Driver Issues:
Commercial Motor Vehicle Safety
Literature Review

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

June 2007

PREFACE

The objective of this project was to provide the Federal Motor Carrier Safety Administration (FMCSA) with a more complete understanding of the non-regulatory factors which make for safer commercial motor vehicle (CMV) drivers. Through the review of available literature, the relationship between the CMV driver and the motor carrier was explored with respect to safety outcomes. A tailored Haddon Matrix was used as a means to structure the literature and provide clear direction for the development of future intervention strategies. Haddon's Matrix provides a framework for identifying factors that influence an event by dividing the event in terms of timeframe (i.e., pre-event, event, and post-event) and the actors and/or environments involved in the event. The Haddon Matrix was adapted for the current project by considering the driver and the motor carrier as the major actors/environments, and identifying events in the driver-motor carrier relationship that are important for improving driver safety. Two separate reviews were conducted. Review #1 examined literature relating to the selection of safe drivers; its outcomes pointed to employee turnover as a primary focus of the data-driven research conducted over the past decade, as well as a primary concern highlighted in trade and industry sources. Review #2 investigated research and trade publications as related to improving driver safety; its outcomes demonstrated that recent literature has largely concentrated on the identification and comprehension of driver characteristics and motor carrier practices as they relate to safety outcomes (e.g., age and CMV driving history). General conclusions derived from the literature and future research needs are also discussed.

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16. Abstract:

The objective of this project was to provide the Federal Motor Carrier Safety Administration (FMCSA) with a more complete understanding of the non-regulatory factors which make for safer commercial motor vehicle (CMV) drivers. Through the review of available literature, the relationship between the CMV driver and the motor carrier was explored with respect to safety outcomes. A tailored Haddon Matrix was used as a means to structure the literature and provide clear direction for the development of future intervention strategies. Haddon's Matrix provides a framework for identifying factors that influence an event by dividing the event in terms of timeframe (i.e., pre-event, event, and post-event) and the actors and/or environments involved in the event. The Haddon Matrix was adapted for the current project by considering the driver and the motor carrier as the major actors/environments, and identifying events in the driver-motor carrier relationship that are important for improving driver safety. Two separate reviews were conducted. Review #1 examined literature relating to the selection of safe drivers; its outcomes pointed to employee turnover as a primary focus of the data-driven research conducted over the past decade, as well as a primary concern highlighted in trade and industry sources. Review #2 investigated research and trade publications as related to improving driver safety; its outcomes demonstrated that recent literature has largely concentrated on the identification and comprehension of driver characteristics and motor carrier practices as they relate to safety outcomes (e.g., age and CMV driving history). General conclusions derived from the literature and future research needs are also discussed.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	Inches	25.4	millimeters	mm
ft	Feet	0.305	meters	m
yd	Yards	0.914	meters	m
mi	Miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	Acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	Gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	Ounces	28.35	grams	g
lb	Pounds	0.454	kilograms	kg
T	short tons (2000 lbs)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit Temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m2	cd/m2
		FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lbs)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	Lux	0.0929	foot-candles	fc
cd/m2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAMVA	American Association of Motor Vehicle Administrators
ANOVA	Analysis of Variance
ANPRM	Advance notice of proposed rulemaking
ATA	American Trucking Association
ATAF	American Trucking Association Foundation
ATRI	American Transportation Research Institute
BBS	Behavior-Based Safety
BLS	Bureau of Labor Statistics
CDL	Commercial Drivers License
CDLIS	Commercial Drivers License Information System
CMV	Commercial motor vehicle
CPS	Current Population Survey
CR	Compliance review
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
CVSA	Commercial Vehicle Safety Alliance
CWS	Collision warning system
DBQ	Driver Behavior Questionnaire
DEA	Data envelopment analysis
DMV	Department of Motor Vehicles
DVI	Driver-vehicle interface
DVN	Driver violation notification
ECM	Engine control module
EPN	Employee/Employer Pull Notice
EU	European Union
FARS	Fatality Analysis Reporting System
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulations
FOT	Field operational test
FTA	Federal Transit Administration
GES	General Estimates System
HOS	Hours of service
HR	Human resources
HRM	Human resource management
ICC	Interstate Commerce Commission
ITS	Interpersonal Trust Scale
LMX	Leader-member exchange
LTCCS	Large Truck Crash Causation Study
LTL	Less-than-truckload
LTSA	Land Transport Safety Authority
MCMIS	Motor Carrier Management Information System
MCSOTS	Motor Carrier Safety, Operations and Technology
MPS	Motivating potential score
NDSU/UGPTI	North Dakota State University Upper Great Plains Transportation Institute

NHTSA	National Highway Traffic Safety Administration
NPRM	Notice of proposed rulemaking
NPTC	National Private Truck Council
NTIS	National Technical Information Service
NYCT	New York City Transit
OSH	Occupational safety and health
OSHA	Occupational Safety and Health Association
OOS	Out-of-service
P-J	Person-job
P-O	Person-organization
PUMS	Public Use Microdata Sample
RJP	Realistic job preview
ROA	Return on assets
ROI	Return on investment
SafeStat	Motor Carrier Safety Status Measurement System
SEA	Safety Evaluation Area
SME	Subject matter expert
SMS	Self-management for safety
SVA	Single vehicle accident
TL	Truckload
TRIS	Transportation Research Information Services
UMTIP	University of Michigan Trucking Industry Program

EXECUTIVE SUMMARY

The primary mission of the Federal Motor Carrier Safety Administration (FMCSA) is to improve safety by reducing crashes, injuries, and fatalities involving commercial motor vehicles (CMVs). The goal of the current project is to provide FMCSA with a more complete understanding of the non-regulatory factors which make for safer CMV drivers. Through the review of available literature, our primary focus is to explore the relationship between the CMV driver and the motor carrier with respect to safety outcomes.

A tailored Haddon Matrix was used as a means to structure the literature and provide clear direction for the development of future intervention strategies. Haddon's Matrix provides a structure for identifying factors that influence an event by dividing the event in terms of timeframe (i.e., pre-event, event, and post-event) and the actors and/or environments involved in the event. The Haddon Matrix was adapted for the current project by considering the driver and the motor carrier as the major actors/environments, and identifying events in the driver-motor carrier relationship that are important for improving driver safety.

This project considers two non-regulatory approaches to support FMCSA's mission of improving safety on the roadways. Review #1: Selecting Safe Drivers addresses the workforce "pipeline" issue—who is applying to and being recruited for CMV driver positions—extending to the hiring process, and further, considering retention and turnover. Review #2: Improving Driver Safety focuses on improving the safety of those drivers already "on the road" by considering the various driver and motor carrier practices that affect safety outcomes, prior to, during, and after safety incidents.

In order to focus on only the most current findings concerning safety in the trucking industry, selection of literature was limited to references published in 1995 or later. Only works published in English and studies conducted in the US, Canada, Australia, or the European Union (EU) were considered. All sources address truck, bus, or van drivers who operate CMVs, or motor carriers that employ such drivers. Relevant reference works were divided into primary and secondary sources based on a review of abstract and/or executive summary information, where available, or the full text, if necessary. The primary sources consist mainly of peer-reviewed literature and conference proceedings that are based on first-hand empirical data, and were annotated by one or more reviewers. References identified as secondary sources consist largely of high-level reviews and synthesis reports that contain relevant information, but do not utilize first-hand data (e.g., meta-analyses). Applicable references from trade publications were also included to fill gaps in search results as necessary. The final database included 65 primary sources (20 annotated for Review #1 and 45 annotated for Review #2), 30 secondary sources, and 36 trade sources.

The outcomes of Review #1 point to employee turnover as a primary focus of the data-driven research conducted over the past decade. Negative impacts associated with turnover and subsequent hiring needs include substantial organizational costs to hire a full complement of drivers each year, estimated as a $7,000 expense per lost employee (Griffin et al., 2000). This number increases further when related human-resource costs, such as recruiting, training, and insurance, are factored in. Furthermore, safety performance decrements associated with inexperienced drivers and operational inefficiencies resulting from new drivers who are not familiar with the service requirements necessary to maintain good customer service are

problematic (Griffin et al., 2000). Additionally, the research points to a number of factors that may impact a driver's decision to leave or stay with an organization. In particular, compensation was indicated by drivers as a reason of primary importance in a study by Stephenson and Fox (1996), and in surveys of motor carriers conducted by Dobie, Rakowski, and Southern (1998), and Min and Lambert (2002), suggesting that carriers that pay better wages are more likely to retain drivers. As a final consideration, an obvious shortcoming to the majority of the academic literature that resulted for this first review is that existing research findings do not provide a link to outcomes beyond implications for turnover, or turnover rates themselves. Safety is a major focus of the trucking industry; yet, in the literature, this outcome was more likely to be referenced for its indirect over its direct relationships with study variables.

In contrast to the first review, the annotated literature for Review #2 is concentrated in the identification and comprehension of driver characteristics and motor carrier practices as they relate to safety outcomes. For instance, age and CMV driving history, including experience and past history of crash involvement and safety violations, are two pertinent areas to this review that are frequently addressed in the literature (Knipling, Hickman, & Bergoffen, 2003). Driving history is another factor the literature supports as impacting safety. In a study by Murray, Lantz, and Keppler (2006), future truck crash involvement was predicted based on past driver behaviors. Using Motor Carrier Management Information System (MCMIS) and Commercial Drivers License Information System (CDLIS) data, they determined that drivers with prior crash involvement were 87% more likely to be involved in a future crash. Results also showed that drivers who had been cited for reckless driving violations and improper turn violations were, respectively, 325% and 105% more likely to be involved in future crashes.

Additionally, a number of studies purport to draw a relationship between driver compensation and safety outcomes, for example, that increased pay is associated with a reduction in crashes. The reviewers offer a cautionary note to these assertions: generally, it is not possible to understand the true nature of the relationship between these two factors. Specifically, it may be unclear whether cash bonuses for safe driving are responsible for higher pay, or that offering better pay at a company improves its ability to recruit and hire greater numbers of quality drivers. Taking an organizational focus, there are also practices of the motor carrier that have been found to influence safety and promote safety culture. Deserving of mention are reports of safety management best practices (e.g., American Trucking Association [ATA] Safe Returns, 1999; Mejza, Barnard, Corsi, & Keane, 2003; Corsi & Barnard, 2003), listing factors including commitment to safety by top management, employee involvement, prioritizing safety in all aspects of an operation, and making safety management a continuous process.

Research gaps within the Haddon matrix for the second review are not as marked as those in Review #1. Nevertheless, literature relevant to the event and post-event stages is lacking in comparison to that for the pre-event stage. This may, as noted previously, simply reflect a desire by researchers to preemptively understand and address safety issues. Moreover, articles found in the pre-event stage often discuss safety-management issues and practices that can also be conceptualized to pertain to the event, or even post-event stages.

This review demonstrates the utility of using tailored versions of Haddon's matrix as a framework for addressing some of the prime safety concerns in the trucking industry and FMCSA alike. These include the recruitment, selection and retention of a safe workforce, and the

factors related to improving safety as associated with existing drivers and motor carrier operations. Although it was not possible to annotate the hundreds of trade sources that were obtained in the same way as the resultant scientific literature, exploring both the academic and industry viewpoints was beneficial and allowed for a more complete understanding of the complex nature of the trucking industry. Precisely because new and updated industry information is constantly being generated, in particular online, only the most recent published trade material was relied upon as cited sources. Lastly, as a caveat regarding the current effort that should be restated here, this document is not intended as a comprehensive review of the many antecedents of safety outcomes, and it intentionally did not duplicate the focus or content of any recent FMCSA-sponsored work.

INTRODUCTION

The primary mission of the Federal Motor Carrier Safety Administration (FMCSA) is to improve safety by reducing crashes, injuries, and fatalities involving commercial motor vehicles (CMVs). As particularly important, FMCSA has identified a need for improving the safety practices of drivers and motor carriers; however, this goal must be balanced by the need for industry productivity and efficiency in an era of goods transport that increasingly focuses on just-in-time delivery. Ultimately, the challenge is to produce safer drivers through encouraging motor carriers to use industry best practices, including the use of data-driven feedback, without concomitantly sacrificing system efficiency. Although positive reinforcement and supportive (non-regulatory) outreach are generally preferred as initial steps in this process, the agency also takes appropriate measures to ensure regulatory compliance and to remediate non-compliance.

FMCSA and its predecessor agencies have historically responded to specific and targeted driver safety issues, rather than viewing the recruitment, pre-employment assessment, entry, training, and operational and regulatory oversight of drivers in a holistic fashion. Examples of specific safety issues addressed in the past have been the development of a Commercial Drivers License (CDL) program in the late 1980s, the development of regulations in the early 1990s to prevent and detect transportation workers' use of controlled substances and abuse of alcohol, and development and publishing in 2003 and 2005 of revisions to the nearly-60-year-old hours of service (HOS) regulations. However, the organization of the highway transportation industry has undergone significant changes since 1980, when the first layers of economic regulation were removed by the Interstate Commerce Commission (ICC). The accelerating pace of changes in the makeup of the industry (firms and people), the increasing demands for efficiency in operation to support the needs of shippers and to conserve fuel, and the decreasing number and availability of potential CMV drivers, demand that FMCSA take steps to better understand the roles, needs, and responsibilities of CMV drivers and the entities with whom they interact.

PROJECT GOAL AND APPROACH

The goal of the current project is to provide FMCSA with a more complete understanding of the non-regulatory factors which make for safer CMV drivers. Through the review of available literature, our primary focus is to explore the relationship between the CMV driver and the motor carrier with respect to safety outcomes. Ensuring safe driving practices is vital from the moment a prospective CMV driver begins training for a license to drive a CMV, as well as throughout the driver's working relationship with a motor carrier, especially in the event of an adverse safety incident (e.g., crashes, injuries, traffic citations). The motor carrier may address the need for safety oversight in a number of ways, including thorough background checks before hire, in-service training, reward programs and promotion strategies for positive safety behaviors, and stringent policies for enforcing governmental and company-specific regulations in the event of a safety violation. At the same time, characteristics of the driver, such as age, experience, attitudes about safety, and behavioral norms (e.g., speeding) strongly influence whether, and to what extent, drivers adhere to motor carrier rules and regulations.

A tailored Haddon Matrix was used as a means to structure the literature and provide clear direction for the development of future intervention strategies. This model was developed by Dr.

William Haddon and is commonly used in highway safety research as a framework for identifying intervention strategies that may aid in preventing or reducing the severity of adverse events, such as injuries or accidents (Teret, 1997). Haddon's Matrix provides a structure for identifying factors that influence an event by dividing the event in terms of timeframe (i.e., pre-event, event, and post-event) and the actors and/or environments involved in the event. The Haddon Matrix was adapted for the current project by considering the driver and the motor carrier as the major actors/environments, and identifying events in the driver-motor carrier relationship that are important for improving driver safety. To this end, targeting the selection of CMV drivers by recruiting, screening, hiring, and retaining the safest drivers is one avenue for improving CMV safety and preventing accidents long before they occur. Additionally, identifying the causes and consequences of adverse safety events may aid in a better understanding of the necessary and desirable driver characteristics and motor carrier practices that may mitigate the occurrence of future incidents, reduce the number of repeat occurrences, and prevent lapses and minor operational errors from progressing to crashes and other adverse safety events.

PROCESS AND METHODOLOGY

With respect to the purpose of this project, a search for relevant published literature regarding CMV drivers was conducted using multiple internet sites and searchable literature databases containing peer-reviewed and trade publications, government reports, and conference proceedings.

Search Strategy

The following databases were used to conduct the literature search:

ABI/INFORM Global: contains 1800 worldwide business periodicals with coverage of business and economic conditions, management techniques, theory, and practice of business, advertising, marketing, economics, human resources (HR), finance, taxation, computers, and more.

ABI/INFORM Trade & Industry: covers more than 750 business periodicals and newsletters with a trade or industry focus. Contains publications on every major industry, including finance, insurance, transportation, construction, and many more.

EconLit: from the American Economic Association's electronic database, covers economic literature, with more than 735,000 records.

The National Technical Information Service (NTIS): from the U.S. Department of Commerce's Technology Administration. NTIS annually receives tens of thousands of new publications, technical reports, and other products from hundreds of government agencies and other organizations.

PsycARTICLES: from the American Psychological Association (APA), contains more than 45,000 articles from 57 journals - 46 published by the APA and 11 from allied organizations. It includes all journal articles, letters to the editor and errata from each journal.

PsycINFO: from the American Psychological Association (APA), contains nearly 2.3 million citations and summaries of scholarly journal articles, book chapters, books, and dissertations, all in psychology and related disciplines.

Transportation Research Information Services (TRIS) Online: a public-domain, web-based version of the TRIS bibliographic database, contains over half a million records of published transportation research including technical reports, books, conference proceedings and journal articles.

The aforementioned databases were searched using a combination of subject and topic terms that were identified as appropriate for the current review. The search criteria identified all publications that had at least one subject term and one topic term in the abstract and/or title.

Subject terms

- Bus
- Bus Driver
- Bus Operator
- Commercial Vehicle
- Commercial Vehicle Driver
- Commercial Vehicle Operator
- Motor Carrier
- Motor Coach
- Motor Coach Driver
- Motor Coach Operator
- Truck*
- Truck Driver
- Truck Operator
- Van
- Van Driver
- Van Operator

Topic terms

- Accident*
- Attitude*
- Behavior*
- Compensat*
- Crash*
- Death*
- Demand*
- Employ*
- Fatal*
- Hir*
- Incentive*
- Insurance
- Performance
- Personality
- Recruit*
- Regulat*
- Retain
- Retention
- Safe*
- Satisfaction
- Select*
- Speed*
- Train*
- Turnover
- Violat*

Note that the asterisk is used as a Boolean operator denoting a root word search. For example, a search using select* encompasses all words that begin with select, including select-s, select-ing, select-ion, and select-ed.

Citations matching the search criteria were captured and compiled into a single database using ProCite bibliographic database management software. First article titles, and when necessary, abstracts were reviewed by the contractor's project staff to determine relevance to the focus of the current effort. The articles marked as relevant were then distributed to project team members for review, with an emphasis on matching article topics to the expertise of the reviewer.

Selection Criteria

In order to focus on only the most current findings concerning safety in the trucking industry, selection of literature was limited to references published in 1995 or later. Only works published in English and studies conducted in the US, Canada, Australia, or the EU were considered. All sources address truck, bus, or van drivers who operate CMVs, or motor carriers that employ such drivers. As defined in 49 Code of Federal Regulations (CFR; part 390), a CMV consists of any self-propelled or towed motor vehicle used on a highway in interstate commerce to transport passengers or property when the vehicle:

1. Has a gross vehicle weight rating or gross combination weight rating, or gross vehicle weight or gross combination weight, of 4,536 kg (10,001 pounds) or more, whichever is greater;
2. Is designed or used to transport more than 8 passengers (including the driver) for compensation;
3. Is designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation;
4. Is used in transporting material found by the Secretary of Transportation to be hazardous under 49 U.S.C. 5103 and transported in a quantity requiring placarding under regulations prescribed by the Secretary under 49 CFR, subtitle B, chapter I, subchapter C.

