are specific to the assailant.

A study of the workers' compensation cases of 66 NYCT workers found that 20 were assaulted while at work. Victims included bus drivers who were robbed or assaulted while driving as well as a station agent who was bitten by rats while working in a token booth.

Station agents, although protected in bullet-proof booths, interact directly with customers, work in isolation, and are vulnerable when they leave their booth booths for work-related or personal reasons. They are sometimes threatened with ignition of flammable liquids. This is not an idle threat, as several booths have been torched. Station agents face constant threats and abuse from customers.

Like station agents, bus operators interact directly with customers and work in isolation. Unlike station agents, however, bus operators are not protected by physical barriers. Disagreements over the fare collection process, bus scheduling, and passenger crowding are some of the possible triggers for confrontation and abuse.

Conductors are also subject to verbal and physical abuse. They are sometimes attacked by disgruntled passengers or when coming to the aid of beleaguered passengers. They may be attacked by homeless persons who use the subway system as their domicile.

Station cleaners and car cleaners, by the nature and location of their jobs, also have the potential for exposure to verbal and physical abuse from passengers.

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## Chapter 4 Musculoskeletal Risk Factors and Disorders in the Transit Industry

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**Summary**

The universe of risk factors that are associated with work-related musculoskeletal disorders in general -- heavy physical work, repetitive motions, sustained and demanding postures, vibration, temperature extremes and workplace stress -- are common in transit industry work. The most prominent of these potentially work-related musculoskeletal disorders include back and neck pain, carpal tunnel syndrome and related wrist conditions, and joint strain, A preliminary analysis of data from the MTA Daily Injury Report System in 2003-2004 shows that back, neck, ankle, shoulder, leg, and wrist strain are the most commonly reported musculoskeletal complaints among transit workers. Focus group discussions and limited direct observations of transit work suggest that performance of a wide variety of potentially hazardous movements are required on a regular basis by many job titles in the transit industry. Limited research on successful interventions to reduce musculoskeletal stress of transit work is available. Additional research is needed to achieve a careful description of the nature, extent and intensity of transit-related risk factors for musculoskeletal disorders; to understand the prevalence and severity of such disorders; and to design and implement successful interventions to reduce the risk of musculoskeletal disorders among transit workers.

### I. Transit work: a complex environment

The universe of risk factors associated with work-related musculoskeletal disorders -- heavy physical work, repetitive motions, sustained demanding postures, vibration, temperature extremes and workplace stress -- are common in transit industry work. New York City transit workers engage in psychologically demanding service work, physically demanding labor and technically demanding operations. They often experience these demands in combination. Work demands are not always predictable, and work location frequently varies, especially for bus and train operators.

The physical and physiological problems of public transit have been investigated extensively in the U.S. and in other countries (Laurig, 1981). Transit workers are at higher risk than other workers and the general population for a wide variety of musculoskeletal, physiological and stress-related disorders (Norman, 1958; Vajsman et al., 1973; Raffle, 1974; Hannunkari et al., 1978; Barak et al., 1987; Ragland et al., 1987; Evans, 1994; Whitelegg, 1995; Ragland et al., 1998; Maciulyte, 2000; Obelenis, et al., 2003; Pankova et al., 2003; Sharoputo et al., 2003).

For all the general knowledge about the demands of transit work, relatively little is known about the musculoskeletal hazards transit workers encounter, about their rates of musculoskeletal injuries and disorders and about appropriate prevention measures to improve workplace conditions and limit work-related musculoskeletal disorders. The purpose of this chapter is to review the state of current knowledge about the extent of work-related musculoskeletal disorders (MSDs) in transit work and the work demands and conditions that lead to MSDs. Important gaps in knowledge need to be addressed through conduct of a comprehensive research program to analyze the MSDs experienced by transit workers, to identify their causes and to develop effective preventive measures.

## II. Sources used to identify ergonomics and other hazards

The current report is based on data gathered from the following sources:

- Peer-reviewed medical and occupational health literature,
- Reports prepared for governments, employers and labor unions around the world,
- Site visits to garages, bus routes and other work areas
- Field observations
- Discussions and focus groups carried out with Local 100 members and union representatives
- Transit Authority Daily Injury Report (DIR) System

### A. Literature search

A search was made of Medline, CINAHL and the Science Citation Index, using one of the words “train”, “subway”, “transit”, “transportation”, or “driving” combined with “health”, “musculoskeletal”, “strain”, “sprain”, “carpal tunnel syndrome” or “tendonitis”. Other researchers contributed a set of references dealing mainly with vibration and stress. A bibliography containing 97 references relating directly to the ergonomics and human factors issues involved in transit work was culled from these combined results.

### B. Site visits

On Monday, March 8, 2004, two vibration researchers initiated a pilot study of vibration hazards experienced by bus drivers. The researchers, accompanied by an ergonomist, visited the Gun Hill Road garage to assess a bus selected by management for whole-body vibration demands at the driver’s seat on a route that led to City Island. Although the purpose of this trip was to test a vibration measuring system, it also provided the opportunity to observe other musculoskeletal demands associated with bus operation. Union representatives and management engineering staff accompanied the research team.

### C. Focus groups

Two transit worker focus group discussions were held with a total of 17 participants. Participants were asked to describe their working conditions, musculoskeletal disorders and health and safety concerns. On June 15, 2004, 9 union stewards and health and safety committee members who currently or previously worked in bus and subway operations and maintenance met to answer questions. A discussion held on July 27, 2004 targeted the concerns of female transit workers. Participants included three bus operators, one train operator, one platform agent and three union officers who had been bus drivers or operators or station agents.

### D. Field observations of track work, other areas.

These observations were made between June and September 2004. A convenience sample of Upper Manhattan buses and West Side trains was observed.

### E. Injury and illness report data

Initial injury and illness report data have been provided by the Transit Authority covering May 2003 to the present. This database is described in Chapter 5 in this report. The database was evaluated to assess the variety, frequency and potential causes of work-related musculoskeletal disorders reported as incidents or injuries occurring between May 2003 and September 31, 2004. Potential MSDs were identified, and 1/6 of these were sampled to provide a preliminary listing of the types of exposures with which these problems were associated.

(Note: This database is not a comprehensive catalog of MSDs as experienced by transit workers. Typically, recurrent or chronic pain and other MSD symptoms are treated initially by primary care physicians. They are often not entered into the employer's databases as work-related. Because we do not have a full count of MSDs, no conclusions about overall or job -specific MSD rates or severity can yet be drawn.)

## III. Musculoskeletal disorders and ergonomics risk factors in the transit industry

### A. Literature Review

#### 1. Back pain

Both bus and train operators are consistently reported as having a higher rate of back and neck symptoms and disorders than other workers. This is usually attributed to heavy physical work, vibration and psychosocial demands (Anderson, 1992; Magnusson et al., 1996; Krause et al., 1997; Johanning, 1998).

Bus drivers in urban California reported notably higher rates of cervical spine pain, postural pain throughout the spine, and overall increased risk of back pain compared to non-driving transit workers (Anderson, 1992). Bus drivers took measures to address their pain, such as exercises, medical treatment and medication. In other California research, back and leg symptoms and disc protrusion were significantly higher in bus drivers than in transit maintenance staff. Increase risk was related to lifetime driving exposure, vibration magnitude and duration. Awkward postures were also associated with increased rates of back pain (Bovenzi et al., 1992; Bovenzi, 1996).

Back pain may be caused or aggravated by a wide variety of hazards, including lifting, leaning, squatting or kneeling and the demands of driving. Researchers used a Fleishman Job Analysis Survey to identify job demands and work environments that were related to back injuries in the 25 titles most at risk for work-related back problems in the New York City Transit Authority (Halpern et al., 1997). Explosive force, excessive demands on the shoulders and arms, and unbalanced or unstable work were strongly related to risk of back injury. Their research also established that worker assessments of excessive demands are useful predictors of back pain risk. This suggests that a work practice and exposure survey of the entire workforce might prove valuable in identifying and correcting significant work hazards that contribute to back pain and disability. It also shows the importance of overall environmental assessment in reducing both accidents and long-term musculoskeletal disorders.

Exposure to whole body vibration is common in driving work (Palmer et al., 2000). A meta-analysis of relevant vibration studies demonstrated that whole body vibration contributes to low back pain, sciatica and spine degeneration (Bovenzi et al., 1999). This supports an earlier epidemiological survey (Bovenzi, 1996). However, Bovenzi points out that dose response and the hazards of specific frequencies are not well characterized in the literature reviewed, and that the research is short of information on health risks of vibration related to gender, including reproductive organ effects.

The human body rapidly shows effects of vibration. Using a truck cab to induce vibration while seated, researchers showed that three hours of exposure counteracted the natural shrinkage of the spine experienced over the course of a day, so that subjects were taller following exposure than when they spent the same period sitting without vibration (Hampel et al., 1999).

Seat design has a major effect on the amount of vibration experienced by the worker (Oesterling et al., 1999). The average overall transmission of vibration is higher with a backrest, but transmission to the neck region is higher without a backrest (Hinz et al., 2002). This demonstrates how important seat design and anthropometry are in vibration studies and in ergonomics intervention. Paddan and Griffin also showed that seat type makes a difference in transmission of vibration (Paddan and Griffin, 2002). The authors point out that projected vibration reductions in refits are often based on changing seats on existing equipment, assuming that seats are equally efficient in different vehicles. (This observation is not supported by the reports of MTA bus drivers.) Of note is that this study focuses on vertical acceleration only and does not account for all musculoskeletal demands caused by seat vibration (Ozkaya et al., 1997).

Johanning notes that vibration levels that are clearly associated with back problems are below the European Union and ISO cut off levels. Other studies have reported that the vibration levels associated with reports of low back pain were lower than the health-based ISO exposure limits (Bovenzi et al., 1992).

Hazardous vibration in railroad locomotives is difficult to reduce using currently installed technology (Johanning et al., 2002). Older seating is especially poor in adjustability and postural support. This situation is likely to be similar in urban transit work. Participatory and collaborative analysis of vibration and other work hazards can be effective in changing the conditions and behaviors associated with vibration-related low back pain (Johanning, 1998).

Although stress is believed to contribute to the reporting of MSDs, low back pain was only minimally associated with one psychosocial factor in a survey of Danish bus drivers (Netterstrom et al., 1989). However, long seniority was more strongly associated with low back pain, suggesting that other physical demands such as postural strain and whole body vibration were the main causes of the increased rates of back pain (Netterstrom et al., 1989). Education and on-the-job time to exercise and to improve other health behaviors reduced self-rated back symptoms in older German transit workers (Johanning et. el., 2002).

### 2. Carpal tunnel syndrome: chronic or acute exposures

Carpal tunnel syndrome is associated with exposures experienced by bus drivers and other workers in the transit system. In particular, nerve compression and carpal tunnel syndrome have been attributed to repetitive forceful motions experienced while bending the hand and keying (i.e. – the type tasks that are required of station agents who handle MetroCards.)

Traumatic hand injury may cause carpal tunnel syndrome. Car drivers develop symptoms after being hit from the front or rear while gripping the steering wheel (Coert et al., 1994). Rear impact accidents while gripping steering wheel may be associated with acute development of carpal tunnel syndrome (Guyon et al., 1977).

### 3. Other musculoskeletal disorders

Increased rates of a variety of disorders are associated with construction work in Russian transport operations, leading to high rates of temporary and longer-term disability related to musculoskeletal disorders (Kudrin et al., 2003). This experience is shared by drivers in Lithuania, where the prevalence of arm and leg pain and back symptoms increase with additional years of work (Maciulyte, 2000). Nearly two-thirds of Lithuanian bus drivers reported neck, back and abdominal pain, with about one-half of those indicating that these symptoms are related to the job task and poor ergonomic working conditions (Obelenis et al., 2003). Drivers in Copenhagen also report high rates of musculoskeletal pain, which is attributed to the bus design, schedules and occupational stress (Poulsen, 2001). Neck and shoulder MSDs are higher in Canadian school bus drivers than in the general population. The authors suggested that this could be caused by exposure to forceful work, repetitive movements, restricted postures and work-related stress (Gourdeau, 1997).

The lower limbs may also be at risk. One case report describes a bus driver experiencing knee injury and meniscal tear related to work (Alcantara et al., 1998). Another case report uses foot pain in a bus driver as an example of a typical problem referred to physiotherapists (Yu, 1995).

What causes the increased rates of MSDs? After controlling for age, gender, weight, height and vehicle type, the risk of back and neck pain in bus drivers increases based on the physical workload and the length of time in the profession (Krause et al., 1997; Krause et al., 1998). Reported ergonomics factors explain part of these increased risks. Problems with adjusting the seat were considered most important, but seat stability, visual demands and clearance, steering, reaching and braking also raised the risk of MSD reporting. Women experienced a 2-fold risk that was not explained by anthropometric or ergonomic factors. Magnusson reports more low back pain, neck pain and shoulder pain in American bus drivers than in other American workers, and more lost work time related to this pain. This study, which measured vibration, lifting and psychosocial factors, showed that lifting and vibration were associated with low back pain. The effect of stress on MSDs was not reported (Magnusson, 1996).

Ergonomic and other work demands on railway cashiers observed in Russia included postural demands, poor air quality and stress (Pankova et al., 2003). Reported health problems included musculoskeletal disorders. In France, division of task by sex leads to more demanding work being done by women train cleaners than men, and higher rates of musculoskeletal problems (Messing et al., 1993). The authors believe that the MSDs are due to forceful work done while crouching and in other uncomfortable postures.

### 4. Psychological stress and MSDs

Stress is experienced in work that combines extensive job responsibilities or demands with limited control over work conditions. Given the urban driving environment, where schedules may not match working conditions, where single drivers face a sometimes rude and even dangerous public, where recent events have made a driver, conductor or station agent potentially responsible for hundreds of people in unimaginable conditions, it is a given that transit workers experience stress. This report will not review the extensive literature on the impact of job stress on the cardiovascular health of transit workers, which has been addressed by a host of researchers around the world, notably June Fisher and others in San Francisco and Paul Landsbergis in New York (Duffy et al., 1990; Greiner et al., 1998; Kompier et al., 2000).

Evans and colleagues note that, because healthy people are better represented in the workforce than in the population at large, the observed increased risk of stress-related diseases in transit workers is probably underestimated (Evans 1994; Evans et al., 1998). The same is probably true for ergonomics hazards. Despite legitimate concerns about specific risks encountered by women, the impact of stress is not necessarily different between the sexes. In a study comparing men and women bus drivers, both sexes had increased adrenaline and other indicators of stress during work (Aronsson et al., 1998). The magnitude and type of stress response and the reported mood did not differ by gender.

Work organization demands can affect musculoskeletal as well as cardiovascular health. Dutch bus drivers who considered the work schedule to be very important reported more musculoskeletal problems, than those who considered safety more important (Meijman et al., 1998). Increased stress levels also raise rates of accidents and absenteeism (Greiner et al., 1998). Greiner and her colleagues emphasize the need to guarantee rest breaks and flexible timing. Workers are unable to control the ill effects of demanding schedules and poor work organization through traditional stress management techniques. As with ergonomics, changes may be required at a much higher level than just the seat or the schedule. Strikingly, roadway and traffic control interventions designed to improve the traffic environment had a positive impact on self-reported health indices in Stockholm bus drivers in the most demanding urban route (Rydstedt et al., 1998).

Finally, noise is also a stress concern. Bus noise levels measured in Brazil were found to be extremely uncomfortable but not above OSHA 8-hour weighted limits (Zannin et al., 2003). Noise must be considered an overall stressor, not only a cause of hearing loss, and one that has an impact on physiology, communication and worker and passenger safety.

### 5. Interaction of temperature and other work factors

Hot and cold working conditions can also contribute to the risk of musculoskeletal disorders. In addition working in the heat depletes necessary electrolytes that support muscle health. Heat can also affect judgment about lifting and other behaviors. Cold can aggravate musculoskeletal disorders, typically with neurological outcomes such as carpal tunnel syndrome. Heat and cold extremes are common in aboveground and underground transit word (Vajsman et al., 1973).

### B. Daily Injury Report data and musculoskeletal disorders

Musculoskeletal disorders (strain, pain, sprain, swelling, numbness, carpal tunnel syndrome) represented 41% of all events reported in the daily injury logs. The great majority of these were strains. Table 1 Injuries list reported by TA workers May 2003-September 2004.

**Table 1**
**Injuries reported by TA workers, May 2003-September 2004**

| Injury | Number | % |
|---|---|---|
| Strain | 1379 | 34% |
| Pain | 124 | 3% |
| Sprain | 114 | 3% |
| Swelling | 12 | .3% |
| Numbness | 9 | .2% |
| Carpal Tunnel | 5 | .1% |
| Total MSDs | 1643 | 41% |
| Other | 2394 | 59% |
| **Total** | **4037** | **100%** |

Source: MTA Daily Injury Report System

Table 2 shows the distribution of types of MSDs in the major body areas. Among these probable musculoskeletal disorders related to excessive physical demands, the back is the most affected area. Strikingly, compared to other sedentary jobs, the hips, legs, ankles and feet are also very frequently affected.

| Table 2: Body area and type of MSD reported (n=1643) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Abdomen chest groin** | **Ankle, foot** | **Shoulder, arm** | **Wrist, hand** | **Hip, leg, foot** | **Back, neck** | **Multiple** |
| Carpal tunnel syndrome | - | - | - | 0.3% | - | - | - |
| Numbness | 0.0% | 0.1% | 0.1% | 0.3% | 0.1% | 0.0% | 0.0% |
| Pain | 0.4% | 0.7% | 1.0% | 0.9% | 1.4% | 1.9% | 1.3% |
| Sprain | 0.1% | 3.6% | 0.4% | 1.5% | 0.9% | 0.4% | 0.2% |
| Strain | 4.8% | 11.3% | 10.7% | 6.8% | 12.2% | 28.9% | 9.1% |
| Swelling | 0.0% | 0.2% | 0.1% | 0.1% | 0.2% | 0.1% | 0.1% |
| Proportion of all MSDs | 5.2% | 15.9% | 12.3% | 9.8% | 14.8% | 31.3% | 10.7% |

Source: MTA Daily Injury Report System

Unfortunately, it is impossible to identify the severity of the problem or the relative rates of MSDs by division, job title or task from the DIR data. One-third of the potential musculoskeletal disorders received medical treatment, as did one-third of all reported injuries. The duration of disability, type of treatment and work time lost are not available from this database. About 60% of the injuries were reported by subways workers and 40% by bus workers. The proportion of each injury type experienced by each major department is similar. Further data is needed to determine whether injury types, severity or causes differ between job titles or departments.

## IV. Biomechanical, environmental and organizational risk factors

Work can lead to musculoskeletal problems when people are required to:

- Repeat the same motions over and over
- Make forceful contractions of muscles and tendons
- Work in stressful, uncomfortable postures
- Hold muscles and joints in one position for long periods
- Encounter vibration from tools or vehicles
- Lean against sharp or hard surfaces that compress tendons, blood vessels and nerves
- Postpone or skip adequate rest breaks
- Endure occupational stress

### A. Daily Injury Reports and causes of MSDs

Workers reporting injuries describe a wide range of demanding working conditions that contributed to the injury. They range from obviously excessive demands related to heavy lifting or trauma to the spine while driving to much more subtle exposures such as using the keyboard in the token booth or sitting for long periods while unsupported. Tables 3 and 4 list risk factors and exposures associated with MSDs reported in Daily Injury Reports. The data were condensed from a sample of 20% of the reported musculoskeletal disorders.

Predictably, many of the cases of pain, strains and sprains reported are attributed to a specific event, typically a fall or trip. These accidents cannot be properly separated from overall musculoskeletal demands, as tissues already weakened by accumulated trauma are more vulnerable in the event of a fall that might otherwise not lead to reportable injuries. The event occurring when the pain is first noticed is not necessarily the ultimate cause of the problem.  A comprehensive ergonomics program must take into account the safety conditions that can contribute to musculoskeletal demands and make awkward and unsafe postures more likely. Thus the apparently accidental events and work practices associated with falls should also be evaluated using ergonomic methods.

**Table 3: Ergonomics risk factors associated with MSDs reported in Daily Injury Reports**

| Repetition or awkward position (apparently light) | Repetition or awkward (apparently medium to heavy) | Other forceful motion (or with vibration) | Heavy lifting |
|---|---|---|---|
| - Keyboard use<br>- Operating bus<br>- Operating train<br>- Signal buttons on bus<br>- Sitting<br>- Climbing into tow truck<br>- Reaching to adjust to mirror<br>- Climbing down ladder<br>- Boarding/ disembarking bus<br>- Holding down master controller<br>- Handing out general order tickets<br>- Turning key to door on train<br>- Reaching for equipment<br>- Detraining<br>- Climbing down between train cars<br>- Bench in swing room<br>- Walking uneven roadway<br>- Stepping across tracks<br>- Hand brake on train | - Sweeping<br>- Reaching over transmission bumper to remove belt guard<br>- Cleaning up<br>- Moving garbage<br>- Moving high-pressure hose<br>- Garbage can lid<br>- Battery tray<br>- Lifting mop bucket<br>- Manhole cover<br>- Dragging signal machine on running rail<br>- Going under car to remove debris<br>- Removing air compressor<br>- Vacuuming<br>- Cleaning a bench wall<br>- Washing bonnets<br>- Tiling a floor | - Open/close train window<br>- Adjusting cab seat<br>- Tightening shop beam<br>- Releasing wheelchair seat<br>- Spelling wheelchair lift<br>- Placing hand brake<br>- Changing brake shoes<br>- Installing bushing onto stabilizer<br>- Pulling down roof hatch<br>- Chipping out concrete<br>- Unsecuring breaker<br>- Removing gauge while performing rag test<br>- Tightening bolts, lug nut<br>- Breaking up ice<br>- Hand tools<br>- Air hammer<br>- High-pressure mobile wash hose | - Lifting a box<br>- Loading and unloading third rail mats<br>- Moving box with hand truck on stairs<br>- Lifting metal hat should<br>- Replacing transmission filter<br>- Lifting brake valve to shelf<br>- Lifting debris<br>- Lifting battery booster pack<br>- Picking up starter motor<br>- Unloading cable<br>- Carrying part of token booth<br>- Bending over<br>- Lifting material by rack<br>- Carrying temping machine<br>- Carrying a locker<br>- Bushing and dumpster<br>- Unloading rails<br>- Lifting: work bag, tool box, bucket, planks, garbage bags, engine door<br>- Assisting obese passenger<br>- Moving rail stop<br>- Variety of rail work |

Source: MTA Daily Injury Report System

| Table 4: Other exposures associated with MSDs reported in Daily Injury Reports | |
|---|---|
| **Trauma (typically vehicle or fall)** | **Environmental conditions** |
| - Vehicle collision<br>- Trip and fall<br>- Hurt foot on track<br>- Struck by object<br>- Struck by rider/customer<br>- Bumpy roadway<br>- Train jerked, caused to grab rail<br>- Adjusting operators seat, pneumatics dropped | - Extreme cold in outside work<br>- Heat stress |
| | Source: MTA Daily Injury Report System |

## B. Range of risk factors for MSDs

### 1. Biomechanical risks reported by transit workers

The small number (n = 17) and nonrandom sampling of focus group participants interviewed to date mean that these findings are not conclusive about the severity and impact of musculoskeletal hazards in transit work. However, the reports are detailed and very consistent with each other: they describe a pattern of physically, physiologically and psychologically demanding work that varies by job title. Workers expect to experience some form of work-related disability before they retire, because they have seen it happen again and again. It should be noted that many of the job titles suffering heaviest work demands, such as MOW titles, have not yet been surveyed.

In order to fully understand the extent of musculoskeletal risk factors, a comprehensive cataloging of job titles and tasks, along with the associated hazards, must be carried out. These focus group results provide initial snapshots of the job demands experienced by transit workers.

**Station agents** frequently experience problem with their wrists and fingers. They face postural force and physiological strain. Typically, they stay in the booth for four hours at a time. It can be difficult to get coverage if a restroom break is needed.

Chairs provided are inadequate, without backrest or proper foot support. When the chair is brought to the level of the standing window, it is too high and the agent's feet dangle. This causes compression of the leg veins and low back pain. The back and neck are strained, especially when raising the arms to the level of the keyboard. Overall, the ergonomic demands of the keyboard and computer are extreme. This includes the lighting, which is very bright overhead.

Temperatures are uneven, despite air-conditioning. In fact, it may be too hot on the floor and too cold everywhere else. The air-conditioner, behind the agent, blows into the back. The cold deal tray aggravates hand problems related to keying. Additional responsibilities, such as handling property bags, require stooping and lifting.

**Station cleaners** have heavy, awkward and often uncomfortable work. Keeping floors clean requires extensive twisting while sweeping or mopping. Heavy trash bags are carried up and down stairs. The refuse cleaner may be the extreme example: the team, consisting of driver and carrier, carries about 600 bags on each shift to the street level. Three teams now do the work once done by five. The clothing allotment is inadequate, as shoes get wet and split and do not last.

**Car cleaners** also work in awkward and demanding postures. They use rags, mops, and brooms, often while gloved, which reduces grip strength. Car cleaning, like maintenance, demands a lot of work with the arms stretched out or above the head.

**Car inspectors** do repair, maintenance and testing in many awkward positions. For example, standing in a pit to do propulsion maintenance requires constant reaching and looking up. It is difficult to see due to inadequate lighting, even when using a droplight.

Car inspectors lean into equipment to brush it out. Those doing overhaul use pneumatic tools, with a lot of torque. They wrench nuts open, and sometimes use their hands as a hammer. The work requires a lot of stooping. They have to move mechanical jacks and blocks; the blocks weigh 20 to 40 pounds. Some use leather gloves, while others use cotton; both affect grip strength.

**Train operators and conductors** face postural demands and suffer the effects of constant vibration. The seats, especially on older equipment, are inadequate. They may have no back, and many require the operator to lean forward or away from the controls, putting strain on the trunk muscles. On some trains the seats are smaller, which is better for female drivers, but they have no back. Men, however, are cramped in the smaller seats. Some train operators just stand. To make things worse, there is only a picnic table in the crew quarters, usually with no back support.

In newer equipment, operators can move the seat back and forth and adjust the height, but the seat hits against the housing and adjustment is limited. The dead man's switch is a particular problem. In older cars, the accelerator required a lot of force; this has been improved on newer models. Even smaller muscles sometimes are exposed to excessive force, for example when opening or closing stiff windows with a pinch grip.

**Bus operators**, in addition to the stress of keeping on schedule, sit in seats that transmit vibration to the back. Potholes, rough roads and motor vehicle accidents are sources of back trauma. Seats are frequently not adjustable, either by design or because they are broken. Some buses are too small for the average man, so the taller man has to recline to get room. Controlling the large steering wheel can cause extreme wrist angles. Legs and feet are at risk of strain and long-term damage because of the demands of the interlock system, the angle of the pedals and the constrained postures required by the seat layout. Workers report that all bus drivers limp by the time they retire. Buses not in good repair cause more problems.

Buses are sometimes just too big. Women drivers may try to compensate for the treatment they receive from the public by raising the seat so passengers do not literally look down on them.