In accordance with the scope of the project, an effort was made to identify literature that addressed one or more of the following topic areas:

- Driver recruitment, selection, hiring
- Driver turnover and/or retention practices
- Driver safety training
- Driver compensation and incentives to drive safely
- Driver-related predictors of accidents
- Characteristics of safe drivers (e.g., behaviors, abilities, demographics)
- Relationships between motor carriers and drivers (e.g., organizational culture, driver commitment, job satisfaction)
- Driver-focused safety practices of motor carriers

In addition, the following topic areas were identified as out of scope for the current project, per discussions with the FMCSA sponsor:

- Aviation
- Rail
- Maritime
- School buses
- Driver fatigue and sleep disorders
- HOS regulations
- Driver physical qualifications; medical conditions
- Crash causation mechanisms
- Environmental and mechanical factors related to accidents

Transportation research outside of CMV operations was excluded due to marked differences between operations in the trucking and motor coach industries and other forms of transportation. Topic areas such as fatigue and HOS regulations were also excluded in a desire to reduce overlap with other on-going research efforts.

The initial stage of the literature search returned over 2,000 total potential citations. Reduction of the ProCite database began by viewing records as grouped by keywords, imported from the specified data sources. It was determined that using a liberal search strategy and subsequently eliminating obviously unrelated sources by keyword was more efficient than attempting to add articles on an individual basis. Articles with unrelated keywords and/or keywords related to excluded topic areas, as specified above, were marked so the articles could be removed at a future point. A second reviewer confirmed that each article marked for deletion was not applicable to the scope of the current project, at which point the article was removed from the database. After this initial pass, reviewers more closely scrutinized the content of the remaining articles through title and abstract reviews. Additional deletions were made throughout the course of the project as full-text was reviewed and articles that were not relevant to the project scope were eliminated, leaving a total of 131 sources.

Relevant reference works were divided into primary and secondary sources based on a review of abstract and/or executive summary information, where available, or the full text, if necessary. The primary sources consist mainly of peer-reviewed literature and conference proceedings that are based on first-hand empirical data. References identified as secondary sources consist largely of high-level reviews and synthesis reports that contain relevant information, but do not utilize first-hand data (e.g., meta-analyses). Applicable references from trade publications were also retained in the database to fill gaps in search results as necessary. The final database included 65 primary sources (20 annotated for Review #1 and 45 annotated for Review #2), 30 secondary sources, and 36 trade sources.

Review Strategy

All articles deemed appropriate for inclusion as primary sources were annotated by one or more reviewers using the format outlined below. References that were published as a series or utilized the same data set are included as a single annotation. The following format was used when annotating primary sources:

Complete Citation (APA Format): Author(s). (Year). Title. *Journal*, *Volume,* Page numbers.

Immediately below the source citation, a Haddon matrix is used to show the context of the source in relationship to all areas being reviewed. A blank matrix is shown in Figure 1 below. For further explanation of the Haddon matrix content cells, see Table 1 on page 8.

Haddon Matrix #			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			

Figure 1. A sample Haddon Matrix with Blank Cells

Author Abstract: If available, this section includes the abstract taken directly from the source article.

Industry Sector: Describes the subject matter of the source (e.g., trucking, bus industry).

Purpose: Briefly summarizes the purpose of the article.

Sample: Provides number of participants and criteria for selection. Also includes relevant sample demographic information.

Methodology: Describes the methods and procedures used to collect the data (e.g., survey, field study, lab experiment, focus group).

Relevant Findings: Identifies specific study findings and general study conclusions that relate to the purpose of the literature review.

Limitations: Describes limitations of the study from the perspective of both the author(s) and the reviewer (e.g., methodology used, inconsistent findings, no causality).

Categorization: Explains where, how, and why the article fits within the framework of the Haddon Matrix as identified in the small matrix presented prior to each annotation (see matrix above).

Secondary sources are provided as a separate reference list at the end of the annotations for each review. Author abstracts are included when available. If no author abstract existed, an abstract was acquired from one of the databases used in the literature search or composed by a member of the project team.

Given the varied content of trade publication sources located in the search, and their nearly universal lack of data-based results, it was not possible to annotate them in the same manner as was done for primary sources. Nevertheless, trade sources were reviewed by members of the project team and have been incorporated into the synthesis, where appropriate, to supplement gaps identified in the literature and better characterize the state of affairs in the industry.

Organization and Presentation of Results

This project effort is presented as a series of two annotated literature reviews. An adapted Haddon Matrix is employed as the framework for describing the intent and focus of each review. The first literature review concerns the selection of safe CMV drivers; the second literature review relates to improving CMV driver safety through the prevention of adverse safety events. Primary source annotations and secondary source abstracts are presented separately for each review.

The content of annotated reviews and any additional commentary are presented as an objective summary/synthesis of the literature, in language understandable to a non-subject matter expert, defined as a person familiar with the motor carrier industry, but who does not necessarily have advanced training or experience in psychology, business, or HR. Each annotation necessarily reflects the level of detail in the corresponding study and primarily concentrates on findings relevant to the scope of the review. In cases where works are clearly related (e.g., identical data sets; pilot and follow-on studies), superscripts separate multiple references contained within a single annotation.

LITERATURE REVIEWS

This project considers two non-regulatory approaches to support FMCSA's mission of improving safety on the roadways. The first approach addresses the workforce "pipeline" issue—who is applying to and being recruited for CMV driver positions—extending to the hiring process, and further, considering retention and turnover. Review #1: Selecting Safe Drivers provides a synthesis and discussion of the available and applicable literature in this area. The second approach is to focus on improving the safety of those drivers already "on the road" by considering the various driver and motor carrier practices that affect safety outcomes, prior to, during, and after safety incidents. In the same manner as for the first review, Review #2: Improving Driver Safety addresses this area.

REVIEW #1: SELECTING SAFE DRIVERS

For this review, Haddon's matrix was adapted such that CMV drivers and motor carriers are the two environments, and the events in the driver-motor carrier relationship are those important for ensuring that the CMV workforce is comprised of safe drivers. To this end, Review #1 encompasses literature addressing the selection of an ideal crop of CMV drivers by recruiting, screening, hiring, and ultimately, retaining the safest employees. Each primary source for Review #1 was annotated and then categorized within one of the six Haddon matrix cells below, as determined by its main focus with regard to environment and event timeframe.

Table 1. Haddon Matrix for Review #1: Selecting Safe Drivers

	Pre-Event	**Event** ***(Hiring of CMV Drivers)***	**Post-Event**
Driver Environment	*Who is applying for CMV driver positions (and why)?*	*What factors are part of the decision a person makes to accept or reject a job offer?*	*What driver-related factors influence whether or not CMV drivers remain at a particular job and/or in the workforce?*
Motor Carrier Environment	*Who is being recruited for CMV driver positions (and how)?*	*What criteria/applicant selection strategies are used as part of the hiring process?*	*What organizational factors influence whether or not CMV drivers remain at a particular job and/or in the workforce?*

Literature Search Results

The literature search for this project generated a total of 20 articles, referencing 16 unique study efforts for Review #1. The material that was annotated covered topics addressing each stage of the event cycle; however, comparable numbers of documents did not result for all six cells of the matrix. Rather, the bulk of the applicable sources for Review #1 pertained to the post-event stage.

As a general overview, referencing Table 1, studies categorized into the pre-event stage, driver environment answered the focus question, *"Who is applying for CMV driver positions (and why)?"* and covered the topics of driver recruitment and driver demographics. Also within the pre-event stage, the available literature addressing the motor carrier environment answered the question, *"Who is being recruited for CMV driver positions (and how)?"* and focused solely on recruitment. The event stage of the matrix for the driver environment was conceptualized to address the question, *"What factors are part of the decision a person makes to accept or reject a job offer?"*; however, the research team located no published literature to address this area. In the motor carrier environment, the event stage was formulated to encompass the question, *"What criteria/applicant selection strategies are used as part of the hiring process?"* and resulted in a single study that investigated criteria for selecting safer drivers. The post-event stage of the matrix and accompanying question, *"What driver-related factors influence whether or not CMV drivers remain at a particular job and/or in the workforce?"* pertained to the driver environment and resulted in a group of studies covering driver turnover and retention. Finally, the post-event, motor carrier environment, and question *"What organizational factors influence whether or not CMV drivers remain at a particular job and/or in the workforce?"* mapped to a variety of applicable studies on driver turnover, retention strategies, management relations, and employee fit.

Selecting Safe Drivers Outcomes

The outcomes of Review #1 point to employee turnover as a primary focus of the data-driven research conducted over the past decade. Driver turnover—in particular, voluntary turnover—has been considered a substantial problem in the trucking industry since deregulation took place in 1980. Deregulation, which allowed new firms to enter the industry, led to an increase in competition among carriers, lower wages, and a more demanding work environment for drivers, thus indirectly increasing turnover (Min & Emam, 2003; Min & Lambert, 2002). Currently, reports of annual turnover rates in excess of 150% are not uncommon within the truckload (TL) segment of the motor carrier industry (Griffin, Kalnbach, Lantz, & Rodriguez, 2000), and therefore, concerning for both motor carriers and safety regulating agencies alike. Whether these employees are leaving the profession entirely or simply "churning" (moving from one company to another; Gallup Organization, 1997), both voluntary and involuntary turnover necessitate additional hiring. This is increasingly true in light of overall growth in the trucking industry paired with an ongoing economic recovery from the recession of 2000 (Global Insight, 2005). In fact, over a 10 year span through 2005, the Gallup Organization (1997) projected an increased need for truck drivers at 12-13%. Paired with a shrinking pool of young, white males—a traditional recruitment source—they suggest a need to explore beyond this group, and possibly look to women and minorities.

Negative impacts associated with turnover and subsequent hiring needs include substantial organizational costs to hire a full complement of drivers each year, estimated as a $7,000 expense per lost employee (Griffin et al., 2000). This number increases further when related human-resource costs, such as recruiting, training, and insurance, are factored in. Furthermore, safety performance decrements associated with inexperienced drivers and operational inefficiencies resulting from new drivers who are not familiar with the service requirements necessary to maintain good customer service are problematic (Griffin et al., 2000). Alternately, if hiring demands are not successfully met by organizations, the outcome is an inadequate staff,

where drivers potentially work beyond their personal limits (and in some cases, legal limits) to accomplish their work—or underqualified and/or undesirable drivers have been hired to fill gaps (Gallup Organization, 1997; Min & Emam, 2003; Min & Lambert, 2002).

Research points to a number of factors that may impact a driver's decision to leave or stay with an organization. In particular, compensation was indicated by drivers as a reason of primary importance in a study by Stephenson and Fox (1996), and in surveys of motor carriers conducted by Dobie, Rakowski, and Southern (1998), and Min and Lambert (2002), suggesting that carriers that pay better wages are more likely to retain drivers. Other factors cited by drivers in the Stephenson and Fox (1996) study pertained to corporate culture. For example, they noted pride in one's company, an organization's fair treatment and appreciation of workers, followed by safety, security, equipment, and working conditions. Motor carrier managers, when surveyed, reported similar factors as impacts to turnover (Dobie et al., 1998; Min & Lambert, 2002). In addition to the above, managers cited reasons of carrier reputation and available benefits (e.g., health benefits).

On a more general level, job satisfaction was linked to turnover in a study by Kalnbach and Lantz (1997), such that new truck drivers who had remained with the company for four months and reported greater job satisfaction were also more committed to the organization and less likely to have contemplated quitting. For most occupations, four months' tenure may be considered a premature point at which to assess job satisfaction; however, in an industry that suffers from annual turnover at the rate that trucking does, this was probably not an unreasonable timeline. In a complimentary research effort, the Gallup Organization (1997) surveyed long-tenured truck drivers who had been with their company for five or more years, and were therefore presumed to be satisfied with their jobs. Results of a regression analysis of 21 job attributes associated with trucking indicated "steadiness of the work," "genuine care of managers," "pay," "support from company while on the road," and "hours of work," respectively, as the top five predictors of overall job satisfaction.

A pair of studies by Gupta, Jenkins, and Delery (1996), and Shaw, Delery, Jenkins, and Gupta (1998) investigated organizational-level turnover in terms of both voluntary and involuntary turnover from the perspective of HR managers in the trucking industry. As driver quit rates were reported at four times higher than discharge rates, this distinction is an important consideration. Generally, they noted a similar set of factors leading to turnover as those previously cited; further, they found that lower quit rates were associated with being home more times per month and less on-board technology. The lowest discharge rates were established for companies using a low selection ratio (few drivers hired out of many applicants), as well as those that employed performance and/or technical knowledge tests instead of unstructured interviews as part of the hiring process. Pertaining to human resource management (HRM) strategies, voluntary turnover was predicted by investment-focused practices. Specifically, they found a negative relationship between voluntary turnover and pay and benefits (higher pay and benefits associated with lower quit rates); a positive relationship with voluntary turnover was determined for companies reporting more time spent on the road and more frequent use of electronic monitoring. Additionally, involuntary turnover was predicted by staffing practices (a low selection ratio), as discussed above.

Although minimizing voluntary and involuntary driver turnover is indeed a means of stabilizing the size of a company's workforce, retaining employees who engage in unsafe driving practices, or are otherwise unsuited for the job, highlights a problem with the prevalent focus of recent academic research efforts. At the post-event stage of the Haddon matrix, an organization has already invested substantial time, money, and HR for the purposes of driver recruitment, selection, and training. Yet there is no guarantee that maximizing only retention will improve the quality of a company's drivers, particularly if recruitment and selection strategies are not concomitantly bolstered.

To this end, a small number of studies in the first review addressed recruitment and selection. Research gaps in these areas may be a function of what researchers perhaps believe is unavoidable industry churn, if, as Richard, LeMay, and Taylor (1995) pointed out, drivers have little loyalty to a company when they perceive that drivers working elsewhere are treated at least as well as they are. Min and Emam (2003) nevertheless posited that it may benefit organizations to tailor policies to recruit drivers with a history of changing jobs less frequently , in addition to older, experienced (>5 years CMV driving experience) drivers, especially as younger, inexperienced drivers were perceived by managers as "obstacles" to successful recruitment and retention (Min & Lambert, 2002). As touched upon briefly above, it again bears mention that the results of Gupta et al. (1996) and Shaw et al. (1998) illustrate the utility of using performance-based and knowledge hiring tests instead of unstructured interview formats, in conjunction with conservative selection techniques, to select only the most qualified drivers.

Although this approach appears logical, it may not be practical or possible for motor carriers to implement at a time when there are already driver shortages, as industry need continues to rise by 1-2% per year (Gallup Organization, 1997), and a mere 18% of students at two and four year colleges indicated that they would even consider a career in transportation (Philbrick & Sherry, 2004). Alternately, in cases where selection procedures are necessarily less rigorous, a composite developed by Jacobs, Conte, Day, and Silva (1996) for transit bus operators may be beneficial. Their model combined six predictor components into a composite measure: biographical information related to temperament and sense of timeliness; personality measures of conscientiousness and openness; and attitudes regarding safety and authority. Resulting composite scores were related to both objective performance criteria (e.g., attendance, accidents) and subjective performance ratings by supervisors. Use of the composite was therefore shown to provide enhanced ability to select bus operators who will drive more safely, miss fewer workdays, and be viewed by supervisors as strong performers. Moreover, a utility analysis suggested that composite use could reduce operating expenses related to accidents/absences by over $550,000 per year, using cost estimates derived from discussions with managers at six transit properties. Although these results appear encouraging, it is important to note that for such a process to work optimally for selecting the safest and most qualified drivers, applicants must buy into it and accurately provide the requested sensitive, personal data. Also, once hired, intra-organizational factors, such as culture and climate, have the rapid potential to influence safety and other behaviors. If these influences are negative, they could easily negate such a system's benefits.

As a final consideration, an obvious shortcoming to the majority of the academic literature that resulted for this first review is that existing research findings do not provide a link to outcomes beyond implications for turnover, or turnover rates themselves. Safety is a major focus of the

trucking industry; yet, in the literature, this outcome was more likely to be referenced for its indirect over its direct relationships with study variables. Despite that turnover is a problem for trucking organizations even more than for the typical employer in the United States, when unsafe drivers remove themselves from the workforce or are discharged, it is then, in fact, appropriate and desirable. It is proposed that further, systematic investigation into the voluntary and involuntary turnover of unsafe or otherwise objectionable drivers is warranted for its potential to help carriers avoid their recruitment, selection, and hiring.

Findings from Trade and Industry Sources

Forums conducted by the Department of Labor in 2005 suggested that the major issues facing the trucking industry at the time included the following: low wages and undesirable benefits relative to other jobs; a lack of career advancement opportunities for drivers; relatively untapped labor markets of recent immigrants with limited English-speaking ability, military veterans, and older workers; a minimum entry age of 21 that makes it more difficult to recruit young people into the industry; and that not enough new workers are in the pipeline to meet labor market demand, in addition to accounting for attrition and turnover (Bearth, 2005).

In comparison with the academic literature, trade-publication sources provide an even more varied explanation of the turnover problem. Statistics from 2006 identify the turnover rate for large TL firms—those with at least $30 million in revenue—at around 116%, a slight decrease from previous years, and 111% for small TL firms, a 9% increase from the previous year (Reddy, 2006c). Less-than-truckload (LTL) firms have an average turnover rate of between 13-15%. Private fleets, like LTL carriers, enjoy a relatively low turnover rate of 16% (Leavitt, 2006). Significant differences in how the various sectors of the trucking industry operate, as well as the activities required of their drivers, may also be driving these exceptional differences in turnover rates. In terms of the differences between private and for-hire carriers, Gary Petty, president of the National Private Truck Council (NPTC) concludes that "driving for a private fleet and driving for a long-haul, for-hire carrier are really two different jobs" (as cited in Leavitt, 2006, p. 18). For one, drivers who work for private and LTL firms are typically home more often, if not every night of the week. Drivers in private fleets often run regular routes and meet with the same customers, providing structure and predictability to their job.

Although the jobs can be vastly different, TL carriers may be able to learn from private and LTL carriers, and it may involve a global change in how drivers are both perceived and treated. Petty notes that "private fleets tend to have a culture of longevity … fifteen to twenty years [tenure] is not uncommon at all" (as cited in Leavitt, 2006, p.18). This long-term mentality is, in theory, within the reach of any trucking company, regardless of long- or short- haul, private or for-hire. Susan Rhodes, a driver recruiter for a small family-owned trucking company, emphasizes that her firm treats drivers "better than family" because drivers are "the connection between the corporate office, the shippers, the customers, and the consumers who eventually use the products we haul" (Rhodes, 2006). Smaller TL firms have fewer drivers than their larger counterparts, often putting them in a better position to maintain one-on-one contact with their drivers. Contrastingly, for larger TL carriers, the dispatcher becomes the sole "face" of the company. An examination of printed and online industry publications in fact revealed that the majority of factors identified as primary contributors to driver retention were attributable to interactions between drivers and field management (i.e., dispatchers). These included communication,

problem resolution, respect and honesty, equipment maintenance, home time, adequate driver training, and clear and fair working rules (White, 2005). Mercer, a TL firm that leases owner-operators, attributes their low turnover rate, at 32%, to a commitment to fostering positive relationships, where drivers are encouraged to speak frankly and discuss any issues they have with their dispatcher. Mercer also makes an effort to pair drivers and dispatchers with similar interests in order to encourage a personal connection (Kilcarr, 2007).

As recommended based on the annotations for this review, it was encouraging to note in the associated trade and industry sources, that there are efforts to shift the focus of motor carriers to the recruitment process as a means of bolstering driver retention. This is related to cost savings, as well as a potential safety benefit, since a well-trained and well-informed recruiter should theoretically be able to identify applicants who will be steady, longer-term employees, while avoiding those who will not (Galligan, 2003). Furthermore, it is suggested that recruiters be up-front with applicants and provide realistic information about the challenges of being a driver, as many times those who quit do so because they were not well informed about the requirements of the job (Kilcarr, 2004; Reddy, 2006b). For those motor carriers that expend time and effort to hire quality drivers up-front, more time can and should be spent on retaining these workers. Experts also stress that a recruiter's job should not end at the point of hire. In fact, for drivers who fail to meet carrier expectations, it is recommended that recruiters go back and review notes from the interview, application, and reference checks to determine what was missed and what lessons learned may reduce excessive turnover in the future (Bookbinder, 2003).

In addition to turnover, the perceived lack of qualified applicants for truck driving positions has also made the process of recruiting drivers more time consuming than in the past. One carrier reported that it took eight months to find drivers for only two positions (Fischer, 2005). However, fortunately, new computer software and the internet are helping to streamline hiring and speed up the process of getting drivers out on the road by improving the efficiency and effectiveness of receiving and reviewing applications. Additionally, many carriers are automating hiring by using online applications and software that allows for tracking candidates through the company from the time they submit their application to the point of hire. When quality drivers are such a valuable commodity, it becomes even more important to keep track of, and follow up with, every applicant (Smith, 2006).

To the same degree that the trade literature over the past five to ten years has targeted driver shortage as the biggest issue faced by the trucking industry, the most commonly proposed solution to this problem has been to increase driver pay. Indeed, average per mile pay rates have been on the rise to better compete with other industries that often recruit from the same pool of applicants, such as construction. However, the wage hikes have not produced the desired result, as driver shortages continue to plague the industry. Instead, wage increases may have had the unintended effect of promoting what the industry terms "job churn" (Reddy, 2006c), as drivers frequently hop, and are sometimes poached, from one carrier to another in order to earn the highest pay possible (Guerrero, 2005).

A recent article in *Transport Topics* argues that wage increases are not effectively attracting new drivers to the industry (Anonymous, 2005a), and anecdotal evidence from motor carriers echoes findings from the academic literature. Quite simply, pay raises are not sufficient to attract and hold good drivers. Rather, improving driver quality of life may be just as, if not more, important

(Reddy, 2006a). Carriers that have seen reductions in their turnover rates often attribute their success to a focus on improving the quality of drivers' working lives by providing more predictable work schedules, more time at home, and better benefits. In addition, fostering driver commitment and loyalty to the company goes a long way toward retention. Motor carriers can increase driver investment by getting them involved and making them feel like a member of the team, as opposed to merely a number. Brad Penneau, a former driver and recruiter with over 18 years experience in the industry, notes that "Pay may attract a driver to a company, but pay will not keep a driver. Pay alone is not an investment, but if a driver has an investment in the carrier, that's harder to walk away from" (as cited in Galligan, 2003, p. 15).

As a means of combating turnover, recommendations from academic sources include a careful and systematic selection of applicants for hire. Not surprisingly, many carriers are concerned that, paired with a perceived labor shortage or, at minimum, a dearth of qualified applicants, maintaining stringent hiring qualifications will put them at a competitive disadvantage and render them unable to keep up with the demands of the industry (Fischer, 2005). Improvements in obtaining accurate background checks and accident history reports have allowed safety-conscious carriers to make more informed hiring decisions. However, some argue that being more thorough also shrinks the pool of available applicants (Bearth, 2006). This may not be an entirely negative outcome; however, as research clearly suggests that past performance predicts future performance. Compromising selection criteria is done at a carrier's own risk, and hiring unsafe or undesirable drivers is bound to affect a company's bottom line. It may even result in legal action if the driver is involved in a crash.

In fact, Paul Berne, an attorney and member of the Trucking Industry Defense Association, notes that claims for negligent hiring—the failure to use reasonable care in the employment selection process—have increased exponentially over the past five years (Bearth, 2006). Even so, as stringent selection procedures targeting only highly qualified drivers may not be an option for many carriers, they have taken to training their own potential driver-applicants as an alternative solution. For example, New England Motor Freight invested about a half-million dollars to start up their own training school. Thomas Hartley, director of safety for the firm, came up with the idea for the school as a way to "produce safe driving" (as cited in Gower, 2005). Motor carriers are also teaming with local community colleges to recruit and train new drivers (Waters, 2006). Many of the new workers in these programs are middle-aged and looking to driving as a second career; in fact, the average age of students enrolled in a commercial driver training program at Hagerstown Community College, in Maryland, is 39 (Heerwagen, 2004). It appears, though, that despite their concerted efforts, motor carriers will continue to face great difficulty recruiting younger workers to the industry.

Jim York, manager of Zurich Service Corp.'s Risk Engineering Transportation Team, proposed that "Perhaps drivers are leaving because they feel that we are not investing in their future success through effective training and support" (York, 2004, p. 53). Citing research suggesting that younger drivers experience more crashes than older drivers, he acknowledged the need for better training for younger drivers in hopes of addressing this safety problem. Related to this need, a UK motor carrier recently won an award for excellence for its development of an apprenticeship program designed to introduce younger workers to driving from as early as age 17. Trainees begin by driving local delivery trucks, and can then move on to an advanced apprenticeship where they are taught to drive larger commercial vehicles (Jack, 2006).

Additionally, the government in Ontario, Canada is teaming with industry groups to create a voluntary apprenticeship program where drivers will learn such things as trip planning, equipment inspection procedures, and how to safely handle cargo (Anonymous, 2005b). Similarly, Pitt-Ohio, a LTL fleet based in Pennsylvania, developed a pilot, in-house "stepping stone" training/apprenticeship program, allowing dock workers a clear path to becoming a truck driver. In this program, dock workers, who have an advantage of already being familiar with how the company handles freight, gain initial driving experience with 14 ft. straight trucks. Successful workers can then move up to a tractor-trailer after 2 years experience. In turn, Pitt-Ohio reports that the drivers trained in-house have been involved in fewer accidents (Cullen, 1998).

As suggested in a report by the Gallup Organization (1997), there is evidence that motor carriers are also making a concerted effort to reach out to populations of workers, beyond young, white males, that have not been actively recruited as truck drivers in the past. Currently, many older workers reaching retirement age are looking towards truck driving as a post-retirement career. Indeed, Schneider National is actively pursuing older workers to join their workforce, and reports that 15% of the professional truck drivers they hired in 2005 were at least 50 years old (Jadin, 2006). Military veterans represent another underutilized labor market for the trucking industry. Many veterans who leave the military have experience operating heavy-duty vehicles, a strong work ethic, and are capable of working independently (Reddy, 2006b), suggesting that they might be a naturally good fit for a career in truck driving. Companies are also attempting to attract Hispanics to the industry by recruiting in traditionally Hispanic communities, advertising in Spanish, participating in job fairs and stay-in-school programs, and hiring bilingual dispatchers and recruiters to bridge the language barrier (Levy, 2005; Schulz, 2001).

A final issue raised by experts and investigated in Griffin et al. (2000) is that it may be difficult to attract and retain workers because of the lack of a well-defined career path for a driver. For example, an accountant's career path may start in from billing, and move on to receivables, to asset management, and ultimately to a position of controller in a trucking firm. A driver will almost always stay a driver, with little to show for it besides seniority (Labbe, 2006). The lack of a career path may also be driving the problem of job churn within the industry. Duff Swain, president of Trincon Group, a consulting firm specializing in long-haul trucking, points out that "As a result of industry deregulation in 1980, driver pay rates have been set by the market rather than based on experience and competence and drivers have little loyalty to a particular employer, since they can obtain comparable pay and benefits with any number of fleets" (as cited in Cullen, July 2004, p. 20). Swain's consulting firm suggests a complete overhaul of the profile of a typical truck driver: "The industry must recruit or create a driver who is security- and career-conscious, and self-motivated to increase their wage or standing in a company" (as cited in Cullen, 2004, p. 20). In the past, motor carriers have attempted to attract workers to driving positions because of the independent lifestyle it affords. While independence is indeed attractive, it is not enough to keep drivers for the long term. Without a clear path for career advancement, drivers are unable to make goals for the future and have little reason to stay loyal to a single company (Swain, 2000; Nguyen, 2007). Interestingly, rather than the existing focus on turnover in much of the literature, a more innovative solution may be required—one that is long term and involves changing the image of trucking to better equip the industry, while also meeting the needs of today's workforce.

Review #1 Annotations

Pre-event

Driver Environment: Who is applying for CMV driver positions (and why)?

Global Insight, Inc. (2005). The U.S. truck driver shortage: Analysis and forecasts. *American Trucking Association.*

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Demographics		
Motor Carrier Environment			

Author Abstract: No author abstract

Industry Sector: Long-haul, heavy duty trucking

Purpose: The purpose of this study was to assess the long-term needs for truck drivers in the trucking industry. The study sought to quantify growth in the demand and supply of truck drivers over the next decade, and also to identify the demographic and regulatory factors that affect the supply of truck drivers. It also explained how the industry can adjust to the imbalances between supply and demand.

Sample: Census data includes over 62,653 responses from the year 2000 where the responders identified themselves as truck drivers.

Global Insight estimated a population of 780,000 long-haul truck drivers, including owner-operators, based on Bureau of Labor Statistics (BLS) data.

Methodology: The study first used Census Bureau statistics, BLS, and industry statistics to quantify the size of long-haul trucking. Global Insight attempted to reconcile the Census and the BLS data, which differ in their definitions of the truck driver occupation and the truck transport industry. The BLS estimate was used for the total population of long-haul heavy duty truck drivers in the Truck Transportation industry, whereas Census supplied demographic data.

The Office of Occupational Statistics and Employment Projection of the BLS used data from the year 2000 to identify job types in all industries. Global Insight extracted only heavy-duty and tractor trailer drivers employed in the "truck transportation" industry and owner-operators from

the BLS data, thus excluding drivers from non-trucking industries. The owner-operator population estimate was comparable to the Census Bureau's 2002 Vehicle Inventory and Use Survey and the 2002 Current Population Survey (CPS) estimates. Global Insight further narrowed the population to include only long-haul, heavy-duty truck drivers, arriving at the final estimate of 780,000 drivers based on the BLS data.

The authors also used 2000 Census of Population and Housing data, CPS data, and the Public Use Microdata Sample (PUMS) to analyze truck driver demographics. (The PUMS contains responses from 5% of the households that received the long form of the census, 62,653 of whom were truck drivers.) The total CPS estimate in 2000 was 1.5 million drivers.

The CPS industry classification is broader than the population of long-haul, heavy duty truck drivers in the truck transportation industry of interest to the authors; however, it was the only source of demographic data available.

Secondly, the authors used proprietary forecasting models to project job growth in the long-haul trucking industry. Third, the authors looked at changing demographics of the general population to develop various scenarios of change in the supply of long-haul truck drivers. Census and CPS data from 2000 were used to analyze the labor force participation rate in heavy-duty driving by age, sex, and race/ethnicity. Lastly, the study analyzed how wages must adjust in order to close the gap between supply and demand. This was done by comparing wages in trucking to wages in industries often seen as alternative occupations for drivers, such as construction.

Relevant Findings: Based on demographic trends and growth rates in labor force participation, Global Insight predicted that the supply of long-haul truck drivers will grow at an average annual rate of 1.6% over the next 10 years. This growth rate will not be adequate compared to the estimated average annual growth rate in demand (2.2%, or 320,000 jobs over the next 10 years.) It was found that one in six drivers was 55 or older in 2000, making the average age of truck drivers higher than that of the overall labor force. An additional 219,000 drivers will be needed to replace these drivers when they retire or leave the industry. Taking both growth and demographic change into account, a net of 54,000 drivers per year will be needed over the next 10 years. The dearth of drivers will widen from a current 20,000 to 111,000 by 2014. Further, individual truck firms will need to hire at a greater rate because of frequent inter-firm turnover, or churn, and ultimately the shortage of qualified, safe drivers will be even greater.

Demographic factors were found to account for some of this predicted

shortage. The entire labor force is projected to grow by only 0.5% by 2014. In addition, the largest demographic group of truck drivers—white males aged 35–54—will make up an increasingly smaller percentage of the population. Some of this decline will be offset by workers who are currently in the 35–54 year old age group continuing to work into their sixties and by an increase in Hispanic male drivers, who already represent an increasing share of truck drivers.

In order to close this gap, firms will need to offer higher wages to attract workers from other industries. The competitiveness of wages in the trucking industry fell during the 2000 recession and has not yet recovered. Whereas average weekly earnings in the long-haul trucking sector were 6-7% above earnings in construction throughout the 1990s, they fell to below 9% in 2001 and remain at below 1%. The authors expect to see wage gains of 6-7% per year over the next three years in long-haul trucking. However, wages will need to grow at an even faster rate (more than 8%) once demographic trends worsen in the second half of the decade. Firms will also need to address non-monetary aspects of the job, such as time away from home. Closing the gap in the supply of truck drivers is achievable by attracting workers from other industries because the shortage in the total number of truck drivers needed by the industry will account for less than 0.1% of the total labor force in 2014.

In summary, the supply of truck drivers is projected to grow, but not enough to meet the growth in demand. Wages and non-monetary benefits will have to increase in order to fill the labor market gap.

Limitations: The study does not directly address safety. However, the shortage in all drivers, especially qualified ones, may put pressure on the industry to hire under-qualified and potentially unsafe drivers.

The CPS, used to analyze demographics, aggregates occupational data, making it impossible to separate non-long-haul drivers from total truck driver data. However, the authors exclude local haul drivers from the total population estimates. Thus, the authors estimate the size of the trucking industry using only heavy-duty long-haul drivers, but analyze demographics using data on both long-haul and short-haul heavy-duty truck drivers.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #1: Driver Demographics, because the paper describes the current and future supply and needs in the driver labor market, including driver demographic factors as explanations for some of the projected shortages.

Philbrick, K.E., & Sherry, P. (2004). *Perceptions of the intermodal transportation industry related to recruitment and retention of human resources* (Publication No. DTRS98-G-0017). National Center for Intermodal Transportation: Research and Special Programs Administration.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Recruitment		
Motor Carrier Environment			

Author Abstract: No author abstract

Industry Sector: Intermodal transportation and the transportation industry in general

Purpose: The purpose of the study was to assess college students' perceptions of the transportation industry and make recommendations regarding future recruiting efforts. The authors highlight the importance of attracting young people to the transportation industry as a way to potentially begin to remediate the shortage of skilled workers in transportation.

Sample: 447 college students.

Methodology: Researchers surveyed students from community colleges and four-year universities using a questionnaire developed specifically for this study. They approached students in public areas on campus to solicit participation. The questionnaire included items intended to measure influencing factors for career choice, occupational values, preference for a career in transportation, job preference (measured using the RIASEC vocational interest typology), knowledge of various career types, perceived desirability of various career types, and demographic information.

Relevant Findings: Individuals considering a career in transportation were found to be more likely to value employee assistance, wellness and fitness programs, labor/management relations, travel opportunities, and opportunities for career advancement and leadership. Not surprisingly, a vast majority of the participants, regardless of career preference, reported that financial gain and competitive fringe benefits were important to them in making a career decision. The transportation industry ranked the third lowest, out of 14 career fields, in terms of desirability. Also, only 18% of participants indicated that they would consider a career in transportation. Participants also indicated only limited knowledge of the different types of careers available in transportation, suggesting that a lack of knowledge about the

opportunities that exist in the transportation industry may be a serious barrier to recruitment. In terms of vocational interest, the results of the study also suggest that people with an interest in conventional jobs, and that prefer highly ordered activities with little artistic or physical skill are most likely to choose a career in transportation. People who highly value career stability, but do not have strong preferences for geographic location, are also prime targets for recruitment into the transportation field. Colleges and universities should clearly be a target for recruiting people to the transportation field. However, more focused recruitment efforts, as well as increased advertising about transportation opportunities, is necessary in order to utilize this recruiting population to its fullest potential.

Limitations: One limitation of the current study is that there is no indication of whether the participants included in the study have declared a major. The 18% of students who would consider a career in transportation may already be enrolled in a traditional transportation-related major. Thus, the necessity of introducing transportation to a more diverse range of students becomes even more important. There are also some limitations to the applicability of this study to the truck driving occupation in particular. Although recruiting directed at community colleges or trade schools may be successful, students at 4-year universities may be less likely to desire a career as a driver, opting instead to attain a position requiring a bachelor's degree (e.g., in management or engineering). Nevertheless, it is clear that recruiting younger populations necessitates an increased effort to educate students about the breadth of opportunities available in the transportation industry and focused efforts to recruit students based on their career values and vocational interests.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #1: Driver Recruitment, as the researchers sought to assess perceptions of the transportation industry in an effort to refine existing recruiting strategies.

Motor Carrier Environment: Who is being recruited for CMV driver positions (and how)?

Dobie, K., Rakowski, J.P., & Southern, R.N. (1998). Motor carrier road driver recruitment in a time of shortages: What are we doing now? *Transportation Journal, 37*, 5–12.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Driver Recruitment		

Author Abstract: No author abstract

Industry Sector: TL and LTL trucking

Purpose: The study is a follow up on a prior study of recruitment strategies conducted in 1989. This paper identifies changes in managerial perceptions of recruitment and recruitment strategies. The authors felt that a reassessment was necessary given the rapidly changing demographics, new regulations, and an increased emphasis on driver retention.

Sample: 62 motor carriers responded to a survey mailed to 517 firms.

Methodology: The study surveyed recruiters listed in the Traffic Management Directory of "Motor Carrier Services," excluding local cartage companies. Motor carrier managers were asked to respond to demographic questions, current and past turnover rates, and the following four major questions from the original 1989 survey: 1) What did managers feel was most important to drivers when they selected a company for employment? 2) What forms of communication were used to reach potential drivers? 3) What incentives did managers stress when recruiting drivers? and 4) What were the pre- and post-employment training requirements for their firms?

Relevant Findings: The top five incentives managers identified as being most important to drivers remained the same from 1989, and included pay, condition of equipment, time at home, carrier reputation, and health benefits. Equipment type, access to management, and pension were not included in the 1989 survey, but ranked sixth, seventh, and eighth, respectively, in the 1996 survey. Firms are also diversifying their recruitment communication sources, using a mix of newspapers, magazines, word of mouth, advertising on company trailers, and driver training schools. The most frequently used source was word of mouth, with over 75% of the motor carriers sampled indicating that they used current employees as an avenue to recruit new employees. The use of newspapers declined from 1989

levels, but magazine use dramatically increased from 10% to 45%, suggesting a trend toward the use of professional association publications as a beneficial recruiting source. Common incentives like pay and health benefits continue to be stressed by motor carriers during recruitment. Time at home made a dramatic jump in 1996 as a recruitment incentive, with over 80% of managers indicating that they stress time at home during the recruitment process (from 40% in 1989). Factors that may be of interest to drivers seeking long-term employment, such as training and advancement opportunities, were ranked last by managers. The majority of firms surveyed had minimum age requirements of 23 years and experience requirements of 2 years, but a small trend of declining age and experience requirements can be detected.

Overall, there seems to be an increased emphasis on using current drivers and trade publications to attract new drivers. Incentives related to quality of life, such as health care and time at home, are also being more heavily marketed, in addition to pay, during the recruiting process.

Limitations: The study cited in this article is now about ten years old. Given the changes that occurred over a seven year time period, it would be advantageous to re-administer the survey and document motor carrier recruiting practices of today. Changes in the motor carrier industry over the past ten years may have also triggered additional changes in recruiting practices. For example, the FMCSA has been established, driver training schools have grown dramatically, and the accessibility of the internet has provided an additional avenue for advertising.