But it is then harder to reach the controls; the feet dangle, and the resulting leg compression leads to swelling and sciatica. This position is uncomfortable and unsafe, because workers have to lean forward, reducing back support and making it hard to concentrate.

**Bus repair** requires much work above the shoulders. Maintainers may stand for eight hours straight, for example when buffing, holding a sander up most of the time. When refinishing buses, they paint, spray, tape the buses – this requires a lot of bending for touchups and to work on the tires. Maintainers may work under the bus. It is especially uncomfortable to do maintenance inside the bus, where they may have to stoop frequently or lie on their backs to remove bolts. Maintainers use air-powered tools, which are too noisy and cause strain through impact and vibration. Heavy lifting is common, such as carrying or removing axles and bumpers.

All operators, conductors and agents have trouble getting breaks. They may reduce the amount of water they drink to limit the need to urinate. The resulting dehydration could aggravate the effects of biomechanical hazards and stress.

Workers reported that defect and maintenance documentation is designed and used more for management control and equipment maintenance than worker safety.

### 2. Similarity of environmental and work organization demands across job titles

Stress is constant. Management tell workers that "everyday has to be perfect" in stations and on the buses. For example, the Bx30 is a fast line, with barely enough time scheduled to get to the end. Despite this, stops on both runs have been added, so there is no time to do the run. Minutes are taken off train schedules. (Although some workers report, “I just make sure I drive my train safely"). The new operators always go faster; they try to make the schedule even if it is not feasible. Even during catastrophes or incidents, such as snowstorms, every run is expected to get in on time. Workers may get five minutes or less at the end of the line. It is the same on the trains. Staff are told they should take comfort breaks but are nonetheless expected to keep to the timetable issued by the dispatcher.

Transit employees described a recent example of extremely stressful work conditions in August 2004. Transit staff was warned that they are responsible for the safety of passengers during this heightened security period. Train operators and conductors have been given some training for fire and evacuation, but the training does not prepare them to respond to the results of criminal acts. Workers report that there is no real emergency training, and they do not understand the evacuation plans. Station personnel reported feeling ill prepared for evacuation, especially in the case of an explosion. The plan is not well worked out. For example, if there is a suspicious package in the middle of the platform, you cannot communicate with dispatchers from the other side. There is only one escape mask in the booth, but there may be two people. The resources and information needed to make the right decisions, and the skills to respond to extreme emergencies, are not typically available either underground or on the buses. Yet operators are daily reminded that emergencies are possible and perhaps likely.

Finally, to add to the overall environmental stressors, New York City buses are full of mechanical sounds, blowers, beeps -- noise rather than information. The public service announcements are also intrusive and irritating. Station agents cannot turn down the microphone into the booth, so customers and announcements blare at them. Work noise on platforms, tracks and trains can be a constant roar.

### C. Expert observations

Limited observations of transit workers in the course of a normal workday were performed. Initial observations were made to begin to characterize the type of hazards most common in each division and job title. Like the focus group results, these data are pilot data only, useful in guiding further research. The observed exposures are consistent with the existing literature and with the DIR data.

Similar to the focus groups, these observations consistently revealed quite notable physical demands experienced throughout the Transit Authority. During the bus site visit, the most significant biomechanical demands observed were repeated powerful blows to the spine experienced by the seated operator when passing over rough roads and potholes. These have the potential to damage the spine and discs and strain back muscles. In addition they require the operator to grip the steering wheel more tightly to control the bus, which creates additional demands on the hands, arms and shoulders. Depending on the size of the operator, the seat adjustments might allow comfortable bus operation, or might not.

Table 5 provides a list of the risk factors identified through observations of bus operators, train operators, station agents and track workers carried out between June and September 2004. These activities and job titles have not been evaluated formally, which makes the observation of varied and extreme physical working conditions all the more striking.

**Table 5: Observed risk factors by job title and task**

| Division | Title | Task | Risk identified | Part affected | Where observed |
|---|---|---|---|---|---|
| MOW | | Carry 4' bar | Pinch grip<br>Lifting | Hand<br>Back | Track and car local A (pm) |
| | | Carry lights | Sustained static posture | Shoulder | |
| | | Detaching and placing track | Extended lean<br>Forceful pulling<br>Lean while twisting | Back<br>Shoulder<br>Leg | |
| RTO | Station agent | Seated at counter | Compression at counter<br>Compression at chair edge<br>No back support<br>Wrong chair height | Arms and hand<br>Leg, veins<br>Low back<br>Upper back, feet/legs/hips | Booths (A, C, 1, 9, F, 6, 7) |
| | Train operator | Seated while reaching for controls | Shoulder extension<br>Wrist bending<br>Leaning | Shoulder, arm<br>Hand, wrist<br>Back | Trains |
| | Train conductor | Reaching for controls<br>Observing platform<br>Standing | Shoulder extension<br>Neck bending<br>Wrist bending<br>Vibration and shaking | Shoulder, arm, hand<br>Neck, shoulder<br>Legs, back | Trains |
| Bus | Bus operator | Seated driving<br>Reaching for controls on left<br>Braking<br>Back door lock | Wrong seat height<br>Wrist and arm twisting<br>Foot and knee | Back, shoulder<br>Arms, hands | Bus (M19, M11, M4, M104, M57, M5) |
| | Bus operator | Opening/closing windows<br>Closing stuck doors<br>Dealing with other maintenance problems | "Hand hammering"<br>Forceful motions | Arm, hand<br>Arm, hand, shoulder, back<br>Arm, hand, shoulder, back | |

Source: Field observations 6/04-9/04

## V. Ergonomics-based approaches to improve working conditions

The literature is replete with examples of successful and proposed ergonomics analysis and correction methods that could reduce the excessive demands of transit work. Examples include Canadian descriptions of technologies used to attenuate vibration in buses and trains (Boileau, 2001) and analysis of the changes in control layouts when systems go from two-person to one-person bus operation (Ito, 1974). However, some ergonomics improvements such as automated bus docking can increase workload and stress, at least initially, even while they decrease error (Collet et al., 2003).

Anthropometrical studies of bus drivers and other transit workers have been carried out around the world (Sanders 1977; Hedberg et al., 1981; Courtney et al., 1985). However, anthropometric design measures are not always based on the right population: for example, buses in Hong Kong were not appropriate for users when they served in the design for the 1985 US male population (Courtney et al., 1985). This finding would suggest new guidelines might be necessary in New York City transit design and purchasing, because the gender, ethnicity and age mix of working population is changing in New York as well.

Human factors theory directs much of cab and bus control design, including information processing, but it does not necessarily pay attention to purely biomechanical demands (Shkol'nikov et al., 1995). Seat design has received a lot of attention, in part because of the spillover from automobile research and in part linked to vibration research (Boileau, 2001). The optimal driver's seat includes incline to reduce hip rotation, seat depth adjustment, height, vibration and adjustable back support at lumbar and upper back (Harrison et al., 2000). However, seating improvements cannot be limited by strict rules, as comfort, an ambiguous concept, may be as important as anthropometric guidelines (Kolich, 2003).

Practical approaches to train cab redesign (Strecker, 1976) and the reduction of bus operator hazards (Miller, 1976) were described as early as 1976. As recently as 2003, recommendations for workplace improvements in underground railroad conditions in Siberia were developed (Sharoputo et al., 2003). The Transportation Research Board has published extensive bus evaluation and design guidelines for bus operator workstations (Transportation Research Board, 1997). Many of the guidelines are useful and correct. However, transit workers report that they are rarely involved at the relevant phases, assignment to such project being typically a plum rewarded to supervisors. In contrast, the evaluation and redesign of an electric train cabin in Sydney Australia consisted of observations of drivers at work, questionnaires distributed to *all* drivers (although only one third responded), and analysis of human fit problems using a computer package. This was followed by a mock up that was tested by the union cab design committee, and evaluated following changes by survey to all workers (Stevenson et al., 2000).

Researchers point out the difficulties of evaluating a workplace that constantly changes and is so diffuse (Korshunov Iu et al., 1992 ; Krivulia et al., 2001; Krivulia et al., 2003). Modifying the Rapid Upper Limb Assessment method to focus on trunk and neck scores in garbage truck and street cleaner drivers, researchers found an association between these awkward postures and self-reported pain ache or discomfort (Massaccesi et al., 2003). Partial demands on the neck were considered particularly significant. RULA scores differed notably between adjustable and nonadjustable seats. This method could be used to evaluate postural demands in train and bus drivers and conductors with limited and specific workstations. However, the PATH or similar method (designed at the Department of Work Environment at the University of Massachusetts-Lowell) will be needed to take into account for the ever-changing nature and location of work demands in many job titles (Buchholz et al., 1996). To assess musculoskeletal hazards in complex environments such as construction, the clinical environment should also be part of the ergonomics assessment process. For example, clinical methods of assessing musculoskeletal disorders are modified for early treatment and prevention in Russian transit workers (Kuzin, Makarov et al., 2003).

Many ergonomic design concepts can be applied simultaneously to worker health and safety, efficient human factors and passenger convenience and safety (Shkol'nikov, Boiarchuk et al., 2000; Kuzina, Delektorskii et al., 2003). The Danish Healthy Bus project was designed to involve workers in health promotion and work improvement activities (NIOH, 2003). It planned to improve health-related behaviors as well as the bus driving work environment through "broad and employee-anchored interventions." However, the exalted expectations of the project to some extent interfered with its success (Poulsen, 2001).

The role of the worker in identifying and resolving ergonomics-related and other health risks has significant policy implications. The commitment of the transit authority of both involving workers and resolving problems will have an effect on the organization and on the relations between the TA and the community it serves (Ragland et al., 1998).

The ideal approach is technically and organizationally comprehensive. A German project describes using human factors methods including workload analysis, task analysis and strain analysis. This approach, combined with participatory work schedule and cab design, can be used to develop a bus workstation that meets workers' biomechanical constraints and reduces workload levels experienced while driving (Gobel et al., 1998). The authors warn that other practical limitations can reduce the efficacy of this multi-pronged approach.

## VI. Summary

Musculoskeletal hazards have been identified in all divisions and most job titles of the transit industry. Disorders that can be caused by those risks are common in transit workers in New York and around the world. The rates of MSDs, specific causes, job titles most at risk and work practices most responsible remain to be adequately understood.

Modern ergonomics literature and practice provides guidance on evaluating and improving working conditions associated with MSDs and other health problems in the public transit industry. A comprehensive analysis will make use of existing research, up-to-date anthropometry and new technologies and research methods. It will require the active involvement of management, line staff, health and safety committees representing all affected job titles, research scientists, physicians, engineers and ergonomists. However, New York City transit staff are concerned, because they do not see the input of working people on the design of new equipment, staffing and scheduling.

The next critical steps are to:

- Assess the burden of MSDs on workers and on the organization

- Identify titles and activities most at risk
- Characterize the risk factors
- Develop and pilot solutions
- Evaluate the efficacy of the solutions themselves and
- Evaluate the overall method of analysis and improvement

Such a consistent and comprehensive approach should immediately resolve some of the more egregious problems facing transit workers. Remaining intractable hazards should then be less of a problem because of the reduced cumulative load. More significantly in the long run, the careful application and evaluation of this combined research and change approach should allow the creation of a method of ergonomic hazard assessment and reduction that can be applied throughout the transit industry.

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## Chapter 5 Data Sources for New York City Transit Worker Research

Michael Frumin

**Chapter Summary**

Work and health data sources abound for New York City transit workers and are described in detail herein. Linkage between job titles or other proxies for potential occupational exposures and health outcomes currently do not exist but are highly feasible. Current workers use only two health insurance companies (GHI and HIP) for health care, which would facilitate data aggregation and mining. Newer data instruments such as Daily Injury Reports and Safety Rule Dispute Resolution Forms offer promising new and time-sensitive tools to understanding safety conditions and impacts. Recent labor-management cooperation in this area bodes well for future collaboration in developing an improved understanding of the health and safety problems of transit workers. Although the use of current data sources for occupational health and safety surveillance and research is largely untested, sufficient data exists in usable and accessible forms to allow the development of an integrated knowledge base to enhance the analysis and understanding of occupational safety and health problems among transit workers.

The following data sources will be described in this chapter:

A. TWU Local 100 Member Database
B. MTA/NYCT Employee Database
C. Daily Injury Reports
D. Safety Rule Dispute Resolution Forms
E. Health Insurance Carriers
    E.1. GHI    E.2. HIP
F. Workers Comp
G. NYCERS Retiree Information
H. Walk-around Inspections
I. MTA/NYCT Medical Assistance Center (MAC) reports
J. Other MTA/NYCT Records
    J1 Employee Assault Records
    J2 Subways pre-operation defect and problem reports.
    J3 Buses pre-operation defect and problem reports.
    J4 Lost Time Incidents
K. HIPAA/Privacy Concerns

A primary advantage of gathering multiple databases that contain information related to a single topic or corpus is to be able to link those databases together. To that end, it is worth a brief discussion of how the databases detailed in this report might be linked with each other.

In order to link separate databases, common identifiers, or *keys*, must be identified. Some of these keys will be perfectly unique and are well suited for precise cross-referencing. Social Security Numbers, and MTA/NYCT's internal employee identifier, called Pass Number, are examples of such unique keys and should be able to provide near-perfect linkages.

When unique keys are lacking, other identifiers, such as name, address, and phone number, can be used. These will not provide perfect results, but the procedures for linking disparate data sources using imperfect keys are well defined and commonly used for public health research and other database exercises.

## A. TWU Local 100 Member Database

The TWU Local 100 maintains a database of vital information on each of its members. This database is kept up to date as a result of updates provided by NYCT and by communication between the Local and its members.