In addition, this study concentrates on management perceptions of factors deemed important to drivers. A more effective study might also directly survey the drivers.

Categorization: This study fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #1: Driver Recruitment, because it summarizes the recruitment practices of 1996 for a sample of motor carriers and compares the results to those documented in 1989.

Event

Motor Carrier Environment: What criteria/applicant selection strategies are used as part of the hiring process?

Jacobs, R.R., Conte, J.M., Day, D.V., & Silva, J.M. (1996). Selecting bus drivers: Multiple predictors, multiple perspectives on validity, and multiple estimates of utility. *Human Performance, 9*, 199-217.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment		Criteria for Selecting Drivers	

Author Abstract: No author abstract

Industry Sector: Transit bus industry in the U.S. and Canada

Purpose: The purpose of this study was to develop and validate a reliable model for optimally selecting bus drivers for employment, and to show the utility of such a model in reducing transit property operating expenses.

Sample: *Job analysis survey:* 309 bus operators; 62 supervisors in 9 transit properties across the U.S. (8 cities) and Canada (1 city).

Predictor battery: 864 bus operators in 9 bus properties across the U.S. and Canada (8 of these properties also participated in the job analysis survey).

Methodology: First, researchers performed a job analysis, using results of this activity to form a theory describing the job of a bus operator and operator performance.

Subsequently, criterion measures were developed that corresponded to the theorized performance dimensions. Data collected to address these criteria consisted of property archival data regarding objective measures of driver performance (number of days of worker's compensation and days absent; total number of accidents). Additionally, supervisors provided subjective driver performance ratings in areas of attendance, safety, and customer courtesy.

A battery of questions reflecting job content was assembled based on results of the job analysis and academic literature review. Consultation

with SMEs from an advisory panel representing the transit industry established the content validity of this predictor set.

Predictor battery data collected from bus operators and a concurrent, criterion-related validity study allowed for an analysis of the relationship between the predictor data and objective and subjective measures of job performance. Based on these results, a predictor composite was formed. Finally, a utility analysis was conducted to estimate a cost savings to transit agencies using this composite for bus operator selection purposes.

Relevant Findings: Based on the job analysis, researchers concluded that the job of a bus operator encompassed three performance dimensions: timeliness, safety, and courtesy to riders. The resulting selection model was derived from an inter-correlation matrix of all variables. This model was used in conjunction with a conceptual view of the predictor set of variables that encompass the job of a bus operator. It combined six predictor components containing biographical information relating to temperament and sense of timeliness, personality measures of conscientiousness and openness, and attitudes regarding safety and authority, into a predictor composite. The six predictor components were weighted equally and summed to calculate a composite score that reliably differentiated candidates and may be used for the purpose of selection. In addition, the composite score was significantly related to existing measures of objective performance criteria and subjective performance ratings.

Content validity, established by SMEs, was bolstered by evidence of criterion-related validity. Significant correlations were obtained among supervisor performance ratings and scores on the composite for safety, courtesy, attendance, and overall performance criteria. The ability of the composite to accurately forecast objective job performance in terms of attendance and accident measures was also supported. Results indicated that use of the predictor composite provided an enhanced ability to select bus operators who will drive more safely, miss fewer workdays, and be viewed by supervisors as strong performers.

Finally, a utility analysis was based on cost estimates for absences and accidents derived from discussions with managers at six different transit properties. Results suggest that use of the composite has the potential to reduce operating expenses related to accidents and absences by over $550,000 per year.

Limitations: Selection of the most qualified and safety-conscious operators is only possible using this system if applicants buy into the process and are willing to provide the potentially sensitive personal data that is requested. Moreover, although this system may select the most desirable workers, once hired, intra-organizational factors such as culture and climate, have

the rapid potential to influence safety and other behaviors. If these influences are negative, they could easily negate the system's benefits.

Categorization: This study fits within the event timeframe of the motor carrier environment for Haddon Matrix #1: Criteria for Selecting Drivers, because it proposes a selection strategy for hiring bus operators who are likely to display good job performance and be safety-sensitive.

Post-event

Driver Environment: What driver-related factors influence whether or not CMV drivers remain at a particular job and/or in the workforce?

Gallup Organization. (1997). Empty seats and musical chairs: Critical success factors in truck driver retention.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Driver Turnover and Retention

Author Abstract: This study set out to do three things: (1) update the trucking industry and labor force demographic analysis from the 1988 Hudson Institute study; (2) provide a better understanding of the unique attitudes about trucking held by people both inside and outside the industry and the effect of these attitudes on personnel management; and (3) develop a retention model based on the factors that are most significant in promoting job satisfaction of long-tenured truck drivers—drivers who have been with their current company for five years or more. Principal findings are: (1) driver turnover continues to represent 80 percent of the trucking industry's need for new drivers; (2) the workforce segment—males 20–24—that has been the main source for the trucking industry, will grow by an average of only 0.7 percent per year between 1994 and 2005; (3) the population groups that show the greatest labor force growth are those that have not traditionally been drawn to trucking—women and minorities. [Reviewer note: this is the TRIS abstract; the author abstract is multiple pages.]

Industry Sector: Trucking

Purpose: An initial purpose of this study was to update demographic information previously obtained by the 1988 Hudson study in order to estimate labor pool size, and compare trucking industry growth with that of construction, an industry with which trucking competes. Additionally, researchers sought to gain a better understanding of public and industry perceptions of trucking, and how these attitudes affect turnover and retention. Data gathered from interviews with long-tenured truck drivers was used to create a model of job retention based on the job attributes that most significantly impact job satisfaction.

Sample: 15 trucking company executives from different firms.
1,000 adults in the continental United States.
801 drivers who had been with their current company for 5 years or more.

Methodology: For the first part of the study, researchers reviewed existing demographic and economic data from DRI/McGraw-Hill and Martin Labbe Associates, the US BLS, and the ATA from the time period of 1994 to 2005.

Researchers conducted in-depth interviews with 15 executives from different trucking firms to extract information regarding how fleet company executives view driver shortage, turnover, and retention issues. Additionally, a random sample of adults in the US was polled to gain an understanding of public perceptions of truck drivers, and the industry as a whole. They were asked questions regarding whether their view of truck drivers was mostly positive, or mostly negative, as well as to rate different characteristics of truck drivers such as friendliness and independence.

Researchers also interviewed long-tenured truck drivers (employed with the same company for five or more years) by phone to understand what aspects of their job led to increased satisfaction and commitment to their company. These drivers were selected based on the assumption that remaining at an organization for that long equates to relative satisfaction with the job. They were asked to rate their level of satisfaction on 21 job attributes. A subsequent data reduction analysis of these job attributes revealed 4 factors, conceptualized as: company support, non-driving activities and customer friendliness, hours of work and time with family, and work rewards. Factor groups, as well as the individual job attributes were then used in multiple regression analyses to determine which most reliably predicted driver satisfaction.

Relevant Findings: Results of the initial review of available data from the US BLS and DRI/McGraw-Hill and Martin Labbe Associates confirmed the increasing need for qualified drivers through 2005. Based on freight volumes across numerous industry sectors and delivery modes, DRI, for example, estimated the truck population to grow by 13.4% (1.26% annually). Having combined the effects of industry growth and driver turnover, and assuming that these would remain stable, a need to hire 894,000 new drivers was estimated between 1995 and 2005. Given such projections, the authors sought to understand what specific factors lead to greater driver satisfaction and commitment so that trucking firms could potentially be better equipped to retain drivers.

Most of the 15 trucking company executives who were interviewed stated that the current driver shortage was moderate to severe, and not as much a shortage of available candidates, as a dearth of qualified candidates. Additionally, 11 of the 15 believed that this problem was more severe than

compared with 5 years prior to the study, in 1991. All agreed that the long-haul, full TL segment suffered most from the shortage of qualified drivers, likely as a result of the quality of life on the road and long periods of time away from home.

Also noted was the shrinking demographic group (young, white males) from which drivers were typically recruited. Executives reported additional frustration regarding minimum-age requirements for their role in preventing companies from hiring directly out of school, so as to mold career drivers. Interestingly, here responses were evenly split when executives were asked about driver quality: half indicated that quality had improved over the past five years, half indicated that it had worsened, and one respondent reported no change. Responses paralleled those regarding the overall driver population when queried regarding their own drivers.

Though executives reported believing that the public has an overall negative perception of truck drivers, instead, 80% of a random sample of US adults purported a positive view. Of characteristics rated for how well they described professional truck drivers, independence was rated the highest, with 93% of the sample reporting that this trait "definitely" or "probably" describes them. As independence is highly valued in American culture, such a public perception of truck driving should be capitalized upon when trying to recruit new drivers into the industry. Interestingly, although almost two-thirds (65%) of the sample agreed that "the industry needs to recruit more women drivers," the two groups who least agreed with this statement were persons 55 and older, and women themselves. The authors suggest that this may equate to substantial resistance from women when attempting to recruit them into the trucking industry.

With regard to the satisfaction and commitment of long-tenured drivers, as expected, researchers found that 86% of their sample were either "very satisfied" or "somewhat satisfied" with trucking as an occupation, and the longer the tenure, the more satisfied drivers tended to be. Of interest, though in the public sample, women appeared to resist the idea of a career in the trucking industry, long-tenured female drivers reported greater job satisfaction than their male counterparts (59% of the women drivers reported being "very satisfied" compared to 42% of the male drivers).

An additional aspect of surveying the long-tenured drivers was to obtain information regarding their level of job commitment, as this strongly relates to retention. Though satisfaction was found to be very high, commitment to the job was not as strong. Compared to the 86% who reported being "very" or "somewhat satisfied" with truck driving, only 63% said they would "definitely" or "probably" choose it as an occupation again. Additionally, only 44% responded that they would "definitely" or "probably" recommend trucking to their family and friends. Similar to the

higher ratings for satisfaction, women were also significantly more likely to say they would choose trucking as an occupation again. This finding, in conjunction with the increased satisfaction reported by female drivers, suggests that recruitment of females could be vital to the trucking industry.

Finally, the 21 job attributes, as subsequently collapsed into 4 categories, were rated by the long-tenured drivers using a 5-point scale ranging from "very dissatisfied" to "very satisfied." Multiple regression analyses using the four factors evidenced the largest increases in overall job satisfaction as a result of improving in the areas of company support (39%; e.g., "friendliness of managers") and work rewards (32%; e.g., "steadiness of the work"). Of lesser importance were the hours of work and time with family factor (20%; e.g., "time spent on the road") and the non-driving activities and customer friendliness factor (9%; e.g., "amount of physical loading and unloading have to do"). The job attributes were also each separately analyzed to determine the most important specific predictors of overall job satisfaction. This analysis revealed "steadiness of the work," "genuine care of managers," "pay," "support from company while on the road," and "hours of work," respectively, as the top five predictors of overall satisfaction.

Limitations: The results from the survey on long-tenured drivers evidenced a high level of satisfaction with trucking, paired with a lesser level of reported commitment to the job; however, the study did not seek parallel information from drivers with shorter tenure at organizations. As driver turnover is extremely common in trucking, resulting often in short successions of brief organizational tenure, research in this area should be considered in conjunction with the current findings. Additionally, the findings of this study are now 10 years old, and are, thus, likely in need of updating.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #1: Turnover and Retention, as the researchers investigated aspects of truck driving that lead to increased job satisfaction in an effort to increase driver retention.

Kalnbach, L., & Griffin, G. (2002). *Predicting and classifying voluntary turnover decisions for truckload drivers*. National Transportation Library (U.S. Department of Transportation). (NTIS No. PB2003-102189)

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Driver Turnover and Retention
Motor Carrier Environment			

Author Abstract: Voluntary turnover rates among truckload carriers are extremely high, ranging from 50% to more than 100% annually. These high turnover rates result in elevated costs for carriers in terms of recruitment and training as well as costs associated with reduced productivity and decreased customer satisfaction resulting from inexperienced drivers. Although much research has been conducted to determine the relationship between job satisfaction of drivers and the likelihood of them leaving or intending to leave an organization, research addressing other reasons why drivers leave their organizations has been lacking. As a result, this project was designed to increase understanding of voluntary turnover of drivers.

To accomplish this objective, written surveys were used to gather data from drivers. Surveys were completed by drivers at two different times during the study. The first survey, assessing personal and situational characteristics, was completed by applicants for the job of driver during the hiring process. The second survey was distributed only to those drivers who quit their jobs during the study in order to ascertain how they made their decisions to leave their organizations. Although the actual number of drivers that completed both surveys was very small, analyses were conducted to determine how those that left the organization compared to those who stayed with the organization. Results and recommendations are provided in subsequent sections of this report.

Industry Sector: Trucking

Purpose: The authors used the unfolding model of turnover, developed by Lee and Mitchell (1994), to classify and characterize reasons why truck drivers voluntarily choose to leave their jobs. The unfolding model of turnover is characterized by four decision paths that may explain why people choose to quit their jobs. The first three paths involve a shock component, defined as a "jarring event that initiates the psychological analyses involved in quitting" (p. 4).

Path 1 involves a shock followed by the enactment of a pre-existing script (i.e., planned or automatic behaviors based on past experience in similar situations) without consideration for alternatives.

Path 2 involves a shock that prompts feelings of image violation, where the person reconsiders his/her attachment to the organization, and alternative job options are not considered before the decision to quit is made.

Path 3 again involves a shock and image violation; however, the person chooses to search for alternatives prior to leaving the organization.

Paths 4a and 4b involve the decision to turnover due to a gradual feeling of dissatisfaction, without the existence of a specific "shock" event. Path 4a is dissatisfaction without consideration for alternatives, whereas path 4b is defined as dissatisfaction leading to a search for alternative opportunities before deciding to leave the organization.

It was hypothesized that: 1) people receive scores on psychological measures indicating a low level of conscientiousness, a high level of risk taking, and high level of openness to experiences will be more likely to leave an organization without considering alternatives, thus taking paths 1, 2, or 4a; 2) people who report more responsible behavior in the past (e.g., longer tenure, more work experience) will be more likely to seek alternatives before quitting, thus following paths 3 or 4b; 3) people who have voluntarily left jobs in the past are more likely to follow path 1 and use a script for leaving the organization; 4) people who perceive there to be many alternatives to their jobs in general will be less likely to search for alternatives before quitting (paths 3 or 4b) than their counterparts who perceive there to be fewer alternatives; 5) low perceptions of fit will lead to more quit decisions due to general dissatisfaction (paths 4a or 4b) than due to a specific shock event (paths 1, 2, or 3).

Sample: The first survey collection included 804 new-hire truck drivers at U.S. motor carriers (i.e., Schneider National, Barr Nunn, C.R. England, M.S. Carriers). Only 37 out of the 247 drivers who left the organization in their first six months of employment completed the second survey.

Methodology: Newly hired drivers were asked to complete a survey as part of their initial paperwork. Turnover data were gathered from organizational records for six months after the initial survey distribution. Truck drivers who chose the leave the organization in that time period were given a second survey assessing their reasons for quitting. The second survey was mailed to their homes to ensure confidentiality. Turnover decisions described in the second survey were classified into one of the five decision paths (where possible) using the methodology developed by Lee et al. (1999).

Relevant Findings: Researchers were unable to classify 7 of the 37 turnover decisions described in the second survey. Out of the 30 classifiable decisions, 13 followed path 3, which is a shock prompting feelings of image violation, followed by the consideration of possible job alternatives before leaving the organization. Also, drivers who left the organization reported lower levels of conscientiousness and more work-related skills than those who chose to stay with the organization.

The small sample size obtained in the second survey precluded the use of statistical analyses to test the proposed hypotheses. Percentage comparisons did indicate marginal support for hypotheses 1, 2, and 4. Qualitative analyses from the second survey also indicate that many of the drivers who chose to quit felt that they had been misled about various aspects of the job (e.g., amount of pay, time at home, and driving routes) and that the organization failed to keep promises made when the drivers were hired. Four drivers also indicated concern about the quality of training they received. Better communication during the hiring process and improved training may go a long way to improve driver retention.

Limitations: Due to the small sample size obtained in the second survey and the inability to classify the turnover decisions of 18% of the truck drivers who did respond, the results should be interpreted with caution. Furthermore, this study only sampled truck drivers who quit within the first six months of hire, making it difficult to generalize to the much larger population of drivers who quit after that period. However, there is still a strong indication that drivers who decide to quit due to a shock and image violation often explore alternative opportunities before quitting, suggesting that there is a window of time when the organization may be able to intervene and attempt to remediate the image violation, reducing the likelihood that the driver will decide to quit. Future research is necessary.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #1: Driver Turnover, as the focus of the article was the five potential paths that lead drivers to voluntarily quit a company.

Kalnbach, L.R., & Lantz, B.M. (1997). The effects of optimism and willingness to trust on work-related attitudes and behaviors: An application to the commercial vehicle industry (MPC Publication No. 97-75). Mountain-Plains Consortium. (NTIS No. PB97-190748)

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Driver Turnover and Retention
Motor Carrier Environment			

Author Abstract: The main objective of this study was to explore the determination of commercial vehicle driver attitudes and the effect of these attitudes on driving performance, job satisfaction, and turnover. It was hypothesized that if a relationship is found, it may then be worthwhile to select applicants with the highest potential for good work habits and company loyalty.
Previous research was reviewed to help define measures of trust, optimism, organizational commitment, job satisfaction, intent to turnover, and commitment to work. Productivity measures included miles driven, out-of-route percentage, late deliveries, and accidents.
Optimism and trust measures were obtained over a two month time period from 584 new drivers from a national trucking company. Turnover of these drivers was measured four months later. The drivers still with the company were sent a second survey to obtain the additional job-related measures. At the same time, productivity measures for these drivers were obtained from the company.
Results showed moderate support for the stated hypotheses. There is some credibility to using measures of trust and optimism in the selection process. Other measures in the study also could help to predict intent to turnover. A discussion and explanation of the results is given.

Industry Sector: Trucking

Purpose: The purpose of the study was to examine trust and optimism as global personality characteristics that may relate to positive work attitudes and work behaviors.

Sample: Initial sample—584 newly-hired truck drivers working for a national motor carrier in the initial sample.
After four months, 103 of the remaining 326 drivers completed the second survey (31.6% response rate).

Methodology: The researchers surveyed new drivers from a national trucking company during their initial training period. The survey included measures of

willingness to trust, optimism, and demographic characteristics. Willingness to trust was measured using 25 items from the Interpersonal Trust Scale (ITS; Rotter, 1967). Respondents were asked to rate the extent to which they agreed or disagreed with statements such as, "Most people can be counted on to do what they say they will do," using a 1–5 point scale where 1 equaled "strongly agree" and 5 equaled "strongly disagree." Optimism was measured using the eight-item Life Orientation Test (Scheier & Carver, 1985). Statements such as, "I am always optimistic about my future" were rated on the same 1–5 scale.

Four months later, a second survey was distributed to those truck drivers who remained with the company. The second survey asked about drivers' organizational commitment (e.g., "I really care about the fate of this organization"), intent to turnover (e.g., "I will probably look for a new job in the near future"), job satisfaction (e.g., "I am satisfied with my current job in this company"), and commitment to work (e.g., "What I do at work is more important to me than the money I earn"). Driver productivity and accident rates were recorded from company data gathered for drivers who stayed with the company. Actual turnover was recorded for drivers who participated in the first survey, but quit in the four months before the second survey.