### 1. Data Fields

- Social Security Number
- Pass Number
- First Name
- Last Name
- Address (Street, City, State, Zip code)
- Phone Number
- Email Address
- Job Title (Job titles are represented by a numeric code, which has a lookup table for free-text descriptions)
- Responsibility Center Number
- MTA/NYCT internal work site identifier
- Work Status (Active, Retired, Terminated, Deceased, Active Retiree, Inactive?
- Sex
- Marital Status
- Date of Birth
- Date of Appointment
- Number of Children

### 2. Accessibility/Ownership

TWU 100 has this DB and extends perpetual effort, with the help of MTA/NYCT, to keep it updated. It should be fully accessible in electronic format.

### 3. Source

Information on this data source was gathered from James Mitchell of the TWU-100 Research Department and his co-workers.

## B. MTA/NYCT Employee Database

MTA/NYCT is presumed to maintain its own database on its employees, including TWU Local 100 members. The primary data that this database may contain that the Local union does not is a historical record of job titles for each member.

### 1. Data Fields (presumed)

- Pass Number

- Job Title
- Date of Appointment

**2. Accessibility/Ownership**

With the cooperation of MTA/NYCT, this data should be accessible in an electronic format.

**3. Source**

Information on this data source was gathered from the TWU-100 Research Department.

**C. Daily Injury Reports**

Since April 1, 2003, TWU Local 100 receives each day an email containing a number of Excel spreadsheets detailing injuries that have occurred on the job and have been called into NYCT's injury reporting hotline. These spreadsheets are automatically processed and placed in a database for use and analysis by TWU Local 100.

**1. Data Fields**

- Member's Social Security Number
- Member's Pass Number
  Link to the TWU Member Database (to show job title, for example)
- Member's Name
- Member's Address
- Member's Phone number
- Member's Regular Days Off
- Member's Dept
- Member's Division
- Member's Responsibility Center Number
- Date/Time of incident
- Location of incident -- free text
- Nature of Injury -- free text
- Body Parts -- free text
- Medical provider, if visited
- Return to work date
- Description of incident (how injured) -- "Employee Alleges..."
- Object Description (if foreign object involved)
- Supervisor Name, Pass Num, Phone
- Supervisor Date of notification
- Person Reporting name, phone, pass num
- Control Number
- Date/Time of report

#### 2. Accessibility/Ownership:

These are available from April 1, 2003 through the present time, and continue to be updated on a daily basis. The database is maintained by consultants to TWU Local 100 and are readily accessible in electronic formats.

#### 3. Source

Information on this data source was gathered from the author of this report, who has worked intimately with the Daily Injury Reports.

### D. Safety Rule Dispute Resolution Forms:

As part of their 2002-2005 collective bargaining agreement, TWU Local 100's members have the ability to stop or refuse any given task that the member deems unsafe. Any stoppage or refusal must be accompanied by the SRDR Form. This paper form is completed by hand and faxed to TWU Local 100 and to the MTA/NYCT Office of System Safety.

#### 1. Data Fields

- Member's Name
- Member's Title
- Member's Pass Number
- Member's Department/Division
- Supervisor's Name
- Supervisor's Pass Number
- Date of Incident
- Time of Incident
- Task being performed
- Location
- Description of rule violation or unsafe task
- Description of Supervisor's actions
- Description of Manager's actions
- Member's Signature
- Supervisor's Signature
- Manager's Signature

#### 2. Accessibility/Ownership

TWU-100 maintains a repository of these forms. Because these forms are completed on paper, they are not currently accessible in any electronic format. The hundreds of these forms on file could be manually entered into a database, and possibly coded according to industrial hazard standards.

### 3. Source

Information on this data source was gathered from Frank Goldsmith, Director Occupational Health, TWU 100, and from examination of a number of said forms.

## E. Health Insurance Carriers

For the last several decades, all of the approximately 40,000 members of TWU Local 100 have received health care coverage administered by either GHI or HIP. Traditionally, two thirds have elected to use GHI, while the other third has chosen the more family and retiree-oriented HIP.

Until recently, GHI and HIP were contracted by the independent, self-insured, Taft-Hartley Health Benefit Trust to administer the payment of healthcare claims for the members of TWU-100. As of June 2003, the Health Benefit Trust was dissolved, and the employer MTA/NYCT retained control over the healthcare coverage of its employees.

These organizations have indicated to myself and to TWU officers a willingness to cooperate and provide data for the sake of research. However, any data that these health insurance carriers may provide in the future must be authorized by MTA/NYCT.

## E1. Group Health Incorporated (GHI)

The health insurance carrier for 2/3 of the Local's members, GHI maintains an extensive electronic database of diagnoses made by health care providers as well as procedures performed and claims paid. I have not as of yet been able to examine the precise structure of GHI's databases, but conversations with its Information Technology staff have indicated that they could provide the following information.

### 1. Data Fields

Identifying information for each member

- Name
- Address
- SSN
- Gender
- Age
- Duration of coverage
- Member ID (Internal to GHI)

Diagnoses

- Member ID
- Date
- Diagnoses (Coded in industry standard ICD-9)

Claims – including inpatient, outpatient, and hospital

- Member ID

- Date
- Procedure (coded by industry standard)
- Dollar amount paid

**2. Accessibility/Ownership:**

GHI's systems are fully electronic and modernized. Records up to four years old are kept in easily accessible online databases, while older records are stored on digital tape backups. GHI has the capability to provide all of this data for the sake of study, but has stated that it will need to be compensated for the cost of doing so.

**3. Source**

Information on this data source was gathered from John Castronovo, Director Account Management, GHI and Ellen DeYoung, Director Information Technology, GHI.

**E2. HIP**

Current understanding is that HIP data are analogous to those of GHI. A more detailed description is pending.

**F. Workers Compensation**

Employees that are injured on the job often receive treatment through the Workers Compensation system. This system involved a fair amount of paperwork that could be used as a source of health data.

**1. Forms/Fields**

All of the following forms contain standard administrative fields and identifying fields for the employer, the employee, insurance carrier, and treating physician(s). Such fields follow:

- Name
- Sex (for employee only)
- Social Security Number (for employee only)
- Date of Birth (for employee only)
- Telephone Number
- Address
- Phone Number
- Filer of Report
- Date of Report

Select forms, which contain data on the cause and nature of the employee's ailment, have been attached to this report for full examination:

- Employer's Report Of Work-Related Accident/Occupational Disease (Form C2):

Available online at http://www.wcb.state.ny.us/content/main/forms/c2.pdf

- Employee's Claim for Compensation (Form C3):
  Available online at http://www.wcb.state.ny.us/content/main/forms/c3.pdf

- Attending Doctor's Report and Carrier/Employer Billing Form:
  Available online at http://www.wcb.state.ny.us/content/main/forms/c4.pdf

#### 2. Accessibility/Ownership

In all likelihood, workers comp records received by TWU Local 100 and/or MTA/NYCT are all on paper. They are of standard format and could, with proper resources, be entered into electronic databases to be used in conjunction with the other data sources mentioned here. The C4 form is always filed with the employer, and should be archived by MTA/NYCT and available for processing.

#### 3. Source

Information on this data source was gathered from Joel Fredericson, Employee Benefits Department, TWU-100, and from examination of specific Workers Comp forms.

### G. New York City Employee Retirement System (NYCERS)

NYCERS is the retirement administration for all New York City public employees. TWU Local 100 members join NYCERS concurrently with registering for employment at MTA/NYCT, except those working for the private Queens bus lines (MABSTOA). NYCERS maintains a limited amount of electronic information on its members. Most relevant to this study is disability status for each current and retired member. I have not as of yet been able to examine the precise structure of NYCERS' databases, but conversations with its Information Technology staff have indicated that they could provide the following information.

#### 1. Data Fields:

Identifying information for each member

- Name
- Address
- SSN
- Gender
- Age
- Duration of coverage

Dates and length of NYCERS membership
Year-end pensionable earnings
Current/last job title
Disability information – stored as free (i.e. non-coded) text

- Nature of disability

- Description of final determination by treating physician

### 2. Accessibility/Ownership

NYCERS has indicated that given proper legal approval they could provide these data for use in research studies.

### 3. Source

Information on this data source was gathered from Michael Goldsen, Director of Operations, NYCERS

## H. Walk-around Inspections

At the time of writing, the TWU Local 100's Safety & Health department and MTA/NYCT's Office of System Safety (OSS) are in the process of developing a Procedural Instruction for conducting monthly safety committee meetings and walk-around inspections. Part of this instruction will include the use of a standardized coversheet and the faxing of this coversheet as well as list of all issues discussed by the safety committee to both the Local and OSS.

### 1. Data Fields

Cover Sheet Data

- Date
- Responsibility Center Number
- Location
- Division/Department
- Pass Numbers of participating committee members
- Key Hazards Cited (checklist of selected hazards)

Issue Status Data

- Date issue opened
- Priority
- Description
- Requesting individual
- Responsible party
- Status
- Date issue closed

### 2. Accessibility/Ownership

Once the procedures for walk-around inspections and safety committee members are in place, cover sheets and issue data, all filled out on paper forms, will be faxed to TWU safety officers and to MTA/NYCT's OSS. These forms could be entered into electronic databases for analysis in combination with other data sources listed here.

### 3. Source

Information on this data source was gathered from Frank Goldsmith, Director Occupational Health, TWU-100 and Cheryl Kennedy, Vice President for System Safety, MTA/NYCT.

## I. MTA/NYCTA Medical Assistance Center (MAC) Reports

The employer maintains a set of Medical Assistance Centers for conducting in-house examinations of employees. Most employees receive checkups/physicals bi-yearly, but those in "safety sensitive positions" – who deal with the riding public and the maintenance of riding vehicles – visit a MAC yearly around their birthday, and after any sick days.

MAC examiners fill out and file a Request for Medical Examination of Employee form ("G-46"), and provide other forms to workers' personal physicians for additional tests/exams/treatment.

### 1. Data Fields

The G-46 Form includes:

Identifying data for member:

- Name
- Sex
- Pass #
- Telephone
- Address
- Date of Birth
- Social Security Number

Employment Information

- Department
- Location
- Responsibility Center #
- Appointment Date
- Tour of Duty
- Regular Days Off
- Current Assignment Date
- Job Title (code)
- Supervisor Name/Pass#

Examination Information:

- Reasons for Service(s) Requested
- Examination Date/Time
- Revisit Required? Revisit Date/Time
- Determined Work Status

- Alleged IOD/Alleged Non-IOD
- Eyeglasses Required(?)
- ICD-9 Code
- Comments

**2. Accessibility/Ownership:**

According to TWU source, MTA/NYCT's Department of Employee Eligibility computerizes the MAC G-46 forms for the sake of gathering and analyzing statistics. Thus, with the employer's cooperation, this rather large source of current and past health information should be readily available in electronic format.

**3. Source**

Information on this data source was gathered from Jose Lagoa, TWU-100, and from examination of said G-46 form.

## J. Other MTA/NYCT Records

MTA/NYCT is a massive, and massively bureaucratic organization. As such, it is known to keep extensive records, both on paper and electronically, detailing many facets of its operation.

Although this author has not had the opportunity to inquire with MTA/NYCT about the specifics of these various records sets, experiential knowledge of TWU-100 members and officers indicates that they exist and are used regularly by the employer.

Some of these record sets that are believed to be applicable to the health and safety of its employees, the members of TWU-100, include:

J1. Employee assault records
J2. Pre-operation subway car defect and problem reports.
J3. Pre-operation bus defect and problem reports.
J4. Lost time accident reports

**1. Accessibility/Ownership**

These are records internal to MTA/NYCT but could be made available and used for research purposes in the proposed labor/management joint health study.

## K. Health Insurance Portability and Accountability Act (HIPAA)

HIPAA provides for the protection of individuals privacy by restricting the release of personal and private information by health insurance carriers and healthcare institutions. It does, however, have certain clauses allowing for the unauthorized release of such data for the sake of research and public health study. Those exceptions are documented in the below excerpts from relevant rules and regulations. Interested readers are urged to consult appropriate websites for for information about HIPAA.

With proper institutional support from a qualified medical research institution, a secure data store could be created to receive, aggregate, and analyze private health information. It could use standard database techniques to link together the different data sources mentioned above and provide access to interested researchers while allowing them to avoid contact with protected private information.

**Excerpts from HIPAA documentation:**

- Extensive Online Documentation
  - US Dept Health & Human Services Office of Civil Rights HIPAA Page
  - [1] US DHHS OCR summary of HIPAA Privacy Rule
  - [2] CDC and MMRW's guide to HIPAA Privacy Rule and Public Health
  - [3] Privacy Rule
  - [4] *Law in Public Health Practice, Chapter 6: Interaction Between Public Health Practitioners and Legal Counsel*, Oxford University Press, 2003, pp 123-142.
- Findings in Privacy Rule summaries
  - In [1] and [2] I found encouraging descriptions of provisions in the Privacy Rule that should enable the desired information disclosure.
  - [1] states, under Permitted Uses and Disclosures, item (5) Public Interest and Benefit Activities (bold added by this author):
    - **Public Health Activities** Covered entities may disclose protected health information to: (1) public health authorities authorized by law to collect or receive such information for preventing or controlling disease, injury, or disability and to public health or other government authorities authorized to receive reports of child abuse and neglect; (2) entities subject to FDA regulation regarding FDA regulated products or activities for purposes such as adverse event reporting, tracking of products, product recalls, and postmarketing surveillance; (3) individuals who may have contracted or been exposed to a communicable disease when notification is authorized by law; and (4) employers, regarding employees, when requested by employers, for information concerning a work-related illness or injury or workplace related medical surveillance, because such information is needed by the employer to comply with the Occupational Safety and Health Administration (OHSA), the Mine Safety and Health Administration (MHSA), or similar state law. See OCR "Public Health" Guidance; CDC Public Health and HIPAA Guidance.
    - **Research** "Research" is any systematic investigation designed to develop or contribute to generalizable knowledge.37 The Privacy Rule permits a covered entity to use and disclose protected health information for research purposes, without an individual's authorization, provided the covered entity obtains either: (1) documentation that an alteration or waiver of individuals. authorization for the use or disclosure of protected health information about them for research purposes has been approved by an Institutional Review

Board or Privacy Board; (2) representations from the researcher that the use or disclosure of the protected health information is solely to prepare a research protocol or for similar purpose preparatory to research, that the researcher will not remove any protected health information from the covered entity, and that protected health information for which access is sought is necessary for the research; or (3) representations from the researcher that the use or disclosure sought is solely for research on the protected health information of decedents, that the protected health information sought is necessary for the research, and, at the request of the covered entity, documentation of the death of the individuals about whom information is sought.38 A covered entity also may use or disclose, without an individuals. authorization, a limited data set of protected health information for research purposes (see discussion below).
See OCR "Research" Guidance; NIH Protecting PHI in Research.