Relevant Findings: Willingness to trust and optimism were not significantly correlated with job satisfaction or other job-related attitudes. However, job satisfaction was correlated with organizational commitment and intentions to leave the company. Drivers reporting greater job satisfaction also reported being more committed to the company and were less likely to have considered quitting. Furthermore, trust significantly predicted actual turnover such that drivers who reported a greater willingness to trust were more likely to have stayed with the company after four months. There were no significant relationships between driver characteristics and accident rates.

Limitations: Although this study utilized self-report data measured at different time points, there is some question about the reliability of the measures used. The measures of optimism and commitment to work demonstrated internal consistencies below 0.70, the typical cut-off score used to establish reliability. Furthermore, job satisfaction was measured using a single item indicator. The sample used in the current study consisted entirely of entry-level truck drivers. It is unclear whether the results obtained would generalize to more tenured truck drivers, or whether the results would remain consistent if the period between the initial and follow-up survey was longer than four months. Willingness to trust may contribute to explaining why newly hired truck drivers' turnover within the first four months of working for a company, but may not be a contributing factor when more tenured employees choose to leave their company.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #1: Driver Turnover, as the authors identified trait characteristics they felt would have an impact on driver turnover rates.

Lauver, K.J., & Kristof-Brown, A. (2001). Distinguishing between employees' perceptions of person-job and person-organization fit. *Journal of Vocational Behavior, 59*, 454–470.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Employee Fit
Motor Carrier Environment			

Author Abstract: This study examines the relationship between employees' perceptions of person-job (P-J) and person-organization (P-O) fit. Survey data was collected from 231 employees (104 office personnel and 127 drivers) of a national trucking company show a low correlation (r = .18) between the two types of self-reported fit. Both P-J and P-O fit had a unique impact on job satisfaction and intent to quit. P-O fit was a better predictor of intentions to quit than was P-J fit, but there was little difference in their relative influence on job satisfaction. The predicted positive relationship between perceived P-O fit and contextual performance (extra-role behaviors an employee performs beyond those prescribed in their job description) was also supported. No relationship was found between perceived P-J fit and task performance. Taken as a whole, these results provide further evidence that employees' perceptions of P-J and P-O fit should be treated as distinct constructs.

Industry Sector: Trucking

Purpose: The purpose of the current study was to examine the differential contributions of perceived P-J and P-O fit as predictors of job satisfaction and performance. The authors defined P-J fit as "the match between the abilities of a person and the demands of a job" (p. 455). Whereas P-O fit was defined as "the compatibility between people and organizations that occurs when at least one entity provides what the other needs, they share similar fundamental characteristics, or both" (as cited in Kristof, 1996, pp. 4–5). In summary, P-J fit refers to a person's compatibility with a job, and P-O fit concerns the match between a person and the organization's values, goals, and mission.

Sample: 231 employees of a large national trucking company (15% of the total number of employees in the trucking company): 104 office personnel and 127 truck drivers.

Methodology: The researchers conducted a survey with office workers and truck drivers of a national trucking company. Perceived P-J fit was measured by asking participants to respond to five statements concerning their fit with the job

in terms of skill and personality/temperament (e.g., "There is a good match between the requirements of this job and my skills"). Perceived P-O fit was measured using three items asking participants about the fit between their personal values and the values of the organization (e.g., "My values match or fit the values of this organization"). Employees also responded to statements measuring job satisfaction and intent to quit. Contextual performance data was gathered using peer ratings of perceived performance and task performance data was obtained from performance appraisal records for office workers, and company records on average miles traveled per month and number of accidents per 10,000 miles traveled for truck drivers.

Relevant Findings: Findings suggest that perceived P-O and P-J fit are both positively related to job satisfaction and negatively related to intent to quit. Additionally, P-O fit had a significantly greater impact on intentions to quit than did P-J fit. P-O fit was also significantly related to contextual performance (i.e., peer ratings of performance), suggesting that greater perceptions of organizational fit are related to peer ratings of engagement in extra-role behaviors (e.g., volunteering to carry out extra activities and helping/cooperating with others). Disappointingly, the hypothesized relationship between perceived P-J fit and task performance was not supported.

Limitations: One major limitation of the current study is the low response rate (15%) obtained from the trucking company. Although there were no significant demographic differences between respondents and the profile of the average worker employed within the company, there could still be potential for self-selection bias such that only employees with extreme positive or negative attitudes chose to participate. In addition to the low response rate, there was an extremely low sample size obtained for the peer-rated contextual performance data (n=47). The small sample size calls into question the generalizability of these results. Thus, the relationship between P-O fit and contextual performance should be reviewed as preliminary and in need of replication before solid conclusions may be drawn.

In light of the focus of the current literature review, the lack of a significant relationship between job fit and task performance was disappointing, as the measure of truck driver task performance included accident rates. However, there is some concern that range restriction for the measure of job fit may have contributed to the lack of a significant finding. The average level of perceived job fit was extremely high, with a mean of 6.22 on a seven point scale and a low standard deviation of 0.86, suggesting that most drivers reported their skills and temperament as an extremely good match to the job of a truck driver. Future research should include testing and validation of the measures of perceived P-O and P-J fit

before reexamining the relationship between perceived fit and performance.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #1: Employee Fit, as the focus of the article was on P-J and P-O fit, and how they relate to job satisfaction and performance.

Richard, M.D., LeMay, S.A., & Taylor, G.S. (1995). A factor-analytic logit approach to truck driver turnover. *Journal of Business Logistics, 16*, 281.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Driver Turnover and Retention
Motor Carrier Environment			

Author Abstract: No author abstract

Industry Sector: TL trucking

Purpose: The purpose of this study was to find a practical solution to give motor carrier management a better understanding of driver turnover.

Sample: 402 out of 1,500 irregular route truck drivers employed by a U.S. motor carrier (26.8% response rate).

Methodology: Researchers conducted a survey of TL drivers within a single motor carrier. Using a scale from 1 to 5, drivers were asked to rate their job satisfaction as well as firm characteristics such as pay, managers, dispatchers, other drivers, and time at home. These responses were used as independent variables. Drivers were also asked to rate their likelihood of leaving the company in the near future. The answer was used as the dependent variable. Respondents were thus classified into two groups: those likely to leave the company, and those likely to remain. Survey results were analyzed using a combination of logit and factor analysis.

Relevant Findings: The authors found that a driver's attitudes towards management, dispatchers, and other companies are significant factors in determining intentions to leave their current employer. Drivers who evaluated dispatchers and management in a positive way were more likely to remain with their company. Conversely, drivers who did not perceive any major differences between the policies and managerial attitudes at their own or other trucking companies were more likely to leave their current employer, even as a result of minor irritants. Drivers who perceived all trucking companies as treating drivers the same, good or bad, had little motivation to remain loyal to their current employer. The authors recommend realistic job previews (RJPs) that set reasonable expectations about managers and dispatchers, and, in doing so, distinguish the company as honest and fair. Recruiter and dispatcher training are recommended to teach supervisory and human relation skills. To retain drivers, motor

carriers need to maintain open communication with drivers about their perceptions of the effectiveness of management policies and activities.

Limitations: The survey was only distributed to drivers from one large TL carrier. Thus, the data may not be generalizeable to other, smaller companies.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #1: Driver Turnover, because it models drivers' choice to leave or stay with a motor carrier.

Stephenson, F.J., & Fox, R.J. (1996). Driver retention solutions: Strategies for for-hire truckload (TL) employee drivers. Transportation Journal, 35, 12-25.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Driver Turnover and Retention
Motor Carrier Environment			

Author Abstract: No author abstract

Industry Sector: For-hire TL trucking

Purpose: Voluntary driver turnover is a major problem for trucking companies since the economic deregulation of the industry in 1980. The purpose of this study was to provide retention strategies for employee drivers (as opposed to contract drivers) to firms in the TL for-hire trucking sector, as this sector suffers from the highest driver turnover rate.

Sample: 1,464 employee drivers from 57 for-hire TL firms.

Methodology: A four-page survey was mailed to carriers for distribution to a portion of drivers in each organization. Drivers were asked why they chose driving as a profession, about job and demographic information, and regarding factors important to them in their decisions to leave or stay with an employer. Importance-ratings for 37 items were made using seven-point scales. These data were then analyzed using a statistical technique to establish which groups of survey items were most closely related and in order to form groups for the purposes of comparing ratings.

Relevant Findings: Overall, drivers identified compensation as the most important reason for deciding to remain with their current employer, although drivers reporting a higher annual income were more likely to report working a greater mean number of hours per week. This was followed by pride in one's company and the profession, and factors regarding fair job treatment and worker appreciation. Aspects related to safety/security and equipment, and finally working conditions, were of lesser importance.

Based on these results, the authors advocate an increase in annual gross pay levels, or a reduction in hours (to increase pay per hour), and the creation of a corporate culture built around employee appreciation and communication.

Limitations: Although 79% of questionnaires were returned and usable, the sampling strategy chosen by the authors attempted to survey only approximately 9% of each company's employees. The authors acknowledge that their sample is not random, but do not specify even whether there was a prescribed methodology for use by each carrier to distribute questionnaires. Additionally, data were collected in 1995, which potentially dates this study's findings.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #1: Driver Turnover, as the focus is on driver attitudes regarding their job and the decision to stay or leave their current employer.

Motor Carrier Environment: What organizational factors influence whether or not CMV drivers remain at a particular job and/or in the workforce?

Griffin, G., Kalnbach, L., Lantz, B., & Rodriguez, J. (2000). *Driver retention strategy: The role of a career path* (UGPTI Publication No. DP-135). North Dakota State University.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Retention Strategies

Author Abstract: The voluntary turnover rate among truckload carriers, at 50-100%, is excessive when compared to other industries. The turnover rate has been known to exceed 150%. It is believed that several factors are involved in this retention problem suggested by anecdotal evidence coupled with human resource management theory. One factor that contributes to such a high turnover rate is the lack of a meaningful career path for drivers. This has been identified in several studies of job satisfaction conducted at the Upper Great Plains Transportation Institute, North Dakota State University, and elsewhere.

The purpose of this study was to evaluate (1) how the motivating potential for this job compares with other industries, (2) how much drivers agree with the components of the hypothetical career path, (3) how likely a career path or developmental opportunities is to improve retention/commitment, and (4) how drivers and managers differ in terms of their perceptions of realistic career paths. From this information and analysis, truckload firms can determine what drivers' career path needs are and identify potential strategies that they can implement to meet those needs.

The initial part of the study identifies a hypothetical career path based on theories of industrial psychology. This is followed with an in-depth analysis of what drivers' perceptions are of a career path that would improve job satisfaction. A final component of the study will identify management's perceptions of what a career path should consist of. This information is evaluated and synthesized into this report with conclusions and recommendations.

Industry Sector: TL trucking

Purpose: The primary goal of the current study was to determine whether the job of a TL driver would be enriched by the implementation of a career path. The

authors used the Hackman and Oldham (1980) Job Characteristics Model to assess whether a career path would be of value to truck drivers by encouraging job enrichment, or making the job more personally rewarding and satisfying. The underlying assumption of the Job Characteristics Model is that employees who find their work rewarding and satisfying will tend to stay with their organization longer, thus improving retention. In addition, the Job Characteristics Model suggests a cause and effect chain reaction, whereby the way the work is designed triggers the driver's psychological experience, which produces positive personal outcomes, and thereby results in improved employee effectiveness.

Sample:

First survey: 3,811 drivers from 11 different trucking companies were mailed questionnaires—736 drivers responded (response rate of 19.3%).

Second survey: managers and decision makers from 191 trucking companies who were members of the Truckload Carrier Association—113 managers responded (59% response rate).

Methodology:

Measures from the Job Diagnostic Survey (Hackman & Oldham, 1980) were included in the first questionnaire to assess driver perceptions of 5 core job characteristics (skill variety, task significance, task identity, autonomy, and feedback), 3 critical psychological states (meaningfulness, responsibility for outcomes, and knowledge of the results), and 4 work outcomes (internal work motivation, growth satisfaction, general job satisfaction, and work effectiveness). In addition, questions asking about drivers' perceived knowledge and skills, need for personal growth, and satisfaction with specific aspects of their job were included to assess whether drivers would be receptive to job enrichment.

In order to trigger the positive chain reaction described in the Job Characteristics Model, the way the work of a driver is designed must have the motivating potential to benefit from the addition of a career path. The five core job characteristics mentioned above are all factors necessary for job enrichment, as determined by calculating a motivating potential score (MPS). The MPS for truck drivers was calculated by taking their average value for skill variety, task significance, and task identity, and then multiplying that by the value for autonomy and the value for feedback. A high MPS would indicate that truck drivers may be receptive to the introduction of a career path that would promote job enrichment.

The authors also developed a hypothetical career path for truck drivers in order to ascertain how drivers would actually react to the proposed career path. The hypothetical career path includes two major stages. The first stage focuses on the development of core driving skills and knowledge through driving experience. Stage one incorporates four levels of promotion on the career ladder, from an "undergraduate driver" at hire to

an "advanced driver" after a minimum of three years of experience. Stage two involves taking on greater responsibility and more involvement with the company by encouraging truck drivers to increase their business knowledge and take on additional job responsibilities such as training, safety management, customer service, or equipment maintenance. Stage two allows for advancement to the title of "senior driver" and later, "master driver." Additional questions asking specifically about drivers' opinions of the hypothetical career path were also included in the first survey.

Finally, a second survey was administered to a sample of managers and decision makers in the trucking industry in order to compare truck driver perceptions of their job to the perceptions of management. Many of the same questions used in the first survey were included in the second survey; however, the wording was modified to reflect managers' perceptions of drivers' attitudes.

Relevant Findings: Results suggest that a majority of truck drivers describe the core job characteristics of their job in positive terms. When compared with normative data from other job families, the MPS score for truck drivers was equal to that of management, and exceeded scores in other job families such as clerical, processing, and bench work. This suggests that the job of truck driving has high motivating potential and may benefit from the implementation of a career path.

However, there were mixed results when drivers were asked about feedback they receive from their supervisors. Over 40% of drivers reported that they never get feedback from their supervisors and that supervisors do not let them know how they are performing, with most, if any, feedback received being negative. When asked about personal feelings regarding their job (psychological states), drivers also responded positively. On the other hand, almost 30% of drivers sampled also indicated that they think about quitting their job, with the majority of those 30% being more experienced, tenured drivers. Thus, the problem of retention may not be limited to only younger drivers with less experience and less tenure in a trucking company. It is somewhat troubling that nearly a third of the sample indicated that they think about quitting their current job, even though they feel positively about other aspects of their job. This result, however, is not surprising given the high turnover percentages among trucking companies.

A vast majority of drivers, ranging from 80 to 90%, also reported a strong desire for a sense of worthwhile accomplishment in their work, opportunities to learn new things, stimulating and challenging work, and opportunities for personal growth and development. The positive results

indicate that drivers would be receptive to additional opportunities for enrichment in their job.

When asked specifically about the hypothetical career path outlined by the authors, 70% of the drivers indicated that implementing such a career path would make them feel better about their job. Eighty-seven percent of drivers also agreed that the career path should be performance-based, rather than based on time with the company.

Manager perceptions of the characteristics of the job of a truck driver were very similar to driver perceptions, indicating a good understanding between drivers and managers of what the job entails. However, managers underestimated the motivating potential of the job, suggesting that they are not entirely aware of truck drivers' reported desire and need for personal growth in the job. Although the results indicate that the implementation of a career path would be beneficial to truck drivers, the career path may not be successful in promoting job enrichment without buy-in and backing from management.

Overall, truck drivers reported feeling positively about their jobs, but may lack a desired level of feedback from supervisors and opportunities for personal growth. Implementing a career path for truck drivers may be a way to make the work of a driver more personally rewarding and satisfying. Tying the career path to performance may also increase effectiveness and allow more recognition for drivers that perform their job effectively and safely. Part of the retention problem in the industry may stem from a lack of opportunities for job growth combined with a lack of recognition from management concerning the need for job enrichment in truck driving.

Limitations: This study is only a first attempt to assess whether there is a need and a desire for the implementation of a career path for truck drivers. Although the potential does appear to exist, the actual career path has yet to be implemented and studied. Likewise, it is still unclear whether such a system would pay for itself. Thus, the organizational costs and benefits need to be examined further.

Categorization: This paper fits within the post-event timeframe of the motor carrier environment for Haddon Matrix #1: Retention Strategies. The purpose of the article was to test whether having a defined career path would lead to greater driver retention.

[a]Gupta, N., Jenkins, G.D., & Delery, J.E. (1996). Motor carrier effectiveness: A study of personnel practices, driver turnover, and company effectiveness in the trucking industry. University of Arkansas, Fayetteville.

[b]Shaw, J.D., Delery, J.E., Jenkins, G.D. Jr., & Gupta, N. (1998). An organization-level analysis of voluntary and involuntary turnover. *Academy of Management Journal, 41*, 511–525.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Driver Turnover and Retention

Author Abstract:

[a]No author abstract

[b]Although there are many individual-level models of turnover, little research has examined the effects of human resource management practices on quit rates and discharge rates at the organizational level. This study used organization-level data from 227 organizations in the trucking industry to explore this issue. Results show that human resource management practices predict quit rates and discharge rates but that the determinants of each are quite different. Implications are derived and directions for future research suggested.

Industry Sector: TL and LTL trucking

Purpose:

[a]Driver turnover (in particular, voluntary turnover) has been a substantial problem in the trucking industry since deregulation took place in 1980. As a means of helping to guide HR decisions, this report provided a comprehensive, largely descriptive, assessment of the practices used by motor carriers to recruit, hire, and motivate their drivers. Researchers focused on the effects of HR practices on turnover rates, and also considered the additional outcomes of performance and safety.

[b]This study used a subset of respondents from the Gupta, et al. sample to investigate, in greater detail, the relationship of HRM practices in trucking organizations to voluntary and involuntary turnover. Distinction was sought between these two types of turnover, the HRM practices that predict each, and the interaction of selection procedures and selection ratio as a predictor of discharge. The study was also conducted to address a perceived gap in the organizational sciences literature, as most studies focus on individual- as opposed to organizational-level predictors of turnover.

Sample:

[a]379 HR managers at trucking companies.

[b]227 HR managers at trucking companies who also provided turnover rate data.

Methodology:

[a]HR managers from trucking organizations with a minimum of 30 company drivers, as listed in the 1993–94 *TTS Blue Book of Trucking Companies*, completed a survey requesting information regarding the nature of their HRM systems as pertaining to their driver workforce. The survey was sent to an initial sample of 1,072 qualifying companies. The resulting sample contained a subset of companies whose managers returned completed surveys.

[b]Shaw et al. further narrowed the Gupta, et al. sample to include only those companies that also provided turnover rate data. As Shaw et al. expanded on the findings of Gupta et al., they reported additional statistical detail: analyses were performed to ensure that groups of survey scale items each explained a sufficient percentage of unique variance and were adequate in terms of their reliability. The authors used HRM variables selected based on previous literature in analyses to predict both voluntary and involuntary turnover, expecting that those practices related to one type of turnover would not be related to the other (i.e., that their theoretical framework discriminated between the two).

Relevant Findings:

[a]After statistically controlling for carrier type, lower quit rates were associated with being home more times per month (as is the case for LTL drivers), higher pay, more attractive benefits, job security, less on-board technology, and smaller and older companies. Smaller and older companies (those that have been in operation longer) were also associated with lower discharge rates. The greatest determinant of discharge rates, however, was selection ratio. Motor carriers using a low selection ratio (i.e., hiring few drivers based on many applicants), as well as employing selection techniques that included performance tests and/or technical knowledge tests (as opposed to unstructured interviews) were found to have the lowest discharge rates. Driver turnover was reported by HR managers to "hurt" driver accident rates (30.1%) and profits (39.5%), among other checklist factors.