- [2] states
  - the Privacy Rule expressly permits PHI to be shared for specified public health purposes. For example, covered entities may disclose PHI, without individual authorization, to a public health authority legally authorized to collect or receive the information for the purpose of preventing or controlling disease, injury, or disability [45 CFR 164.512(b)].
  - Public health. PHI can be disclosed to public health authorities and their authorized agents for public health purposes including but not limited to public health surveillance, investigations, and interventions.
    Health research. A covered entity can use or disclose PHI for research without authorization under certain conditions, including 1) if it obtains documentation of a waiver from an institutional review board (IRB) or a privacy board, according to a series of considerations; 2) for activities preparatory to research; and 3) for research on a decedent's information.
- [2] also provides some useful definitions
  - **Public health authority.** An agency or authority of the United States, a state, a territory, a political subdivision of a state or territory, or an Indian tribe, or an individual or entity acting under a grant of authority from or contract with such public agency, including the employees or agents of such public agency or its contractors or individuals or entities to whom it has granted authority, that is responsible for public health matters as part of its official mandate [45 CFR 164.501].
  - **Research.** A systematic investigation, including research development, testing, and evaluation, designed to develop or contribute to generalizable knowledge [45 CFR -164.501].

- Findings in actual Privacy Rule

**§ 164.512 Uses and disclosures for which consent, an authorization, or opportunity to agree or object is not required.**

A covered entity may use or disclose protected health information without the written consent or authorization of the individual as described in §§ 164.506 and 164.508, respectively, or the opportunity for the individual to agree or object as described in § 164.510, in the situations covered by this section, subject to the applicable requirements of this section. When the covered entity is required by this section to inform the individual of, or when the individual may agree to, a use or disclosure permitted by this section, the covered entity's information and the individual's agreement may be given orally.

(b) Standard: uses and disclosures for public health activities.

(1) Permitted disclosures. A covered entity may disclose protected health information for the public health activities and purposes described in this paragraph to:

(i) A public health authority that is authorized by law to collect or receive such information for the purpose of preventing or controlling disease, injury, or disability, including, but not limited to, the reporting of disease, injury, vital events such as birth or death, and the conduct of public health surveillance, public health investigations, and public health interventions; or, at the direction of a public health authority, to an official of a foreign government agency that is acting in collaboration with a public health authority;

(i) Standard: uses and disclosures for research purposes.

(1) Permitted uses and disclosures. A covered entity may use or disclose protected health information for research, regardless of the source of funding of the research, provided that:

(i) Board approval of a waiver of authorization. The covered entity obtains documentation that an alteration to or waiver, in whole or in part, of the individual authorization required by §164.508 for use or disclosure of protected health information has been approved by either:

(A) An Institutional Review Board (IRB), established in accordance with 7 CFR 1c.107, 10 CFR 745.107, 14 CFR 1230.107, 15 CFR 27.107, 16 CFR 1028.107, 21 CFR 56.107, 22 CFR 225.107, 24 CFR 60.107, 28 CFR 46.107, 32 CFR 219.107, 34 CFR 97.107, 38 CFR 16.107, 40 CFR 26.107, 45 CFR 46.107, 45 CFR 690.107, or 49 CFR 11.107; or

(ii) Reviews preparatory to research. The covered entity obtains from the researcher representations that:

(A) Use or disclosure is sought solely to review protected health information as necessary to prepare a research protocol or for similar purposes preparatory to research;

(B) No protected health information is to be removed from the covered entity by the researcher in the course of the review; and

(C) The protected health information for which use or access is sought is necessary for the research purposes.

(2) Documentation of waiver approval. For a use or disclosure to be permitted based on documentation of approval of an alteration or waiver, under paragraph (i)(1)(i) of this section, the documentation must include all of the following:

(i) Identification and date of action. A statement identifying the IRB or privacy board and the date on which the alteration or waiver of authorization was approved;

(ii) Waiver criteria. A statement that the IRB or privacy board has determined that the alteration or waiver, in whole or in part, of authorization satisfies the following criteria:

(A) The use or disclosure of protected health information involves no more than minimal risk to the individuals;

(B) The alteration or waiver will not adversely affect the privacy rights and the welfare of the individuals;

(C) The research could not practicably be conducted without the alteration or waiver;

(D) The research could not practicably be conducted without access to and use of the protected health information;

(E) The privacy risks to individuals whose protected health information is to be used or disclosed are reasonable in relation to the anticipated benefits if any to the individuals, and the importance of the knowledge that may reasonably be expected to result from the research;

(F) There is an adequate plan to protect the identifiers from improper use and disclosure;

(G) There is an adequate plan to destroy the identifiers at the earliest opportunity consistent with conduct of the research, unless there is a health or research justification for retaining the identifiers, or such retention is otherwise required by law; and

(H) There are adequate written assurances that the protected health information will not be reused or disclosed to any other person or entity, except as required by law, for authorized oversight of the research project, or for other research for which the use or disclosure of protected health information would be permitted by this subpart.

(iii) Protected health information needed. A brief description of the protected health information for which use or access has been determined to be necessary by the IRB or privacy board has determined, pursuant to paragraph (i)(2)(ii)(D) of this section;

(iv) Review and approval procedures. A statement that the alteration or waiver of authorization has been reviewed and approved under either normal or expedited review procedures, as follows:

(A) An IRB must follow the requirements of the Common Rule, including the normal review procedures (7 CFR 1c.108(b), 10 CFR 745.108(b), 14 CFR 1230.108(b), 15 CFR 27.108(b), 16 CFR 1028.108(b), 21 CFR 56.108(b), 22 CFR 225.108(b), 24 CFR 60.108(b), 28 CFR 46.108(b), 32 CFR 219.108(b), 34 CFR 97.108(b), 38 CFR 16.108(b), 40 CFR 26.108(b), 45 CFR 46.108(b), 45 CFR 690.108(b), or 49 CFR 11.108(b)) or the expedited review procedures (7 CFR 1c.110, 10 CFR 745.110, 14 CFR 1230.110, 15 CFR 27.110, 16 CFR 1028.110, 21 CFR 56.110, 22 CFR 225.110, 24 CFR 60.110, 28 CFR 46.110, 32 CFR 219.110, 34 CFR 97.110, 38 CFR 16.110, 40 CFR 26.110, 45 CFR 46.110, 45 CFR 690.110, or 49 CFR 11.110);

(B) A privacy board must review the proposed research at convened meetings at which a majority of the privacy board members are present, including at least one member who satisfies the criterion stated in paragraph (i)(1)(i)(B)(*2*) of this section, and the alteration or waiver of authorization must be approved by the majority of the privacy board members present at the meeting, unless the privacy board elects to use an expedited review procedure in accordance with paragraph (i)(2)(iv)(C) of this section;

(C) A privacy board may use an expedited review procedure if the research involves no more than minimal risk to the privacy of the individuals who are the subject of the protected health information for which use or disclosure is being sought. If the privacy board elects to use an expedited review procedure, the review and approval of the alteration or waiver of authorization may be carried out by the chair of the privacy board, or by one or more members of the privacy board as designated by the chair; and

(v) <u>Required signature.</u> The documentation of the alteration or waiver of authorization must be signed by the chair or other member, as designated by the chair, of the IRB or the privacy board, as applicable.

# Chapter 6 Current and Planned Transit Occupational Health and Safety Research in New York City

Steven Markowitz MD

**Summary**

Occupational health and safety research of transit work in New York City has attracted little interest until recently. Over the past five years, however, there has been emerging research activity by New York-based university scientists in documenting occupational health problems of such workers. Current or proposed research subjects are eclectic and address, in separate studies, specific exposures such as air pollution, repetitive trauma, whole body vibration, stress, and select chemical exposures, and their associated health outcomes. Integration of the interests and skills of university scientists into an organized multi-disciplinary research program would accelerate the progress of research in this area and increase the likelihood that research findings will be responsive to expressed needs and will translate into enhanced occupational safety and health for transit workers.

In this chapter, we describe current and/or planned research that relates to the occupational health and safety of New York City transit workers. These descriptions are based on voluntary submissions by research scientists and have been modified only slightly to promote standard reporting. The list is inclusive but not intended to be exhaustive. No judgments about the quality or importance of the studies are included. The status of the studies will change over time, and readers are urged to contact the research scientists directly to learn of progress of any specific study.

### 1. Air pollution exposures and respiratory function among subway and bus commuters

**Investigators:** Steven Chillrud (LDEO of Columbia University); Patrick Kinney (Mailman School of Public Health of Columbia University); Paul Brandt-Rauf (MSPH), Yair Hazi (MSPH)
**Proposed funding agency:** pending
**Proposed time frame:** 4 year study
**Total cost**: not available

**Aim**

The objectives of this study are to (1) measure and compare exposures, effect biomarkers, and lung function levels in subway and bus commuters in NYC and (2) to examine the relative importance of particulate metals, black carbon, and ultra fine particles in the development of inflammatory and oxidative stress responses measured in exhaled breath condensate.

**Background and prior results**

Combustion emissions from diesel bus engines result in relatively high levels of ultra fine particle numbers and concentrations of black carbon, both of which have been hypothesized to be related to cardiovascular and respiratory health outcomes, including premature mortality, via inflammatory response and/or oxidative stress. Generation of steel dust in underground subway systems results in elevated commuter exposures to transition metals (Fig 1 and 2). Exposures to airborne particulate matter enriched in transition metals has also been hypothesized to potentially play a role in adverse cardiovascular and respiratory health outcomes via inflammatory response and/or oxidative stress.

**Study Design**

We would look at biomarkers of inflammation and oxidative stress in exhaled breath condensate and compare that to exposure levels of transition metals, black carbon and ultrafine particle numbers. Based on prior results we expect relatively large differences in exposures to the different pollutants depending on whether they commute by bus or subway.

Personal exposures to metals and black carbon will be measured on filters collected on customized air monitors worn by the subjects. Personal exposures to ultrafine particle numbers will be estimated by particle counting on buses, subways, and at homes.

We would want to work with Straphangers Association and community groups in the outer boroughs to identify commuters who travel primarily by bus or subway to work. Expected number of subjects would be 200 (100 bus riders and 100 subway riders). Also want to compare within the same type of transport short commute rides (< 20 minute rides) to medium (20 minutes < ride < 60 minutes) and long commute rides ( ride > 90 minutes). Especially interested in comparing exposures on MTA buses with pollution control to exposures on private bus companies that may have much higher exposures.

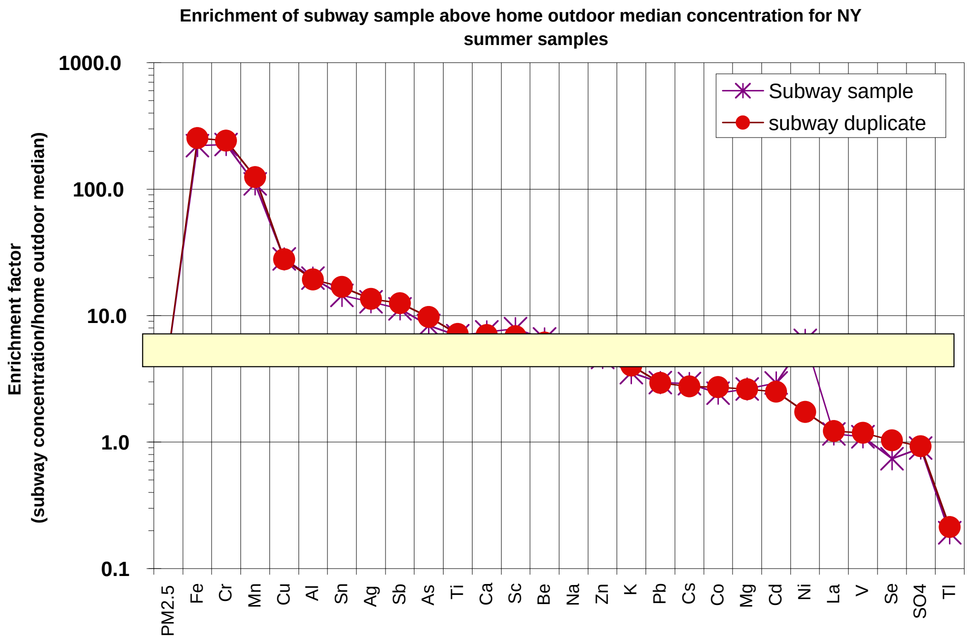


**Fig. 1**: Enrichment of subway samples as defined by the ratio of air concentration in a 8-hr samples from the NYC subway to the median air concentration measured on the set of 41 home outdoor locations throughout NYC collected in the summer of 1999 in the TEACH study. The transparent box is placed to show which elements are elevated above and below the enrichment factor for $PM_{2.5}$. Particulate concentrations of Fe and Cr are highly correlated to Mn and their slopes are consistent with these three metals coming from steel dust generated in the subway systems.

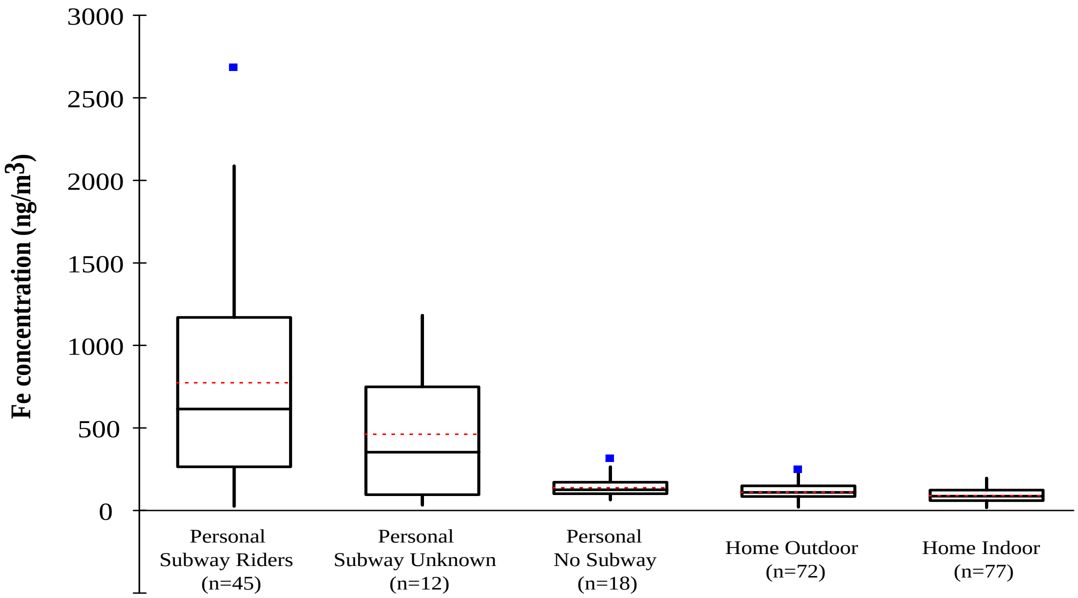


**Fig 2**. Distribution of airborne Fe in subsets of personal samples, home outdoor samples, and home indoor samples collected in winter and summer field seasons. Similar results for Mn and Cr (data not shown). The personal samples were broken into three subsets: (1) for students that had reported that they had ridden the subway; (2) for students for which we did not have the information (e.g., lost or incompletely filled out); (3) for students reported that they had not ridden the subway. The number of measurements in each category is given in the x-axis labels. The solid line represents the median, the red dashed line represent the average, and the box top and bottom represent the $75^{th}$ and $25^{th}$ percentile concentrations, respectively. The tips and tails of the whiskers represent the most extreme data point within an inner fence (not marked on diagram) located at 1.5 x the inter-quartile range (IQR). Filled square symbols show moderate outliers or data points that are located between the inner fence and an outer fence defined as 3 x IQR.

### 2. Air and particle dynamics in the NYC subway system

**Investigators**: Steven Chillrud (LDEO of Columbia University), David Brown (Argonne National Lab), James Simpson (LDEO), Peter Schosser (LDEO) and Dale Chayes (LDEO).
**Proposed funding agency:** pending
**Proposed time frame:** 4 year study
**Total cost**: not available

**Aim**

The objectives of this study would be to improve understanding of air movement and air exchange rates on air composition, including aerosol particles, and particle dispersion in representative components of the NYC subway system.

**Background**

Air exchange rates, which are strongly influenced by train movement, have a major impact on air and aerosol composition in the NYC subway system. Understanding the role of ventilation rates and train movement on air and particle movement in the NYC subway system is critical to gain a comprehensive understanding of the factors influencing air quality in the stations and tunnels as well as for designing ventilation improvements to the system. Models of air and particle dispersion for subway systems that would result from this work would also have application to planning and response for hazardous material emergencies in the subway.

**Study Design**

Time series measurements of air velocity, temperature, relative humidity, size segregated particle abundance, and gas concentrations would be collected for a number of tunnel environments to improve models of air and particle dynamics in a number of subsurface sections of the NYC transit system. Mean residence time of aerosols could also be derived through measurement of radon daughter activities. Tracer release experiments could also be designed to help test and refine models of air and aerosol particle dispersion. An initial assessment would be derived by deploying monitoring equipment (size segregated particle counters, gas sensors, temperature sensors) on electric and diesel work trains that systematically traverse the NYC subway system as part of routine operations.

Air flow will be characterized using arrays of up to 50 sonic anemometers (instrumentation capable of monitoring very low winds and turbulence), together with temperature and relative humidity sensors, which would be deployed in subway tunnels in selected sites, together with a limited number of aerosol particle counters and gas sensors.

Concentrations of gases with significant underground sources within the subway would be measured, including $CO_2$ (human respiration and diesel work trains), methane (humans) and CFCs (subway air conditioners) to better understand the transport of these materials and the exchange rates of air between different parts of the system and the outdoors. Variations in other gas levels could also be explored (sulfur hexafluoride, ozone, CO). Size-segregated particle counters would be used to collect time series of particle numbers from 0.3 µm to above 10 µm, the spectrum of particle sizes in steel dust generated by subway activities. Condensation nuclei counters would be used to determine ultra-fine particle number concentrations as tracers of local input of air with combustions emissions (input of above ground air or emissions from diesel work trains). These data would allow dispersion modeling of other types of particles.

Size segregated particulate matter will also be collected on filters in areas with different air exchange rates to determine variations in chemical composition, including mass, black carbon, and a suite of elements by high resolution inductively coupled mass spectrometry.

David Brown at Argonne National Lab would oversee modification and implementation of a subway system computer model for NYC. This model for predicting air flow and contaminant transport was developed originally for Washington DC. A long-term goal would be to have this NYC subway model linked to real time subway air velocity data and exterior meteorological data (additional funding required).

Peter Schlosser's group at LDEO/Columbia University could conduct purposeful tracer release experiments with sulfur hexafluoride gas (chemically and biologically inert) to further refine and test numerical models of NYC subway air exchange.

### 3. Epidemiologic study of health effects in transit workers from chronic exposures to manganese, chromium, iron and PAH compounds

**Investigators**: PI's: Paul Brandt-Rauf (Columbia University Mailman School of Public Health) and Steven Chillrud (LDEO of Columbia Univ); Co-Investigators: Joe Graziano (MSPH), Pat Kinney (MSPH), James Simpson (LDEO), Regina Santella (MSPH), Saugata Datta (LDEO)
**Proposed funding agency:** pending
**Proposed time frame:** 5 year study
**Total cost**: not available

**Aim**

The objectives of this study are to (1) develop time-weighted exposure estimates for manganese, chromium, iron and polycyclic aromatic hydrocarbon (PAH) compounds, (2) to test whether biomarkers of respiratory inflammation and oxidative stress are associated with time-weighted exposures, and (3) to test whether respiratory health status and/or lung function are associated with time-weighted exposures. The bus drivers are expected to be able to act as a control group for the metal exposures of subway workers as well as providing a group with elevated exposure to PAH exposures in comparison to subway workers.

**Background**

There is increasing interest in potential health effects of airborne exposures to manganese, chromium, iron, and PAHs at relatively low levels, including respiratory, neurodegenerative, cardiovascular, and cancer outcomes. The generation of steel dust from subway operations and PAH exposures from traffic emissions result in transit workers having chronic exposures to these compounds.  Although the levels of these metals to which subway workers are exposed are probably more than two orders of magnitude below current OSHA standards, they are more than 100 times above outdoor levels.  Thus, there is particular concern regarding potential chronic health effects of long-term exposures.  This proposed study is a follow-up of an on-going pilot study funded by the Columbia NIEHS Center that is measuring airborne exposures to metals and looking for biomarkers of exposure in blood and urine in 40 subway workers.  We are currently in the recruitment phase of the pilot study.

**Study Design**

The goal of the exposure assessment phase would be to understand the relative exposures of the different job titles and to use knowledge of historical changes in transit practices and technology to develop estimates of a range of time-weighted exposure categories.   Workers would be stratified into time-weighted exposure levels taking into effect current exposures for different job titles based on measured personal air samples, number of years in the system and their historical job duties, and the changes in practices and technology over those years (e.g., for subways: installation of air conditioning on trains, change in use of electric motor for majority of breaking power, change in brake shoe materials; for buses: change in fuel type and pollution control technology; installation of air conditioning).   In addition to being used to investigate relationships between biomarkers and health outcomes with time-weighted exposures for individual workers, these novel exposure metrics will also be used investigate the potential role of cumulative exposures on health outcomes on grouped data.  Our aim is to classify exposures into strata defined on the basis of both the level and duration of exposure, as outlined in the following matrix:

| Years of job experience | Yrs < 2 | 2<Yrs<7 | 7 < Yrs < 12 | 12<Yrs<25 | Yrs > 25 |
|---|---|---|---|---|---|
| Bus drivers (n= 100) | n =30 | n =30 | n =30 | n =30 | n =30 |
| Subway -Low exposure (n= 150) | n =30 | n =30 | n =30 | n =30 | n =30 |
| Subway-Medium exposure (n = 150) | n =30 | n =30 | n =30 | n =30 | n =30 |
| Subway -High exposure  (n = 150) | n =30 | n =30 | n =30 | n =30 | n =30 |

To investigate current exposures, and to validate the exposure model, personal air samples and biological samples (blood and urine) will be collected on workers from a range of different job titles including sub groups of smokers and non-smokers, women and men.   To have sufficient power for the different subgroups, we expect to need a study population of 650 subjects.

Exposure and bio-monitoring: Personal air sampling, stationary air sampling, and questionnaires will be employed to characterize steel dust exposure levels associated with different job titles, activities, locations, and obtain the history of job titles the workers have had during their careers.  Personal sampling will employ a portable, battery operated pump housed in a customized under-the-arm harness, based on equipment we have recently developed for this purpose.  Stationary samplers (filters and particle counters) will be placed at selected locations in the subway system and on buses for comparison purposes.  At the end of the personal air sampling, participants will also be requested to provide a urine sample and a physician will draw 30 ml of blood.  Whole blood, serum and urine samples will be stored at –20 °C until analyses can be performed.  We will measure urine and serum or whole blood concentrations of Mn and Cr.  We are not aware of any prior study that has quantified the absolute amount of manganese absorbed after airborne exposure in either humans or animals (20). Cotinine levels in the blood will also be measured to control for possible exposures to metals in environmental tobacco smoke. Creatinene will be measured in urine to control for degree of hydration. We also will consider the use of iron isotopes measured in blood samples as potential indicators of the source of Fe in the blood (21). Synchrotron Analysis may be used to determine the oxidation states of Fe, Mn, and Cr in airborne particulate matter.

To assess health impacts of Mn, the following clinical health outcomes will be measured:

1. Brief neurological exam focusing on eye-finger coordination, hypomotility, exaggerated tendon reflexes, hypermyotonia, finger tremor, adiadochokinesis, speech disturbance, walking difficulty, etc.
2. Digit Span Forwards and Backwards for memory and attention
3. Benton Test of Visual Retention test of non-verbal memory by reproducing ten figures
4. Purdue Grooved Pegboard Test of visual-motor coordination by timing the fitting of notched pegs into a board
5. Steadiness Tester both the Groove-Type Steadiness Tester for measurement of hand action tremor and the Nine Hole Steadiness Tester for intention tremor

To assess biomarkers of Cr effects, we will analyze blood samples for evidence of DNA damage based on tests for DNA-protein cross-linking.

For assessing effects of Fe and PAH compounds, we will measure biomarkers of inflammation and oxidative stress in exhaled breath condensate. In addition, we will measure DNA-PAH adducts in lymphocytes collected from the blood, and PAH metabolites collected in urine. We would also measure ultra-fine particle number concentrations on buses and subway locations as a potential confounding pollutant with potential for causing inflammatory response (especially for bus drivers).

### 4. Knee pain in bus drivers

**Investigators:** George Friedman-Jimenez, MD and Jean Xiao, MD (Bellevue / NYU Occupational and Environmental Medicine Clinic)
**Proposed funding agency:** not available
**Proposed time frame:** 1 year study
**Total cost**: not available

### Background

Over the years, it has come to the attention of the Transport Workers' Union that bus drivers commonly suffer from knee pain. It is their impression that right knees are more affected than left knees. This suggests that the pain is caused and/or aggravated by physical factors related to frequent forceful depression of the brake pedal required to allow the door to be opened. A previous investigation by Jonathan Dropkin, an ergonomist from Mt. Sinai, suggested that the force and repetitiveness of the effort, and perhaps improper placement of the drivers' seats in relation to the brake pedals, could be causing or contributing to the problem. It is not clear whether the knee pain is due to knee osteoarthritis, tendinitis, cartilage injuries, ligament injuries, or other knee pathology.

The pain tends to be chronic, occurring and worsening over months and years. Some drivers have been disabled by knee pain, and some have required knee replacement surgery for advanced osteoarthritis.

Evidence of the relationship between knee pain and the ergonomics of the bus drivers' seats and brake pedals is anecdotal at present. With assistance from the Bellevue / NYU Occupational and Environmental Medicine Clinic, the TWU has administered a large number of brief, anonymous, knee pain questionnaire surveys to bus drivers. The purpose of the survey is to determine whether pain is more frequent in the right knee than the left knee, what diagnoses have been made by the drivers' personal physicians, and basic demographic factors that could be related to knee pain.