Safety factors were broadly reported as "potentially affected by driver behaviors." Reported driver behaviors included accident frequency ratio, traffic violations per driver, equipment violations per truck, and driver absenteeism rate.

Reported driver compensation and benefit policies established that TL firms offer lower pay rates than LTL firms, giving potential insight into the higher quit rates for TL drivers. Additionally, longer tenure at a

company garners higher pay; however, incentive systems and compensation innovations to bolster wages were not often reported. The authors suggest that motor carriers link financial incentives to desirable driver behaviors, such as safe driving records. Although it costs companies financially to do so, these costs must be weighed against the costs of high turnover, including necessitating the hire of inexperienced drivers, who may be a greater safety risk.

Finally, other HRM practices, such as staffing and training were discussed. Recruitment did not appear to be of primary concern to respondents, despite a perceived shortage of applicants. Newspaper advertisements and walk-ins were cited as the primary sources for new drivers. The authors indicate that alternatives, such as radio and television, should be given greater consideration. No systematic relationship was evidenced between the amount of training respondents reported and financial performance outcomes, quit, or discharge rates. In addition, the type of training (e.g., safety, on-the-job, simulator) was not a factor.

[b]This research focused specifically on the turnover data from the Gupta, et al. report and carried out further statistical analyses. Results of this study confirmed that it is important to distinguish between involuntary and voluntary turnover. Reported driver quit rates were over four times greater than reported discharge rates, indicating that voluntary turnover is a much bigger problem in the industry than involuntary turnover.

Additionally, different HRM practices predicted the two different turnover types. Investment-focused HRM strategies (e.g., pay, benefits) and employer expectations (e.g., time on the road, use of electronic monitoring) predicted voluntary, but not involuntary turnover. Staffing practices (e.g., selection ratio) predicted involuntary, but not voluntary turnover.

Examining individual variables, HRM-investments in pay and benefits were negatively related to quit rates, while employer expectations (time on the road, electronic monitoring) were positively related to quitting. Also, involuntary turnover was positively related to selection ratio, indicating that a more conservative approach to hiring is associated with lower discharge rates. Despite predicting that electronic monitoring would also be related to involuntary turnover, since this technology may give employers better information on which to base discharges, no relationship was found.

An interaction resulted between selection procedures and selection ratio for discharge rates. This relationship suggested, as one would expect, that discharge rates are low when there is high use of valid selection procedures combined with a favorable (low) selection ratio. Selection

procedure validity was established by the authors based on a review of meta-analytic or validity generalization studies, if a validity coefficient of at least 0.25 was reported for a measure. Interestingly, the highest discharge rates existed with high use of valid selection procedures in conjunction with a high selection ratio. Perhaps an explanation of this finding exists for companies with high discharge rates, who must hire many drivers to meet needs, yet are able to identify and discharge those who are poor performers. Low use of valid selection procedures produced a relationship whereby selection ratio was irrelevant to discharge rates.

Overall, the study suggests that in order to reduce quit rates, trucking organizations should strive to pay well and provide good benefits, use electronic monitoring sparingly, and provide for low duration of time on the road. Further, as a means of minimizing involuntary turnover, use of valid selection techniques and a conservative selection ratio is recommended.

Limitations:

[a]The report is informative, but entirely descriptive. Analysis outcomes, reported in this review where available, were summarized and did not include statistical values to allow for first-hand interpretation. This report provides the basis for much additional data mining (i.e., Shaw et al.), but does not include any hypothesis testing or theoretically-driven analysis. At present, some of the information it provides is dated; for instance, suggesting recruitment using radio and television, given the current popularity of the internet.

[b]Driver turnover is not linked with safety outcomes or cost, both of which are industry concerns. In fact, lower turnover in an organization may actually be related to reductions in financial performance, if unsafe or otherwise poor drivers are retained when they should be discharged.

Categorization:

Both studies fit within the post-event timeframe of the motor carrier environment for Haddon Matrix #1: Turnover and Retention, as their primary focus is on the explanation and impact of HRM practices regarding these outcomes.

Holmes, S.M., Power, M.L., & Walter, C.K. (1996). A motor carrier wellness program: Development and testing. *Transportation Journal, 35*, 33-48.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Retention Strategies

Author Abstract: Motor carriers have experienced a shortage of drivers, leading to high turnover rates and the attendant costs of hiring and training new drivers. Drivers cited compensation, loneliness, unpredictable work schedules, poor working conditions and lack of advancement opportunities as reasons for leaving. Two approaches to the driver shortage problem are recruiting and retention. While pay issues may dominate recruiting efforts, retention may depend on other issues such as how drivers are treated by their employers. Some employers have reported favorable results with programs designed to aid employees in achieving and maintaining better health. The development of such a wellness program by a motor carrier is described.

Industry Sector: Over-the-road and short-haul trucking

Purpose: The purpose of the study was to develop and implement a driver nutrition program and test whether this program reduced driver health risk by decreasing weight, body fat, blood pressure, and other problem areas of driver health. It is expected that implementing a motor carrier wellness program will increase driver satisfaction and provide an added benefit to drivers that may increase their desire to stay with the organization.

Sample: 300 truck driver completed nutrition survey—15 drivers were identified for the nutrition program; 15 drivers were identified for the control group.

Methodology: Researchers developed a survey to determine drivers' current health and nutrition habits. Using the results from the survey, a nutrition program was developed and implemented using a small sample of over-the-road truck drivers within the TL company. A matched sample of short haul truck drivers was selected as a control group. The short haul truck drivers were selected based on similar weight characteristics to the test group participants. The short haul truck drivers also had the advantage of being home every evening, as opposed to being on the road. Both groups received an initial health screening. In addition, participants in the test group received an in-depth examination of their test results, nutrition information pamphlets, and were provided with daily "healthy snack" bags

to encourage better snacking habits. At the end of six months, both teams completed a second round of health screenings. The pre- and post-screenings were then analyzed and compared for the test and control groups.

Relevant Findings: The test group reported improvements in weight, body fat, cholesterol, and smoking habits. The test group also reported high levels of satisfaction when evaluating the program and anecdotal evidence suggested improved mood.

Limitations: Although the authors make a strong argument for improving retention through the implementation of wellness programs and back the argument with previous research, there is little evidence that the wellness program described in the study improved driver retention. In fact, driver attitudes about the company were not directly assessed. Instead, drivers reported being satisfied with the wellness program itself. Although a wellness program may improve driver retention by reducing driver stress and increasing job satisfaction, the current study provides little evidence to support that assertion. Future research specifically tying wellness program implementation to subsequent rates of driver turnover would be necessary to draw a clear link to driver retention.

Categorization: This paper fits within the post-event timeframe of the motor carrier environment for Haddon Matrix #1: Driver Retention, as the researchers in this study created a wellness program for drivers and attempted to tie its benefits to greater job satisfaction and incentive to stay with the company.

[a]Min, H., & Lambert, T. (2002). Truck driver shortage revisited. *Transportation Journal, 42*, 5–16.

[b]Min, H., & Emam, A. (2003). Developing the profiles for truck drivers for their successful recruitment and retention: A data mining approach. *International Journal of Physical Distribution & Logistics Management, 33*, 149.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Retention Strategies

Author Abstract: [a]Despite the recent economic downturn and the subsequent increase in unemployment rates, driver turnover remains a serious problem in the trucking industry. Since driver turnover contributes to cost inflation and service disruptions, it has a far-reaching effect on the trucking firm's competitiveness. To control high driver turnover, trucking firms have attempted to implement various driver recruitment and retention strategies, including pay raises, bonuses, equipment upgrades, and flexible schedules, Based on exploratory findings of selected U.S. firms, this article has studied the impact of these strategies on turnover. This article also assesses the extent of driver shortage and its impact on competitiveness, while developing a profile of drivers who are likely to cause turnover.

[b]Chronic driver turnover can adversely influence a trucking firm's competitiveness through disrupted delivery services, equipment down time and excessive recruiting expenses. Thus, a key to the survival of the trucking firm rests with its ability to recruit and retain qualified drivers who are less likely to cause turnover. In an effort to develop the ways to recruit and retain those drivers, data mining techniques are proposed. Based on an empirical study of trucking firms in the US, this paper not only develops a viable driver recruitment and retention strategy, but it also demonstrates the usefulness of the proposed data mining techniques.

Industry Sector: For-hire trucking

Purpose: These articles aimed to identify the important causes of driver shortages, assess the degree to which various motor carrier policies are effective at reducing turnover, and recommend the most viable driver recruitment and retention strategies based on driver profiling.

In addition, the [b]2003 article identified data mining techniques that have the potential to help motor carriers identify drivers who fit the profile for optimal retention.

Sample: [ab]422 motor carriers from 3,000 Midwestern and Southern national and regional carriers (14% response rate).

Methodology: Researchers surveyed a stratified sample of motor carriers, including various national and regional sectors of the trucking industry, to determine potential causes of high turnover. The survey was tested for response bias, and analyzed using both hypothesis testing for pre-conceived theories, and, in the later [b]paper, data mining techniques (based on decision trees) to find new patterns.

Based on survey outcomes, the authors developed "If-Then" rules that were expected to explain the impact of organizational characteristics on driver turnover. These rules combined both motor carrier and driver characteristics to form profiles intended to predict high and low turnover rates. Combinations of the following characteristics were used to develop decision trees and to build the profiles: firm size, operating area (national, regional, local), carrier type (TL, LTL), carrier location, percent part-time drivers, unionization, tenure, age, experience, and annual starting salary.

Relevant Findings: [a]Consistent with other studies, pay was identified as the most important factor influencing turnover; however, condition of equipment and company reputation were also cited as important. This study found that, according to motor carrier managers, the three most important obstacles to driver recruitment and retention are a lack of qualified drivers in terms of age, experience, dependability, and safety, a tight labor market that reduces the size of recruiting pools, and fierce competition between motor carriers forcing a rise in driver pay rates. Mandatory drug testing, lack of driving schools, lumper costs, and labor union demands were not found to be of great significance to drivers.

[b]The 2003 article suggests that motor carrier incentives and recruitment policies should be tailored for different driver and firm profiles. Motor carriers should focus retention efforts on drivers who fit profiles with higher turnover rates, and recruitment efforts should be focused on drivers fitting profiles with lower turnover rates. In general, retention incentives should be targeted at non-unionized, part-time drivers with shorter tenure, while targeting recruitment efforts at older drivers who have more than five years of CMV driving experience.

Limitations: These papers do not directly address safety as an important consideration in recruitment and retention strategies. Although the authors' main concerns were with reducing the costs that result from high rates of

turnover, this research may also be used in conjunction with studies that link a lower turnover rate to better safety outcomes. The development of profiles as a means to target retention efforts should also include a careful examination of driver safety. Retention efforts should primarily focus on keeping the safest drivers, not just those drivers most likely to quit.

In addition, the response rate is relatively low and the sample is geographically restricted to Southern and Midwestern carriers. Because of this, many of the decision tree rules and subsequent driver profiles are narrowly focused and may not generalize to the larger, national population of motor carriers and drivers.

Categorization: This paper fits within the post-event timeframe of the motor carrier environment for Haddon Matrix #1: Retention Strategies. Although this paper also discussed recruitment, its purpose was to suggest recruitment strategies that maximize retention and reduce turnover.

Morrow, P.C., Suzuki, Y., Crum, M.R., Ruben, R., & Pautsch, G. (2005). The role of leader-member exchange in high turnover work environments. *Journal of Managerial Psychology, 20*, 681–694.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Management Relations and Turnover

Author Abstract: **Purpose—**To assess the role of leader-member exchange (LMX) in affecting voluntary turnover in a high turnover work context.
Design/methodology/approach—Following consideration of traditional predictors of employee turnover, how LMX is related to voluntary turnover is examined among 207 over-the-road truck drivers using a telephone survey.
Findings—Leader member exchange is found to be nonlinearly related to turnover such that turnover is lowest when LMX is moderate (i.e., both "bad" and "good" LMX are associated with higher levels of turnover).
Research limitations/implications—Findings indicate that LMX and other antecedents should be examined for nonlinear relationships to turnover. This research may help to bridge the gap between turnover research and that associated with supervision and leadership.
Practical implications—These study results suggest that unrealistic expectations should not be formed regarding the power of any single factor (e.g., LMX) to reduce turnover.
Originality/value—This paper suggests that nonlinear relationships between antecedents of turnover and turnover receive fuller consideration.

Industry Sector: Over-the-road trucking

Purpose: LMX concerns the quality of a driver's work-related and social relationships with his/her supervisors. Past research has suggested that the relationship between LMX and turnover is relatively weak. This study sought to examine the potential for a curvilinear relationship between LMX and turnover in a high turnover work environment (i.e., the trucking industry). It is hypothesized that turnover is lowest when LMX is moderate. Thus, having too much, or too little LMX is related to higher levels of turnover.

Sample: 294 of 724 truck drivers employed with a mid-sized motor carrier in the Midwest—207 of the respondents provided usable data, after surveys with missing or incomplete data were removed.

Methodology: A telephone survey was initiated in a medium sized trucking firm that employed approximately 724 drivers. Drivers were given information about the survey with their payroll statements and asked to call al toll-free number to participate in the survey.

LMX was assessed using 12 statements intended to measure 4 major components: affect (friendship and liking), loyalty (feeling of mutual support and obligation), contribution (performing at a level beyond minimal standards), and professional respect (appreciation of job knowledge and competence). Drivers were asked to indicate their agreement with statements such as "I like my team leader very much as a person," and "I am impressed with my team leader's job knowledge" on a 1 (strongly disagree) to 5 (strongly agree) scale. Drivers were also asked to respond to statements concerning organizational commitment (e.g., "I feel a strong sense of belonging to this organization") using the same 1–5 scale, and to report their average amount of time spent at home per week.

Demographic and organizational information such as company tenure, number of dependents, driver pay, and average loading/unloading wait time was gathered from company records. Voluntary turnover was also recorded by tracking resignations for approximately one year after data collection. Seventy five of the 207 drivers that participated in the study quit during the 1 year period.

Relevant Findings: The authors used logistic regression with actual turnover as the dependent variable. The LMX variable was calculated by taking an average score out of 5 on the statements assessing LMX. The possibility of a curvilinear relationship was assessed by testing the significance of the squared LMX variable (suggesting a "U" shaped relationship) and the cubed LMX variable (suggesting an "S" shaped relationship).

After controlling for demographic characteristics commonly associated with turnover (i.e., tenure, number of dependents, organizational commitment, pay, time at home, and consignment wait time) there was a significant "U" shaped curvilinear relationship between LMX and turnover. Both low and high LMX were associated with higher turnover rates. Turnover probability was highest when drivers indicated that their LMX relationship was extremely negative (1–1.5 on a 1–5 scale) or extremely positive (4.5–5 on a 1–5 scale). On the other hand, average levels of LMX (2.5–3.5 on a 1– 5 scale) were related to the lowest probabilities of turnover. This suggests that simply improving the quality of the relationship between supervisors and subordinates will not reduce turnover rates. Instead, it appears that there is a threshold for "good" LMX, such that turnover probability decreases until the threshold is reached and at that point begins to increase again. The authors theorize that turnover may be more likely at high levels of LMX because

employees who have strong relationships with their supervisors are often afforded special attention (e.g., better training, more performance feedback, additional opportunities for advancement) making them more marketable. Thus, they are more likely to leave voluntarily to pursue better job opportunities.

Interestingly, organizational commitment, a person's sense of loyalty or belonging to their organization was not related to turnover intentions in this study. This is contrary to past research exploring the relationship between commitment and turnover, where organizational commitment is typically negatively related to turnover intentions, such that people who are more committed to their organization are less likely to want to quit. The authors theorize that the lack of a relationship between commitment and turnover may be due to the nature of this particular work environment. Jobs are readily available in the trucking industry, potentially making level of organizational commitment less relevant when it comes to turnover decisions.

Limitations: Subjective data from supervisors concerning perceptions of LMX were not utilized in the current study. Thus, LMX was only assessed from the perspective of the subordinate. It is also unclear what type of recommendations for practice can be drawn from the results of this study. Clearly, promoting interactions between supervisors and subordinates is important. In spite of this, interactions of *superior* quality appear to increase the likelihood of turnover. More research is necessary to determine how much LMX is too much, or if there are other factors yet to be explored that contribute to, or better explain, the curvilinear relationship demonstrated in this study.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #1: Management Relations and Turnover, as it examines the relationship between LMX and turnover rates.

[a]Ozment, J. & Keller, S. (1999). Exploring dispatcher communication effectiveness: Implications for retaining drivers in the trucking industry. *Journal of Managerial Issues, 11*, 94–109.

[b]Keller, S.B. & Ozment, J. (1999a). Managing driver retention: Effects of the dispatcher. *Journal of Business Logistics, 20*, 97.

[c]Keller, S.B. & Ozment, J. (1999b). Exploring dispatcher characteristics and their effect on driver retention. *Transportation Journal, 39*, 20–33.

Haddon Matrix for Review #1: Selecting Safe Drivers			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Management Relations and Turnover

Author Abstract: [a]No author abstract

[b]No author abstract

[c]No author abstract

Industry Sector: [abc]TL trucking

Purpose: [abc]The following articles explore the relationship between dispatcher characteristics and driver turnover. The primary goal of this research was to examine potential interventions that may be instituted by motor carriers at the level of the dispatcher to reduce truck driver turnover. The first [a]article examined the relationship between dispatcher sensitivity and dispatcher responsiveness. The second [b] article re-tested the aforementioned relationships with a larger, more diverse sample, and in addition, proposed a theoretical model incorporating relationships between sensitivity, responsiveness, and driver turnover. The third [c]article expanded upon the first and second by examining dispatcher demographic characteristics (e.g., age, tenure, past experience as a driver) as antecedents of dispatcher responsiveness and driver turnover.

Sample: [abc]Initial sample: 132 dispatchers from a single TL carrier—73 usable responses were obtained and analyzed.

[bc]Second sample: 222 dispatchers from 5 leading TL motor carrier firms ranked in a listing of the 100 largest motor carriers in the US (Transport Topics, August 11, 1997). Researchers received 164 questionnaires—149 were identified as usable.

Methodology: [abc]All data collection efforts involved surveying dispatchers from national TL carriers using a mailed questionnaire. Dispatchers were asked to respond to statements assessing their sensitivity to voice (e.g., "I always encourage drivers to let me know when something goes wrong on the job"), sensitivity to reasons for driver turnover (exiting behavior; e.g., "When drivers quit, it is most important to understand their reasons for quitting"), and responsiveness to receiving complaints or becoming aware of driver resignations (e.g., "It is very important to respond to all driver complaints"). Responses were rated using a 5-point Likert scale from strongly agree to strongly disagree. Data cited in articles two and three also asked dispatchers to report their monthly truck driver turnover percentages, how much their drivers are paid relative to other drivers, and how much time their drivers are regularly routed home relative to other drivers. Additional dispatcher characteristics such as age, tenure, education, and job satisfaction were also included in the data collection.

Relevant Findings: [abc]Although the initial analysis, using a sample of 73 dispatchers, did not yield a significant relationship between dispatcher sensitivity to voice and dispatcher sensitivity to exit, subsequent analyses using more refined measures and a larger sample did suggest a strong relationship ($r = 0.60$) between those factors.