**Status**

The survey is currently in progress. If the survey confirms the impressions of the drivers that there is more knee pain than would be expected, the TWU and the Bellevue / NYU Occupational and Environmental Medicine Clinic will propose a research study to further investigate the problem. This would be an epidemiologic study of knee pain and physical / ergonomic factors in bus drivers. The objectives would be to characterize the knee diagnoses more precisely, and to test hypotheses of association of specific knee diagnoses with specific modifiable ergonomic variables related to the geometry of the drivers' seats and pedals. If specific ergonomic risk factors are identified, hypotheses will be generated regarding ergonomic modifications that would be expected to address the problem. The results and hypotheses generated would then be used to propose a clinical trial of a preventive intervention, which would require support of both labor and management, to test the effectiveness of the most promising solution for the problem.

### 5. Whole-body vibration (WBV) exposure and Seat Ergonomic Assessment (WBVSEA)

**Investigators:** Eckardt Johanning MD, M.Sc. – Occupational and Environmental Health Science, Albany, New York; Dr. Fischer, Dr. Christ; BIA – Institute for Worker Safety, Germany; Paul Landsbergis, PhD, Mt. Sinai School of Medicine, N.Y.
**Proposed funding agency:** pending
**Proposed time frame:** 3 year study
**Total cost**: $300,000

**Background**

Prolonged and excessive whole body vibration (WBV) is considered a general physical stressor and has been associated with a variety of occupational health disorders, especially of the musculoskeletal system, the spine and lower back. Two forms of vibration exposure relevant for acute or chronic occupational health problems are known: Whole-body vibration and segmental or hand-transmitted vibration. Long-term whole-body vibration stemming from engines and vehicles has been identified as an important mechanical stressor causing early and accelerated degenerative spine disorders, leading to back pain and prolapsed discs ((Dupuis & Zerlett, 1987; Bovenzi & Hulshof 1999; (Johanning, 2000). Poor body posture, inadequate seat support and muscle fatigue have been described as co-factors in the pathogenesis of musculoskeletal disorders of the spine in operators/drivers. High prevalence of back pain, early degenerative changes of the spine and herniated lumbar disc problems have been consistently reported among vibration exposed vehicle operators: tractor drivers, truck and interstate bus drivers, crane or earth moving equipment operators and helicopter pilots. Also among operators of rail-bound vehicles (i.e., railroad and subway trains) with relatively low vertical but higher lateral vibration and frequent high shocks (irregular vibration) the prevalence of back complaints and disorders appears to be high (Johanning 1991) (Johanning et al., 1991) (Johanning et al., 1996; Johanning et al., 2002), (Johanning, et al., 2004)).

**Methods**

1. Vibration exposure

The aim of the field measurements will be to study the physical time history of the acceleration a(t) ("vibration and shock exposure") using current international and national guidelines (ISO 2631 et al., and ANSI) and state of the art instrumentations/equipment. The most important assessment is the acceleration between seat cushion and the human body of the seated person (bus or subway operator (motorman)). Detailed human whole-body vibration (WBV) exposure measurements will be done during normal revenue service with standard and widely used vehicles during an entire, typical work shifts. In addition to the basic rms vibration values for each vertical, lateral and for-aft axis, the Crest Factors, the Seat Effective Amplitude Transmissibility factor, the Power Spectral Densities, the Maximum Transient Vibration Value and the Vibration Dose Values will be calculated and reported to better describe irregular vibrations and shocks, and provide important information for any prevention intervention and improved technical design.

2. Seating posture and seat/cab design

Key ergonomic factors of the bus or subway cab and seat characteristics will be assessed. Postural seating stress by the vehicle operator will be assessed with innovative testing apparatus the CEULA system (BIA, Germany). This is a device that measures real-time body posture status and changes over time and calculates spinal rotation and movement for three axes depending on job tasks and over the entire time period (job shift) to assess postural stress.

3. Health symptoms questionnaire

With a standardized health symptoms and work condition questionnaire the subjective rating of current seat and cab design features and failures will be assessed, in addition to health complaints and medical disorders related to vibration and ergonomic seat/cab design.

4. International Comparison of Transportation System

The current cab and seat design of MTA vehicles will be compared to other systems in Europe and Canada regarding ergonomic design features (adjustability and suspension systems, etc.)

**Preliminary results**

A MTA subway operator study from the late 80s showed relative high level of vibration exposure and a higher rate of lower back disorders among subway operators compared with two controls (Johanning et al., 1991). In a limited pilot study in 2003 and 2004 assessing subway and bus operator vibration and shock exposure using newer and up-dated ISO guidelines, results of measurements of two newer vehicles suggest that the operators continue to be exposed to considerable vibration and shock over a typical work shift. Although the vertical axis basic vibration values were in a range that are comparable to other road and rail vehicles in the lower and mid-range, the multi-axis and shock evaluation indicated a possible exposures risk. Furthermore, a recent epidemiological study regarding railroad engineers, who had similar WBV exposures and job tasks showed that the rate of musculoskeletal complaints and disorders was about 2 to 4 times higher compared to a control group without such WBV exposure and poor seating characteristics. The preliminary and comparable data regarding whole-body vibration exposure and ergonomic working conditions indicate that there is a timely and medical need to scientifically assess among bus and subway operators current work conditions and possible future prevention opportunities/priorities.

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### 6. Occupational Stress and Health of Female Transit Workers

**Investigators**: Frank Goldsmith, DrPH, Local 100, Transport Workers Union; Paul Landsbergis, PhD, MPH, Mount Sinai School of Medicine
**Funding agency:** NIOSH Research Center, Universities Occupational Health and Safety Education
**Proposed time frame:** 3 year study
**Total cost**: $10,000

**Background/Significance**

This pilot study is designed to examine the possible health impact on women of work as a bus and train operator or conductor in New York City. This study will focus on the stressors faced by and the health status of women working in non-traditional jobs in the transit industry. The results of this pilot study will be used to help gain funding for a larger-scale study.

Professional driving, particularly bus driving, is a stressful occupation. Research worldwide has shown an increased risk of cardiovascular disease, hypertension, gastrointestinal illnesses, musculoskeletal disorders, and sickness absenteeism among bus drivers compared to other occupations. Less research has been conducted on subway train operators, however, several previous studies have indicated increased risk of back disorders possibly due to whole-body vibration among train operators. No previous studies have been conducted on occupational stressors and the health of subway train conductors. While conductors do not face the stress of driving, according to anecdotal evidence, they are subject to the stresses of dealing with the public. As with bus drivers, conductors can face stressful social interactions and abuse from the public. No previous studies have been conducted of women working in non-traditional jobs in the transportation industry. However, research in other industries suggests that women working in non-traditional jobs may face job stressors in addition to those inherent in their job tasks.

**Methods**

This study will primarily involve analysis of existing medical insurance claim data from Group Health Insurance (GHI) and the Health Insurance Plan (HIP) to determine the rates of diseases experienced by male and female transit workers in various job titles, and trends in these rates over time. Workers compensation claim data often includes few cases of work-related diseases, however, existing claim data will be analyzed to determine patterns of work-related injuries. Rates of injuries, cardiovascular disease, hypertension, musculoskeletal disorders, reproductive health problems, and conditions related to psychological stress such as anxiety disorders, depression and insomnia would be computed by gender and by job title, and controlling for age. Rates will also be computed by year of computerized data available to assess possible trends over time. Such methods of occupational disease surveillance were developed by Park et al., and utilized by Dr. Landsbergis in studies of the auto industry and health care industry.

Focus groups will be conducted with a sample of female transit workers to assess job stressors, work organization factors, their experience in non-traditional jobs, and working conditions that may increase their risk of occupational disease.

In addition, interviews will assess the feasibility of conducting blood pressure monitoring in the workplace during working hours in order to assess workers' cardiovascular health status. New, more reliable and valid methods are now available for assessing work-related cardiovascular risk at the workplace, including ambulatory (portable) monitoring of blood pressure during work hours, either using an automatic upper arm monitor or a portable wrist monitor.

The study population will be women working in "high stress" jobs for the New York City Transit Authority (bus and train operators and conductors).

**TABLE 1. NEW YORK CITY TRANSIT WORKERS**

| Job Titles | Approx. Number of Workers | % Women Workers | |
|---|---|---|---|
| | | 1990 | 2003 |
| Bus Operators | 6,000 | 10-15% | 30-35% |
| Train Operators | 6,000 | 10-15% | 35-40% |
| Conductors | 5,000 | 15-20% | 40-50% |

As Table 1 indicates, most female transit workers have been hired since 1990, and therefore most are young and are of childbearing age. Due to the requirements of the mandatory employment physical examination, the group of new workers is a healthy population when hired. Thus, analysis of trends in disease claims over time as work exposures accrue would be one important component in determining the work-relatedness of disease claims.

### Results

The study is underway, thus no results are available to date. We expect that findings from the study will focus on:

1) the feasibility of analyzing patterns of stress-related medical insurance claims as an effective method for identifying high-risk job titles
2) the feasibility of conducting blood pressure monitoring in the workplace during working hours
3) the concerns about work stress, work organization, working conditions, and health raised by female transit workers in their focus groups

### Future plans

The findings of this study will form the basis of a proposal for funding of a large-scale study of Occupational Stress and Health Among Female Transit Workers. The larger study is likely to include questionnaire surveys of female transit workers, additional focus groups, measurement of blood pressure of transit workers during a work day (if feasible), and the analysis of medical insurance claim data as on-going occupational disease surveillance system (if feasible).

### 7. The Creosote Transit Workers Study: Exposure to Creosote in the Linden Facility

**Investigators**: Jackie Moline MD, Mount Sinai School of Medicine
**Funding agency:** TWU Local 100
**Proposed time frame:** 1 year

**Total cost**: not available

Creosote is a coal tar derivative used as a wood preservative. Occupational exposure to creosote occurs in the railroad and transit industry, and in the dockbuilding and pile driving trades as workers have extensive direct contact with "creosoted" wood pilings. Creosote is known to be carcinogenic in animals and is classified as a probable human carcinogen. There have been few studies investigating the health effects of creosote in humans.

Creosote is also a skin irritant, causing contact dermatitis and photosensitization. In a 1981 NIOSH study, dockbuilders from the metropolitan New York area were evaluated to assess health effects related to creosote exposure. All six workers in the study had skin erythema and dermal exfoliation of the face, and irritation and folliculitis on the forearms. In all other studies of workers (of which there are few recent studies), skin irritation has been described. Animal studies have also found that creosote causes skin irritation and photosensitization.

Creosote is absorbed through the skin and by inhalation. A recent study by Borak, et al. in the Journal of Occupational and Environmental Medicine found that dermal exposure to creosote accounts for 90-95% of the absorbed dose. Therefore, it is essential to prevent dermal exposure to creosote not only to minimize dermal effects, but also to lessen systemic absorption. For the past two years, we have been working with Local 1456 of the United Brotherhood of Carpenters, the Dock Builders, Pier Carpenters, Shorers, House Movers, Pile Drivers, Divers Tenders and Foundation and Marine Constructors Union (Dockbuilders) to investigate whether creosote exposure is associated with increased rates of cancer. The dockbuilders have noted that they have increased pulmonary symptoms when working with creosote; no studies have investigated the pulmonary effects of creosote on workers.

The purpose of this feasibility study is to determine the extent of exposure to creosote in the Linden Transit Authority location. Workers will be asked to fill out a brief questionnaire outlining recent use of creosote and smoking history. All questionnaire data will be coded for analysis.

**Methods**

A short questionnaire will be administered by Mickie Brown, RN asking for the number of years worked as a transit worker, the number of years worked with creosote and the number of hours worked with creosote during the previous week. The subjects will also be asked about current tobacco use**.**

Air measurements will be performed for one shift, near the end of the workweek, and urine will be collected the following morning, to best assess the systemic absorption of creosote. We will measure systemic absorption to creosote by standard urinary markers of creosote metabolites, 1-hydroxypyrene, as well as and 1-/2-naphthols and 2-/9-phenanthrenols. Air sampling will use full-shift personal air samples for airborne creosote components, both particulate and vapor, and will be collected using two separate filters in series. Particulates will be collected on a Teflon filter contained within closed-face filter cassettes, while the vapors will be collected on activated carbon material within glass sampling ("sorbent") tubes. Particulates will be analyzed gravimetrically using OSHA Method #58: material deposited on Teflon filters is extracted with benzene, which is then evaporated to dryness and the resulting extract is weighed to determine the "benzene soluble fraction" (BSF). The extract will then be redissolved in acetonitrile and analyzed by HPLC for 16 polynuclear aromatic hydrocarbons (PNAs). Vapors will be analyzed by HPLC using NIOSH method #5506: PNAs are desorbed from the sorbent tubes by benzene, which is then evaporated to dryness and redissolved in acetonitrile and analyzed by HPLC for 16 PNAs. In addition to creosote sampling, total and respirable particulates levels will be determined gravimetrically. Prior to BSF analysis, total particulates will be determined using the Teflon filters described above. Respirable particulates will be collected on separate Teflon filters using a cyclone sampler. Samples will be analyzed in an American Industrial Hygiene Association accredited laboratory.

Systemic absorption to creosote will be performed by analyzing 1-hydroxypyrene and 1-hydroxynaphthalene. These analyses will be performed using 1-hydroxypyrene as our primary marker of dermal exposure to creosote and we plan to also quantify 1-/2-naphthols and 2-/9-phenanthrenols, via standard methodologies using HPLC. The urine samples will be analyzed in Dr. Mary Wolff's laboratory at the Mount Sinai School of Medicine.

The data collected in this study will provide needed pilot information for a potential, larger study of the health effects of creosote in transit workers, if needed.

Dr. Moline will address the members of the Transport Workers Union employed at the Linden Facility, and describe the pilot proposal. Working with the union, Dr. Moline will identify different job tasks that may have varying exposure to creosote. Volunteers will be recruited for participation for this one-day project.