Additional testing of the model suggested a positive relationship between sensitivity and dispatcher responsiveness, such that the more sensitive a dispatcher is to driver concerns and reasons for quitting, the more likely they are to act upon those concerns. Furthermore, responsiveness was related to driver turnover, such that more responsive dispatchers also indicated lower levels of turnover. Interestingly, dispatcher age was positively associated with driver turnover, whereas dispatcher experience was negatively associated with driver turnover, indicating that older dispatchers have higher rates of driver turnover but more experienced dispatchers have lower rates of driver turnover. The authors give no explanation for this seemingly contradictory result.

[c]In addition, the third study in this series replicated past findings that driver pay and time at home are negatively associated with turnover. As expected, the more pay a driver gets and the more time a driver gets to be home, the less likely they are to leave a trucking firm.

Limitations: [abc]All three studies used self-report methodologies to examine only dispatcher sensitivity and responsiveness. Although the use of turnover rates may provide some insight into driver behaviors, future studies should collect information from both the driver and the dispatcher to more fully understand the dynamic relationships between dispatchers and their drivers. This is especially important when soliciting information about

dispatcher behaviors, as driver perceptions of dispatcher sensitivity and responsiveness may vary greatly from a dispatcher's self-perception of their own attitudes and behaviors.

Categorization: These papers fit within the post-event timeframe of the motor carrier environment for Haddon Matrix #1: Management Relations and Turnover, as they focus on how the relationships between drivers and dispatchers affect turnover rates.

Secondary Sources

Federal Motor Carrier Safety Administration. (2003). *Results from the 2003 R&T stakeholder forums* (TRIS No. 00989307).
Executive Summary: FMCSA's Office of Research and Technology held a series of five stakeholder forums throughout February and March 2003. These forums were structured to gather stakeholder input regarding the agency's research agenda, and educate stakeholders about the FMCSA Research and Technology program and key ongoing projects. The forums were attended by a wide range of stakeholders, including representatives from: motor carriers; motor coach companies; industry associations; safety advocacy groups; state enforcement agencies; commercial vehicle manufacturers; academia; and vendors of systems and services focused on improving commercial vehicle safety. The forums generated over 150 recommendations regarding FMCSA's research program. Recommendations ranged from the need for better data sources to specific research questions that need to be investigated to improve commercial motor vehicle safety. The majority of recommendations focused on driver-related factors. Recommendations also were made regarding vehicle, carrier/shipper, and roadside/environmental issues. This document summarizes the forum's recommendations.

Federal Motor Carrier Safety Administration. (2005). 2005 model commercial driver's license manual (FMCSA Publication No. DTFH61-97-X- 00017).
No summary information available

Grenzeback, L.R., Lin, S., & Meunier, J. (2005). *Operational differences and similarities among the motorcoach, school bus, and trucking industries* (TRIS No. 00987800). Transportation Research Board.
Foreword: This synthesis will be useful to commercial truck and bus carriers, state agencies, and others interested in improving commercial vehicle safety. This synthesis discusses the operational differences and similarities among the motorcoach, school bus, and trucking industries. It provides a single resource for information on industry profiles, safety statistics, and general business operations. Information for this synthesis was obtained through a literature review that included Federal Motor Carrier Safety Administration (FMCSA) databases, industry association publications, industry trade magazines, internet searches, and documents from the Bureau of Labor Statistics and the U.S. Census Bureau. This information was supplemented by interviews with staff of various relevant government and industry organizations.

Moffat, G.K., Ashton, A.H., & Blackburn, D.R. (2001). *A challenged employment system: Hiring, training, performance evaluation, and retention of bus operators*. Transportation Research Board. (NTIS No. PB 2002-107846)
Foreword: This synthesis will be of interest to transit agency professionals and the consultants who work with them in dealing with bus operator employment processes. It offers a snapshot of public agencies' practices in bus operator hiring, training, performance evaluation, and retention. Each of these areas is uniquely different, but also highly interrelated; therefore, it is necessary to consider all areas for a complete understanding of the subject. The transit industry is experiencing the same stresses on its employment

processes as are affecting employers across the country. This tight labor market, combined with changing work-force demographics and difficult transit working conditions, creates a definite staffing challenge. Survey information provided might suggest that transit has not yet adopted an across-the-board, systematic approach to employment systems, where the elements of hiring, training, performance evaluation, and retention are handled in an integrated fashion. The focus in this document is on presenting information reported simply and in such a way as to reinforce the interrelated nature of employment processes and opportunities for transit agencies to realign efforts so that they might work in an integrated fashion. This document integrates information from a literature review of transit and related periodicals and websites, from survey responses from 29 transit agencies, and from contacts with agencies reporting new and innovative practices.

National Private Truck Council. (2006, June). Standards of fleet excellence (Version 1.0).
NPTC Summary: NPTC's Standards of Fleet Excellence is a copyrighted 158-page document designed to help qualify and quantify the value of a company's private fleet using criteria—including best practices, benchmarks, protocols and metrics—commonly found in many of America's leading private fleets.

National Transportation Safety Board highway special investigation report: Transit bus safety oversight. (1998). Washington, DC: National Transportation Safety Board. (NTIS No. PB 98-917006)
Author Abstract: After the National Transportation Safety Board (NTSB) conducted several accident investigations involving transit buses (Normandy, Missouri; Cosmopolis, Washington; New York, New York; and Nashville, Tennessee) and held a public hearing on transit bus safety in March 1998, it found that substantial safety deficiencies and little Federal or State government safety oversight existed within the transit bus industry. During the public hearing, participants discussed transit agency self-regulation, the extent of Federal and State safety oversight, accident data, pupil transportation, and driver selection and qualification.

Occupational Safety and Health Association, National Highway and Transportation Safety Administration, & Network for Employers for Traffic Safety. (2006). *Guidelines for employers to reduce motor vehicle crashes* (OSHA Purchase Order No. B-9-4-2-3576). Washington, DC: U.S. Department of Labor.
Booklet Introduction: This booklet outlines ten steps for building a driver safety program in your workplace. These steps will be useful to any organization regardless of size of the organization, type of traffic encountered, number of vehicles involved, or whether employees drive company or personal vehicles for work purposes. Also included are real-life examples of successful safety programs, key traffic safety issues to address in the workplace, instructions for calculating your organization's loss from motor vehicle crashes, and a list of resources to help you fine-tune your program.

Pratt, S.G. (2003). *Work-related roadway crashes: Challenges and opportunities for prevention.* Department of Health and Human Services: National Institute for Occupational Safety and Health. (NTIS No. PB 2004-101216)
TRIS Abstract: The purpose of this document is to provide an overview of current issues

affecting work-related roadway crashes with a focus on preventing injuries and fatalities to vehicle drivers and passengers. Fatalities and injuries to pedestrian workers are not within the scope of this document, nor are events occurring at locations such as parking lots and industrial sites away from public roadways. The document begins by illustrating the scope and nature of the problem and presenting data on both fatal and nonfatal injuries. The next section summarizes the large body of regulations that apply to the operation of motor vehicles. Some are specific to work-related driving, and others apply to all drivers or all vehicles. The sections that follow address special topics critical to the formulation of strategies to prevent work-related roadway fatalities and injuries. These topics include driver fatigue, special issues regarding the motor carrier industry, driver distraction and cell phone use, age-related factors, and general fleet safety issues. Following the discussions of special topics are detailed strategies for preventing work-related roadway crashes. The document concludes with lists of additional readings and vehicle-related Internet resources from government agencies, research organizations, industry, and citizen groups.

Smadi, A. (1998). *Educational and technical assistance to CMV drivers and motor carriers*. Washington, DC: Federal Highway Administration, Office of Motor Carriers. (NTIS No. PB 99-149759)

TRIS Abstract: The Peer Exchange is a process adopted by the Office of Motor Carrier and Highway Safety in which teams of professionals, representing state and federal government and private industry, identify effective commercial motor vehicle safety findings for implementation by other jurisdictions throughout North America. The peer exchange process has proven to be an effective technique by which to share and develop ideas among States to address important safety issues. The educational and technical assistance peer exchange had two main objectives: to identify best practices for providing effective educational and technical assistance to commercial drivers and motor carriers, and to disseminate information on the best practices to States and private industry.

Staplin, L., Lococo, K.H., Decina, L.E., & Bergoffen, G. (2004). Training of commercial motor vehicle drivers. *CTBSSP Synthesis of Safety Practice, 5*.

Foreword: This synthesis will be useful to commercial truck and bus carriers, state agencies, and others interested in improving commercial vehicle safety. The synthesis identifies and documents training strategies and curricula from existing commercial driver training programs, with the goal of identifying those commercial motor vehicle driver training tools and techniques that hold the greatest potential to improve commercial motor vehicle safety. Information for this synthesis was obtained through surveys of commercial motor vehicle training schools and carriers; a review of relevant literature; and a review of comments received on the U.S. DOT Federal Motor Carrier Safety Administration (FMCSA)-issued advance notice of proposed rulemaking (ANPRM) and notice of proposed rulemaking (NPRM)

Stumpo, D.M. (2001). Performance beyond words: Are employees most important? *Bus & Paratransit Conference* (pp. 1-8). Washington, DC: American Public Transportation Association.

Author Abstract: Leaders within our transportation industry have consistently stated that employees are very important. The American Public Transportation Association has defined

two main strategic goals on the development of our industry's workforce. Our managers and supervisors have stated that training and development is the core requirement to long range success. Ask yourself, "Why is training and development, attracting and retaining transit workers such a problem? Why doesn't the transit industry create a market of certified transit professionals? Why aren't we teaching our employees how vision, mission and values link to our every day business?"

Organizations still ponder with the need to invest current dollars in training and certification processes, in place of short-term fixes that tend to add only little value to our industry's success. Anyone managing a multi-million dollar public transit operation today realizes that this industry employs over 450,000 people in North America and moves over four billion people annually. Ensuring our employees have the tools needed to be successful, improving their skills through training and managerial dedication that will pay dividends.

Many leaders underestimate the importance of designing an organization's future with this in mind. However, I challenge our leaders to take the steps to have the goals of training, development, and recognition as part of our industry's way of operating. Having these goals that invests in our employees, will sustain long needed success for our customers and the growth of our industry into the 21st Century.

REVIEW #2: IMPROVING DRIVER SAFETY

For the second review, Haddon's matrix was adapted in a similar manner to that used in the first. The two environments again consisted of the driver and the motor carrier; however, for this review, the events in the driver-motor carrier relationship are those important for improving driver safety. Thus, the Haddon Matrix for Review #2 outlines driver- and motor carrier-related factors that impact safety, such as driver characteristics, as well as those that play a role in maintaining safe operations and enhancing the safety performance of CMV drivers. The available, published literature on these topics was annotated and subsequently characterized within one of the six Haddon matrix cells below, as determined by its primary focus with regard to environment and event stage:

Table 2. Haddon Matrix for Review #2: Improving Driver Safety

	Pre-Event	Event *(Adverse Safety Incident)*	Post-Event
Driver Environment	*What driver-related factors affect safety?*	*How are driver behaviors related to event occurrence?*	*How can feedback provided to the driver benefit safety?*
Motor Carrier Environment	*What motor carrier practices affect safety?*	*How are motor carrier operations related to event occurrence?*	*How can feedback provided to the motor carrier benefit safety?*

Literature Search Results

The references obtained for Review #2 resulted in annotations of 45 sources, referencing 36 unique study efforts. These covered topics addressing each stage of the event cycle in the Haddon matrix; however, in contrast to the distribution of references for Review #1, the bulk of the annotations for Review #2 fit within the pre-event stage.

As shown in Table 2, studies for the driver environment of the pre-event stage of the matrix addressed the question, *"What driver-related factors affect safety?"* and encompassed the topics of driver compensation and driver characteristics (e.g., age, abilities, perceptions). In the motor carrier environment, the literature that resulted for the pre-event stage and accompanying question, *"What motor carrier practices affect safety?"* consisted of themes such as safety management and incentive programs. The event stage of the matrix for the driver environment addressed the question, *"How are driver behaviors related to event occurrence?"* and encompassed literature relating to unsafe driving behaviors. Also within the event stage, the available literature pertaining to the question, *"How are motor carrier operations related to event occurrence?"* focused on the area of motor carrier operations, particularly the association between commodity segments and safety performance measures. For the post-event stage of the matrix and the driver environment, a number of studies in the areas of driver self-management and attitudes toward technology addressed the question, *"How can feedback provided to the driver benefit safety?"* Finally, with regard to the post-event stage of the matrix and motor-carrier environment, the question, *"How can feedback provided to the motor carrier benefit safety?"* resulted in literature in the area of safety oversight.

Improving Driver Safety Outcomes

In contrast to the first review, the annotated literature for Review #2 is concentrated in the pre-event stage of the matrix. This suggests a perceived priority regarding the identification and comprehension of driver characteristics and motor carrier practices as they are related to safety outcomes. Studies pertaining to the relationship of driver behaviors and motor carrier operations to safety event occurrence, or the impact of feedback provided to drivers and motor carriers on safety outcomes, were considerably less prevalent. This may reflect an academic, if not industry, desire to understand and address safety issues preemptively; that is, at the pre-event stage of the Haddon matrix. With more than 5,000 deaths each year in the U.S. as a result of accidents involving large trucks (NHTSA Traffic Safety Facts, 2005), and annual industry direct costs for safety expenditures, such as training and incentives, in the billions of dollars (ATA, 1999), making a case for improving driver safety is not difficult.

Indeed, establishing which driver-related factors impact safety has implications for improving recruitment and selection techniques; as such factors may serve as "markers" for targeting desirable drivers in the future. For instance, age and CMV driving history, including experience and past history of accident involvement and safety violations, are two pertinent areas to this review that are frequently addressed in the literature (Knipling, Hickman, & Bergoffen, 2003). These characteristics of drivers, as related to safety, lend insight into statistics reported in the Large Truck Crash Causation study (LTCCS; 2006). The authors of that study determined that when a large truck was responsible for a crash, 87% of the time this was due to an error on the part of the truck driver, such as a poor driving decision or a failure to correctly recognize the situation.

The effect of age as a driver factor impacting safe operations is often confounded in studies that do not investigate or control for related variables of driving experience, or tenure, because older drivers are also frequently more experienced drivers. Nevertheless, research suggests that the relationship between driver age and safety outcomes is often a "U" shaped function, such that both younger and older drivers are less safe on the road than those in the middle age range. For example, Blower (1996) assessed differences between younger (18-21) and older (30-49) truck drivers and found that the younger drivers were more likely to have experienced a moving violation in the previous three years, and when involved in a traffic accident, were more likely to have been cited by police as responsible for the accident (70% versus 55% of older drivers). Regarding crash severity outcomes, a study of single vehicle accidents (SVAs) within a Canadian for-hire carrier determined that drivers under the age of 24 were more likely to be involved in severe crashes; however, because SVAs account for only a small percentage of all trucking accidents, this finding must be interpreted with caution. It does, nevertheless, raise the possibility that physical driving skill (e.g., quick reaction time) may have played a role in allowing younger drivers to avoid less severe crashes in some cases (Goodwin, 1996). In a related finding, a laboratory study by Llaneras, Swezey, Brock, Rogers, & van Cott (1998) reported that driving-related abilities in older, commercially-licensed drivers (> 65 years), such as accurately and quickly positioning controls and object tracking, were significantly impaired when compared with those under 50. Of note regarding the applicability of these results is that, while the average age of the U.S. workforce is indeed increasing, the proportion of CMV drivers who are employed over the age of 65 continues to be small in comparison with younger and middle-aged workers. This, in part, may be a function of the taxing nature of truck driving as a

profession (Mayhew & Quinlan, 2006), as an examination of worker's compensation claims in Oregon over seven years determined that the average number of workdays lost to injury increased from 41.9 days for drivers under 25 to 87.0 days for drivers over 65 (McCall & Horwitz, 2005).

Driving history is another factor the literature supports as impacting safety. In a study by Murray, Lantz, and Keppler (2006), future truck crash involvement was predicted based on past driver behaviors. Using Motor Carrier Management Information System (MCMIS) and Commercial Drivers License Information System (CDLIS) data, they determined that drivers with prior crash involvement were 87% more likely to be involved in a future crash. Additionally, results showed that drivers who had been cited for reckless driving violations and improper turn violations were, respectively, 325% and 105% more likely to be involved in future crashes. A pair of studies by Nafukho and Hinton (2004), and Nafukho, Hinton, and Graham (2007) also utilized accident data. Results indicated that drivers who were involved with three crashes also had the highest mean monthly mileage driven, while those with one crash drove the least. The authors suggested that because high-mileage drivers were associated with greater crash involvement, carriers should consider compensation based on the value of goods transported instead of miles driven. One obvious difficulty with this suggestion would appear to be that drivers may only then be motivated to haul loads of higher value. Additionally, these results were reported in such a manner that did not preclude exposure as a simple explanation for their findings. In other words, drivers with higher monthly mileage rates may have also been involved in more accidents simply because they were on the road more.

A number of studies purport to draw relationship between driver compensation and safety outcomes, for example, that increased pay is associated with a reduction in crashes. The reviewers offer a cautionary note to these assertions: generally, it is not possible to understand the true nature of the relationship between these two factors. Specifically, it may be unclear whether cash bonuses for safe driving are responsible for higher pay, or that offering better pay at a company improves its ability to recruit and hire greater numbers of quality drivers. Data reported by Belzer, Rodriguez, and Sedo (2002) indicated that truck drivers receiving a higher pay rate, or who received a raise during the study's data collection period were less likely to be involved in a crash. A pair of studies by Monaco and Williams (2000), and Williams and Monaco (2001), also investigated crash probability and determined that a $0.10 increase in pay rate per mile would reduce the probability of crash involvement by 1.76%. In a study on implementing safety incentive programs, a pilot investigation of a long-haul trucking firm in Canada demonstrated a decrease in driver turnover from 98% to 20% after offering safety bonuses to drivers who had not been involved in an adverse incident after six months (chosen because most of the company's turnover occurred after this duration of time; Barton, Tardif, Wilde, & Bergeron, 1998; Barton & Tardif, 2002). Indeed, to the extent that driver pay and incentives are higher due to the payment of safety bonuses, an associated reduction in turnover (as noted by Barton et al.,1998) is further linked to accident rate in a pair of studies by Staplin and Gish (2005), and Staplin, Gish, Decina, and Brewster (2003). These authors reported that drivers who changed jobs less frequently were less than half as likely to be involved in multiple crashes, as drivers who had changed jobs more than three times per year. However, the causal direction of this relationship remains unclear. Is accident involvement more common in drivers who frequently change jobs, or do drivers change jobs because they were involved in accidents?

Taking an organizational focus, there are also practices of the motor carrier that have been found to influence safety and promote safety culture. Deserving of mention are reports of safety management best practices (e.g., American Trucking Association [ATA] Safe Returns, 1999; Mejza, Barnard, Corsi, & Keane, 2003; Corsi & Barnard, 2003), listing factors including commitment to safety by top management, employee involvement, prioritizing safety in all aspects of an operation, and making safety management a continuous process. Driver opportunity for safety input and top management commitment to safety were also among antecedents in a model of safety culture that was based on driver perceptions of their respective corporate safety cultures (Arboleda, Morrow, Crum, & Shelley, 2003). The use of incentive or recognition rewards for safe performance, holding regular safety meetings, and consistently tracking all driver-related accidents and incidents for the purpose of taking disciplinary action, such as termination or suspension, in response to safety violations were also noted.