### 8. Multidisciplinary Approach to Ergonomic Hazards of Transit Workers

**Investigators:** Robin Mary Gillespie, MA, MPH (Mount Sinai School of Medicine)
**Funding agency**: pending
**Proposed time frame:** 3 years
**Total cost**: na

**Aims**

The proposed project is designed to assess the rates of work-related musculoskeletal disorders among Transit Authority workers, identify contributing causes and pilot a participatory method of hazard abatement.

1. What are the rates of musculoskeletal disorders and symptoms among Transit Authority (TA) workers?
2. What are the distribution, character and intensity of musculoskeletal risk factors among TA workers?
3. What is the association between job title and rate of musculoskeletal disorders and symptoms among TA workers?
4. What is the association between job tasks and rates of musculoskeletal disorders and symptoms among TA workers?

5. What modifications to work activities have been effective or could be effective in reducing musculoskeletal risk factors in TA work?

**Methods**

1. Musculoskeletal disorders (MSDs) and symptom rates

The study will begin with an assessment of available records of reported injury and illness, including the daily incident reports, insurance company data as described elsewhere, and workers compensation claims. It will be followed by the distribution of an epidemiological survey of musculoskeletal disorders and symptoms. A sample of workers, stratified for job title, age, race and sex, will be recruited for this phase, and an incentive will be offered to enhance recruitment success. Power analyses to determine minimum sample size and distribution characteristics have not been completed.

The cohort analyses will be complemented by a nested case-control study with cases defined by symptoms, self-reported diagnoses, workers' compensation claims, physician-diagnosed conditions. Risk factors for evaluation will include job title, exposure time parameters (e.g., years in job title, hours of work, overtime), intervening factors (e.g., shift, location) and standard demographic factors (e.g., race, age, gender, ethnicity). Results from this phase will answer questions 1-4 above.

2. Job hazard assessment

The second phase will consist of in-depth ergonomics assessment of job titles targeted thought the initial risk assessment. Assessment methods will include task analysis, job content analysis, Rapid Upper Limb Assessment and PATH assessment. This component will use the participatory model of assessment and intervention, based on the work of June Fisher and others. A trained ergonomics team, probably for each division, will consist of workers and line-level management. This team of skilled workers, directed and supported by the ergonomist, will engage workers in the following activities in each targeted job title:

1. Job task analysis, to identify the components of each job title
2. Estimating the frequency and duration of tasks
3. RULA analysis, PATH analysis, NIOSH lifting equation calculations, or other load assessments for targeted tasks, depending on the types of demands (e.g. upper limb repetition, lifting, heavy postural loads, standing)
4. Psychosocial assessment for target tasks

In coordination with the ergonomics team, researchers will develop a database structure to catalogue exposures by job title, task, observed and expected impact, and physical and psychosocial load rating. This database will allow the team to rate exposures to develop target list for intervention.

3. <u>Identifying and testing ergonomics improvements</u>

Based on the data gathered in the job tasks analyses, surveys, discussions with workers, and observations, the ergonomics teams will identify existing or potential ergonomics improvements. They will prioritize, target and assist in carrying out improvements. The effectiveness of these improvements at reducing MSDs, symptoms and risk factors, as appropriate, will be assessed following implementation.

**Outcomes**

The outcome of this project is three-fold. First, it will document the rates and characteristics of work-related musculoskeletal disorders in the Transit Authority workplaces. Second, it will produce an in-depth database of risk factors and job demands, unprecedented in this industry, which is the essential precursor to a comprehensive improvement plan. Finally, it will design a pilot test a model structure for ongoing ergonomics assessment improvements and evaluation that can be implemented in other divisions and by other employers.

### 9. Subway Strategic Observers: How They See, What They Do

**Investigators**: Harvey Molotch, PhD (New York University)
**Funding agency:** not available
**Proposed time frame:** 1 year
**Total cost**: not available

**Background**

Using New York subway transit workers as empirical case, this study examines how individuals performing public roles sense danger and how they respond to perceived threats. Such individuals who labor in public places are often “first responders” in instances of mayhem and may be the best hope for preventing trouble in the first place. Such “strategic observers” develop specialized knowledge of public environments and at least potentially play a role in safeguarding them. Understanding the nature of their activities takes on special urgency in the context of terrorist threats to US cities.

**Methods**

Researchers will interview 100 individuals performing a range of subway jobs (token booth staff, subway conductors, subway operators, and track inspectors), as well as a number of others with specialized authority or knowledge about the subway system. Extensive ethnographic field observation will also be undertaken, incorporating photographs and video.

# Chapter 7 Conclusion

Steven Markowitz, MD

Transit workers develop important common diseases and injuries to which their work is likely to be a causal or contributing factor. Such injuries and outcomes have been identified as a result of a large body of epidemiologic studies. Their causal relation to work is enhanced in plausibility by supporting mechanistic studies. The major health outcomes of concern are cardiovascular diseases, which includes hypertension, heart disease, and stroke; lung and bladder cancer and possibly other cancers; emphysema and asthma; post-traumatic stress disorder and other stress-related psychological disturbances; and low back pain and other musculoskeletal disorders. Most available studies address the risk of disease in bus drivers; fewer studies exist for subway workers.

The occupational hazards of transit workers are unusually diverse, encompassing much of the spectrum of occupational health, including chemical, safety, ergonomic, physical, psychological, and biologic hazards. These exposures are matched to important, sometimes life-threatening, outcomes, such as asbestos exposure and lung cancer; hypertension and heart disease; traumatic death and post-traumatic stress disorder; live electricity and electrocution; vibration and disabling back injuries, etc. This diversity of hazards and associated diseases and injuries is highly unusual in a single industry and presents a considerable challenge to develop and to apply appropriate policies and practices of prevention and control.

The opportunity for synergy among the hazards of transit work is especially impressive. The bus driver experiences both job-related hypertension and exposure to air pollutants such as fine particulates and carbon monoxide, which work in concert to damage the heart. Similarly, the subway worker has the stress of keeping to tight time schedules, dealing with a demanding public, and suffering frequent loud noise, all of which contribute to high blood pressure. Occupational health sciences have not fully characterized how occupational risk factors interact, but evidence available to date suggests that important exposures, such as asbestos, may, together with co-existing agents, multiply the risk of critical diseases, such as cancer.

Current knowledge about occupational health and safety in the transit industry points to two broad needs: 1) Examination of health and welfare policies to maximize health protection of transit workers and to alleviate the deleterious impacts of transit work on health; and 2) Development of a research and surveillance program that better measures the impact of transit work on health and, as importantly, can assess the effectiveness of interventions to limit the negative impact of transit work on health.

### 1) Examination of health and welfare policies to improve transit worker health

The diverse hazards of transit work require diverse solutions, using the full range of the hierarchy of hazard controls in the workplace. These include product substitution (e.g. using safer products), engineering controls (e.g. ventilation), personal protective equipment (e.g. respirators), and administrative controls (e.g. rotating workers). Many factors –

including the diversity of hazards, diffuseness of worksites, ceaseless operations, high degree of contact with the general public, critical importance of transit service – conspire to make the application of a rational scheme of controls in the transit industry an extraordinary challenge.

Even if the best controls were in place, transit work is intrinsically difficult, whether it involves spending much of the workday sitting in a tiny cabin in a train underground or moving a 16-ton bus through New York City traffic. Most New York residents have sufficient experience on subways or on New York City streets to understand how difficult such work must be. Under such circumstances, in consonance with other applicable hazard controls, administrative controls should be considered, such as shortening the workday or week (without reduction in pay) or retirement with sufficient pension after a lengthy though limited period of service (e.g. - after 20 years instead of 25 years of service). Indeed, there is precedent. Other city workers who perform vital and hazardous public service (e.g. police and fire fighters) have a shortened period of service prior to becoming eligible for retirement.

Our purpose in this report was not to conduct a review of applicable health and safety policies and practices of the NYCTA in operating the transit system. Thus, we are not in a position to make specific suggestions about specific worksites in the transit industry. Our view is that accumulating evidence from research about the health and safety of transit work demonstrates that there are significant hazards in this work, and that full attempts to ensure that such hazards are recognized and minimized should be made.

### 2) Development of a research and surveillance program on transit worker health

The nature and extent of occupational disease, disability and injury experienced by New York City transit workers awaits full characterization. Systematic study of such problems in New York is sporadic and fragmented. This is surprising given the importance of the industry and the ample resources in occupational health research in New York City. There are, however, sufficient "warning signs" about the work hazards and health problems of transit workers to justify further investigation into the occupational health of transit workers.

While research on transit work from other geographic areas is highly applicable to New York City, local research is nonetheless needed. First, we currently lack a coherent comprehensive picture of the impact of transit work on the health of transit workers in New York City. Second, local factors in New York City may alter the nature or expression of occupational health problems of transit workers. Third, it is a truism in occupational health that interventions to change conditions that impact occupational well-being are usually undertaken only after it is shown that such conditions hurt workers in the locale where the interventions are contemplated. Finally, alterations intended to be beneficial to health require careful longitudinal measurements in order to know whether such alterations are, in fact, of benefit.

Enhanced occupational safety and health research and surveillance of New York City transit workers is highly feasible. There are large numbers of such workers, so that statistical variation (random error) and accounting for non-occupational risk factors (confounders) should not be especially problematic. Ready sources of data, especially health and job title data, exist, as documented in Chapter 5, providing the research community with a rich and accessible resource. Transit workers have enormous concerns about their health and how it is impacted by their work, ensuring their cooperation. Management requires and values a stable, experienced workforce, thereby, providing the basis for a consensus about the need to identify factors that promote, or alternatively, detract from the health of the transit workforce. The industry has enormous economic and environmental importance to New York City (and hence the country).

We therefore recommend that a coordinated research and surveillance program for transit workers be developed. This program should examine the most important and common hazards and health conditions relevant to transit work. Development and conduct of such research should involve participation of the workforce and the cooperation of management. Research topics that point to or demonstrate interventions to minimize hazard and promote health should be emphasized. Research should lead to establishment of sustainable systems of surveillance to ensure continued identification of effectiveness of current policies and to identify new problems.

**3) Developing a Center of Excellence of Occupational Health of Transit Workers**

In 1996, the National Institute for Occupational Safety and Health (NIOSH) developed a new framework to guide occupational safety and health research, entitled the National Occupational Research Agenda (NORA) (http://www.cdc.gov/niosh/nora). This agenda was important in establishing priorities for research and also in providing a platform for collaboration among interested parties in government, academia, industry, and labor. The NORA Agenda identified areas of concern according to three major categories, including 1) Disease and Injury**,** 2) Work Environment and Workforce**,** and 3) Research Tools and Approaches, with 5 to 8 specific sub-topics per category.

Enhanced research in transit worker occupational safety and health fulfills many of the research priority areas set out by NORA. These are detailed in the following table.

**Intersection of Transit Work and Research Priority Areas of the National Occupational Research Agenda**

**A. Disease and Injury:** musculoskeletal disorders, low back disorders, traumatic injuries, hearing loss, infectious diseases, and asthma and chronic obstructive lung disease.

**B. Work Environment and Workforce: e**merging technologies, mixed exposures, organization of work, and special populations at risk.

**C. Research Tools and Approaches:** control technology and personal protective equipment; exposure assessment methods; intervention effectiveness research, social and economic consequences of workplace illness and injury, and surveillance research methods.

Indeed, few other single industries encompass as large a part of the National Occupational Research Agenda as does the urban mass transit industry in New York City and other metropolitan areas. This is true due to the enormous variety of work that is required to accomplish urban public transit.

In order to develop a critical mass of expertise, attention, and resources, we recommend the development of a university-based Center of Excellence of Occupational Health and Safety of Transit Workers in New York City. The goals of such a center are outlined below.

Creation of such a Center has enormous advantages. It would provide an excellent opportunity to give direction and coherence to future transit research. It would create a structure that assures that such research is tethered to the perceived needs and interests of transit labor and management. It would provide a mechanism for the rapid translation of new scientific advances into practice in the transit industry. The Center would also serve as an incubator for new inquiries into the nature and extent of health and safety problems of transit work. By including faculty across universities in the New York metropolitan area, the Center would also promote collaboration of people with diverse talents and knowledge.

**Goals of a Center of Excellence of**
**Occupational Health and Safety of Transit Workers**

1. Build and coordinate a multi-disciplinary research team to address inherently multi-faceted issues in transit worker occupational safety and health;

2. Develop, maintain, and make accessible a unified research database that integrates multiple data sources relevant to transit worker occupational safety and health;

3. Design and implement hazard, illness and injury surveillance system for transit workers;

4. Conduct epidemiologic analyses of health status of transit workers, including illness, injury, disability, and mortality, in relation to occupational exposures;

5. Initiate and support pilot research studies that explore new areas and provide provisional information needed to attract funding for larger studies;

6. Convene interested persons from labor, management, universities, and health care providers to address research priorities and conduct in relation to transit worker occupational safety and health.

Such a Center of Excellence is a highly familiar structure in the Federal and academic scientific research community. It follows the model of similar centers created and funded by the National Institutes of Health and the Centers for Disease Control and Prevention in many universities. This model provides accountability, ensures quality, and enables dissemination of research findings throughout the country.

Mass transit is New York City is a critical industry. It provides enormous benefits to the environment and to the economy in New York City. Its proficiency depends, to a large degree, upon the skill and well-being of the transit workforce. Our current knowledge about the well-being of the workforce is limited. While sporadic research has been initiated, it is fragmented and unlikely, in its present form, to enhance substantially our current knowledge about transit worker health and safety. Creating a Center of Excellence of Occupational Health and Safety of Transit Workers will provide a mechanism for overcoming this knowledge deficit and, ultimately, for improving the health and welfare of transit workers in New York City.