Furthermore, experts responding to a survey regarding management practices recommended training, such as apprenticeship programs, standardized training for new hires, refresher training, and remedial training (Knipling, Hickman, & Bergoffen, 2003). In fact, companies identified in the ATA Safe Returns report (1999) as having superior safety records reported spending at least $2,500 per power unit per year on direct safety costs (incentives, meetings, training), an amount that is nearly $1,500 more than the average firm spends. As a counter point to the above training recommendation, however, it should be mentioned that in a study by Dobie and Glisson (2005), although motor carrier managers and drivers agreed regarding components of safety training programs that they found beneficial (e.g., personal safety training), drivers, in turn, did not indicate that training availability would affect their decision to stay at a company. In fact, 50% stated that it did not matter whether or not the company they worked for offered such training. This may be due, at least in part, to the fact that 61.7% of drivers surveyed indicated that they were not compensated for time spent in training, nor did they receive other benefits in the form of promotions or route assignments. The benefits to training with regard to the potential for improved safety are not tangible, and therefore not enough to keep drivers at companies without a strong, homogeneous safety culture.

There is a small body of literature cited in this review linking differences in motor carrier operations to safety performance. Findings for motor carriers were not conclusive due to the limited number of studies, and because each study analyzed different segments of the trucking industry and different safety areas. Nevertheless, there is reason to believe that passenger carriers, on measures including compliance reviews (CRs), roadside inspections, and fatal crashes, are among the best performing motor carriers when compared with carriers of particular commodities (Corsi, Newhouse, Shukla, & Chandler, 2002). Furthermore, in a comparison of for-hire and private commodity segments, Keane, Corsi, and Braaten (2002) determined that private carriers were statistically safer than for-hire carriers on seven of nine safety measures. Also, results across the four Safety Evaluation Areas (SEAs) of the Motor Carrier Safety Status Measurement System (SafeStat) indicated that passenger carriers and the LTL freight segment were the safest for-hire performers. The tank and household goods segments were the safest private carriers.

A more micro-level approach to investigating how driver actions are related to event occurrence documents deleterious impacts on safety pertaining to aspects of individual driving behavior. For example, Sullman, Meadows, & Pajo (2002) surveyed truck drivers in New Zealand to assess the

relationship of aberrant driving behaviors to previous crash involvement. Data analysis yielded four distinct groups of behaviors. The first group, labeled "errors", consisted of mistakes involving failures of observation and misjudgment. The second group, labeled "lapses", encompassed problems with attention or memory. The third group, labeled "violations", was made up of deliberate deviations from practices believed to be necessary to safely operate a vehicle. Finally, the fourth group, labeled "aggressive violations", consisted of violations that specifically involved expressing hostility toward another road user, or driving in an aggressive manner. Only the group of behaviors labeled "violations" significantly predicted crash involvement; however, to the extent that social desirability may have affected responses for drivers who did not feel comfortable negatively portraying themselves in a survey, this relationship may actually be stronger than documented.

Similarly, quantitative data were collected in two studies investigating unsafe driving behaviors. The first, a naturalistic study of driving in long-haul truck drivers, used instrumented trucks and video to track driver actions surrounding critical incidents (Hanowski, Perez, & Dingus, 2005). Critical incidents were recorded based on triggers that were likely to produce video of drivers engaged in activities that were not related to primary driving duties (i.e., "distraction events"). A total of 34 distraction types, and 7 clusters that tended to statistically separate based on event duration and frequency of occurrence were identified. The majority of all incidents grouped into a single cluster, representing "average frequency" and "average event duration." Considered a greater safety risk, high frequency events are dangerous because the driver is repeatedly being inattentive to the driving task (e.g., looking around or outside of the cab to the left and right). Also, visually demanding tasks are dangerous because they take drivers' eyes off of the road (e.g., reaching to the floor). Especially concerning are tasks combining moderate levels of duration, visual demand, and frequency (e.g., talking on/adjusting CB or talking on a cellular phone). Although no crashes were recorded during the course of this study, results suggest an opportunity to use these objective data as an educational tool, especially because professional drivers may be inclined to overestimate their skills or safety. The second set of qualitative data regarding unsafe driving behaviors investigated speed-related variability during driving, or celeration, for its ability to predict accident rate. This was done through a series of studies conducted by af Wahlberg (2000; 2004; 2006). Indeed, support for using this measure as a slightly superior predictor of accidents over individual speed variables of mean and maximum speed was generated in the final study. However, even as each effort sought to address weaknesses from the previous, a new shortcoming to the existing data and/or results seemed to appear as an explanation for an overall lack of significant findings (e.g., low power; restriction of range; small sample size).

A final set of studies relevant to this review address the means by which drivers and motor carriers can receive feedback to improve safety performance and outcomes. Feedback may be provided by technology or from people, but in every case it is important that it be accurate, appropriate to the situation, and where possible, that those who are receiving the feedback have been given a role in developing the related safety program or technology. This should help build a strong safety climate and ensure that users will buy into how, when, and at what intervals they will receive feedback and/or interact with the technology. As reported in a pair of studies by Roetting, Huang, McDevitt, & Melton (2003), and Huang, Roetting, McDevitt, and Melton (2005), truck drivers were quite receptive to receiving feedback concerning their safe driving behaviors, especially if the feedback was positive. If coming from a person, the greatest

preference was for feedback from a safety director or supervisor, as opposed to peers, dispatchers, or motorists. Feedback from in-vehicle technology was viewed as objective and valuable for its potential to aid drivers in case of a crash or incident.

In independent jobs where people typically work alone, such as CMV driving, the only logical behavior-based safety (BBS) management programs are those that employ self-monitoring, as opposed to techniques where peer-to-peer feedback is provided. To this end, Olson, & Austin (2001) performed an intervention on bus operators who monitored and reported their own safety-critical behaviors, in addition to being observed by experimenters posing as passengers. Behaviors included coming to complete stops, remaining stopped during passenger loading/unloading, mirror checking, and proper selection of stopping position. A 13-day baseline, compared with observations over the subsequent 18 days, indicated an average of 12.3% improvement across drivers and conditions. Despite a small sample size that cautions against generalization, extrapolating to the entire transit system in the study (68 drivers) translated into the possibility of 31,200 fewer at-risk behaviors per month. In another self-management for safety (SMS) study, Hickman and Geller (2003) investigated differences in short-haul truck drivers who either recorded their intentions to engage in specific safe versus at-risk driving behaviors prior to leaving the terminal, or recorded actual behaviors after returning to the terminal. An on-board monitoring device tracked instances of overspeeding (>63 mph) and hard stopping/braking (>0.319 *g*). Both groups decreased their risky safety behaviors during the four week intervention, but then returned to near baseline levels of performance over the four weeks after the intervention was discontinued. This suggests that behavioral change in this study was related specifically to SMS techniques, and was not an artifact of training or increased safety awareness. In order to retain SMS benefits, then, it may be necessary for organizations to maintain ongoing monitoring and oversight programs.

Feedback from on-board vehicle and driving monitoring technologies is another avenue for improving driver safety, albeit an oftentimes controversial approach because of its potential for misuse. As a natural response, drivers may be wary of having their actions monitored and recorded, especially if they do not have a full understanding of the purpose of the technologies, how they work, and what information they provide. As these devices and monitoring systems have matured, false-alarm rates have dropped, and costs for the devices and their operation have decreased. Increasingly, more motor carriers are using the technologies, or considering doing so. The use of technology to help counteract deficiencies in driving-related abilities that decline with age, as well as errors related to lack of job experience, may prove invaluable, especially in light of the current driver shortage and resultant need for motor carriers to explore recruiting inexperienced, older workers pursuing second careers (Llaneras et al., 1998). Testing of one such collision warning system (CWS) with visual and auditory warning components was performed in a simulator study of transit bus operators (Reinach & Everson, 2005). No statistical differences among conditions (no system; visual warning only; visual plus auditory warnings) were found for stopping distance to a lead-braking vehicle during critical events. Additionally, time-to-collision differences were not demonstrated. However, initial brake application response to the critical event was slightly faster for the visual plus auditory warning condition. Low power was cited as an explanation of the lack of obvious performance benefits to the system; however, there is also the possibility that the task itself was to blame, or that the visual and/or auditory interface simply was not optimized for use in a low-speed, high-obstacle-laden urban driving environment. Nevertheless, drivers generally found the CWS useful and overall not annoying or distracting,

but noted that the visual and auditory warnings were slightly more annoying and distracting than the visual-only warnings. Clearly, as is the case with many of these evolving technologies, there is a fine line between effective and annoying warnings. In all instances, investigating driver acceptance is recommended during later stages of product development, as well as in the field, to help ensure worker buy-in and support for the technology.

Finally, a small number of applicable studies reported on the usefulness of information regarding CMV driver safety as contained within various databases maintained by outside agencies, for the purpose of providing subsequent feedback to motor carriers. Research by Lantz and Blevins (2002) linked individual driver conviction data from the CDLIS to employers, such that those motor carriers with higher (worse) "history measures" were associated with more safety problems, including higher out-of-service (OOS) rates, accident rates, and SAE scores. Using this methodology, it appears that high-risk motor carriers can be systematically identified based on the drivers they employ. As a practical use of such data in the field, this motor carrier history measure was incorporated into the Inspection Selection System (ISS) utilized by roadside inspectors beginning in March 2007. A second study assessed the utility of driver violation notification (DVN) programs, whereby states automatically inform motor carriers of changes in employee CDL records based on recorded violations and convictions (Smith, Owens, Stock, Lantz, & Murray, 2005). Support was established for an estimated economic benefit to instating DVN programs using cost data from three states with existing DVN-type programs. The authors calculated a benefit/cost ratio of $121million/$7.8 million per year (~ 16:1). Focus groups, interviews, and surveys provided to DVN users indicated a benefit to safety as related to the timeliness of reports generated by existing DVN programs. Additionally, non-users were enthusiastic regarding the potential for a DVN program to decrease carrier liability while increasing safety. These studies offer more in the way of suggestions than hard data regarding the safety impact of providing feedback at the motor carrier level. Nevertheless, they are a helpful starting point in the development of reliable, comprehensive, real-time (or at least very current) information dissemination systems for carriers who may use such data to improve the safety of their firm and employees in particular.

Research gaps within the Haddon matrix for the second review are not as marked as those in Review #1. Nevertheless, literature relevant to the event and post-event stages is lacking in comparison to that for the pre-event stage. This may, as noted previously, simply reflect a desire by researchers to preemptively understand and address safety issues. Moreover, articles found in the pre-event stage often discuss safety-management issues and practices that can also be conceptualized to pertain to the event, or even post-event stages. For instance, research on incentive programs recommends the use of bonuses and rewards as a means of improving safe driving behaviors (event), yet may also be framed in terms of feedback (i.e., rewards for good behavior; post-event). Although crafting study placement within the matrix based on "need" would have resulted in a more balanced distribution of the literature, it would not have changed the respective findings. For this reason, where a particular study fit within the matrix was entirely determined based on the perceived intent of the author(s) regarding "who" results were geared towards (driver or motor carrier) and which focus question and stage of the event cycle was best addressed.

Limitations to the Review #2 literature suggest two general caveats. The first is related to using crash data, especially as the sole safety outcome for a study. Although beyond the scope of this

review, it is well-established that crashes are associated with a multitude of factors in addition to those covered in this document, including fatigue, stress, workload, time of day, medical conditions and health, alcohol and drug abuse, and even personality. It is, of course, impossible to control for all of these in any given research effort. Perhaps then, in contrast to the first review, it should be positively noted that a more direct link to safety outcomes was at least feasible for studies in Review #2. Second, with regard to reports of best practices: indeed it is valuable to understand what industry top performers are doing that makes them superior to other firms. However, this leaves much to speculation regarding what safety missteps lesser performing companies make, so that these pitfalls may be circumvented by others. It seems perhaps odd to recommend research to identify industry "worst practices;" yet for the singular purpose of avoiding the possibility of history repeating itself, it may be a worthwhile endeavor. Furthermore, information on best practices is also typically provided as groups of practices in which top performing companies are engaged. Not only does this make it impossible to isolate and evaluate the potential impact of any individual practice, but rarely are poor performing organizations in a position (financial or otherwise) to implement a full complement of drastic, costly changes.

Findings from Trade and Industry Sources

Safety is also reported as a prevalent concern of trade sources; however much of the information regarding safe driving that is published stems directly from the scientific literature and is not novel. The sheer volume of articles referencing the same studies annotated in this review suggests that, at the very least, the trucking industry is taking notice of academic safety research. Results from the LTCCS are noted at every turn, with emphasis on the finding that "driver factors were up to 10 times more prevalent than vehicle or environmental factors in events that led up to crashes" (as cited in McNally, 2006). A study sponsored by the American Transportation Research Institute (ATRI) and annotated in this document (see Murray, Dick, et al., 2006) was labeled a "landmark report" by Jim York, a frequent contributor to the trade publication *Fleet Owner*, due to its development of a model using past performance data to predict risk of future crash involvement (York, 2005). In fact, consulting firms are using the ideas behind the ATRI report and applying them to the driver turnover problem. *FleetRisk Advisors* is using two years worth of data on driver demographics, driver performance, company logistics, and financial performance to develop models to predict and rank drivers with the highest risk of turnover (Kilcarr, 2006).

Despite some redundancy, it is more the case that the trade literature complements the academic press than detracts from it. For instance, trade publications are able to quickly disseminate information, such as in a recent article in *Transport Topics* cautioning against using cash awards when implementing safety incentive programs (Abt, 2006). As the author noted, cash does not provide long-lasting recognition to drivers, especially in comparison to material awards such as rings, belts, or jackets. Also, cash rewards are taxable, thus a $100 award does not translate into a full $100 for the driver. Because long-term motivation is important when building an incentive program, cash awards may not always be as good an idea as they are made to sound in the scientific literature. Correspondingly, this type of award quickly disappears, because it is more likely to be perceived as part of one's income, rather than something extra.

Additionally, experiences from the insurance industry as reported in trade sources supplement the literature on driver behaviors, suggesting that risky drivers are more than simply those with a lack of skill or inadequate training. In an interview with Peter Van Dyne, technical director for Liberty Mutual, he explains that "many crashes are caused by drivers' habits and practice, not by their lack of technical knowledge. For example, a driver may be careless about making lane changes, or the use of cruise control, even though he or she knows the proper procedures" (as cited in Leavitt, 2005). This reinforces the notion that safety cannot simply be improved with more training. Often drivers possess the skill and knowledge needed to drive safely, but a bad habit or outside factors, such as a weak safety climate or lack of communication within an organization, will intervene and result in unsafe driving behaviors.

Insurance providers also offer additional information in trade sources that would generally not be part of a scientific publication (as insurers are generally less involved with this literature than academics). An example of this type of information is an explanation for why private carriers benefit from lower insurance rates than for-hire fleets. Just as they typically have lower turnover rates than for-hire carriers, insurance providers report that private fleets are perceived as a "better risk" than their for-hire counterparts. The reasoning behind this risk differential reflects the inherent differences in how each sector operates. Greg Golden, COO for the Aon Truck Group (a company that provides brokerage services to the trucking industry), explains that private fleets "tend to exclusively carry their own goods, have more regular routes, and far fewer long, over-the-road trips, which means they are also apt to have a more stable driver work force" (as cited in Leavitt, 2005, p.16). Indeed, research comparing private and for-hire carriers parallels the assessment of insurance companies—private fleets are generally safer than their for-hire counterparts (Keane, Corsi, & Braaten, 2002). However, Golden also notes that "when for-hire carriers move toward this private carrier operating model, we [insurance companies] typically see their risk levels drop and their profitability improve" (as cited in Leavitt, 2005, p. 16). Again emphasizing a need to move toward the operating model typical of private fleets, Liberty Mutual reports that companies that use scheduled departure times and planned routes have fewer crashes and crash costs than those that do not. In addition, companies may be unintentionally encouraging bad and/or unsafe driving habits, such as speeding, due to poor routing, or late departures coupled with expectations of on-time delivery (Leavitt, 2005).

Finally, the trade literature is useful for the anecdotal evidence it provides from various motor carriers and industry experts; for example, ways to effectively increase oversight while drivers are on-the-road. Companies that download engine control module (ECM) data at every vehicle service evidence 34% lower crash rates and 50% lower costs than those that do not regularly do so, reports Peter Van Dyne of Liberty Mutual. Because ECM data have the potential to help identify risky behaviors, such as extreme braking resulting from following too closely, companies that download these data regularly are better equipped to intervene and correct bad habits before they result in a crash (Leavitt, 2005). Setting up an essentially real-time scenario for receiving safety information in order to assist with carrier oversight, New England Motor Freight instated a policy requiring drivers to report crashes at the scene or from the nearest phone. They are also provided with disposable cameras and encouraged to take pictures at the scene of an accident for use in court (Atkinson, 2002). Generally, communication between drivers and motor carriers is viewed as key to successful oversight, particularly with respect to preventing incidents before they occur and handling them effectively when they do take place.

Review #2 Annotations

Pre-event

Driver Environment: What driver-related factors affect safety?

Belzer, M.H., Rodriguez, D., & Sedo, S.A. (2002). *Paying for safety: An economic analysis of the effect of compensation on truck driver safety* (Contract number: DTFH 61-98-C-0061). FMCSA.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Compensation		
Motor Carrier Environment			

Author Abstract: No author abstract

Industry Sector: Trucking

Purpose: The purpose of this study was to thoroughly test the theory that driver compensation is linked to safety by using multiple datasets. The authors expected that compensation would be linked to safety, as quality drivers are attracted to jobs with higher current and expected future pay, and because turnover rates have been linked to both compensation and safety.

Sample: Three separate samples were used in this study: 198 truck-load firms were taken from The National Survey of Driver Wages and the University of Michigan Trucking Industry Program (UMTIP) supplement; 11,540 individual J.B. Hunt drivers were examined for 1 - 26 months, for a total observation count of 92,528 person-months; and data on 1,000 drivers, employed by various firms, were taken from the UMTIP survey of drivers.

Methodology: The three data sets were analyzed separately. The first data set, which was used for cross-sectional analysis, gathered information regarding pay, benefits, and hours from the National Survey of Driver Wages and a supplemental UMTIP survey. The National Motor Carrier Directory and MCMIS provided data on the number and type of vehicles and crashes, respectively. This data was used to run a negative binomial regression to predict the number of crashes in each firm as a function of various pay variables and other carrier characteristics. The predictions were converted to elasticities, indicators of sensitivity to a change of 1% in the independent variables, for all significant variables.

The second set of data, which came from J.B. Hunt drivers, was used for an individual firm, driver-level study. Data were analyzed using standard multivariate regression from two time periods, one before a pay increase and one after.

The third set of data, which included individual drivers from a sample of firms, came from an UMTIP survey and was collected in two periods from truck stops in the Mid-West. The first period covered the Summer of 1997 and the second period lasted from the Spring of 1998 through the Winter 1998/99. This data was used to develop a driver supply curve. The supply curve indicates how many hours drivers work for a given pay rate. The same data was also used in a probit regression to predict the likelihood that a driver reported having a crash during the past year. This type of regression uses a dependent variable with two possible categories. In this example, the categories were "crash occurs" or "crash does not occur." The model shows the probability that a driver will experience, or not experience, a crash based on the independent compensation, demographic, and operating variables.

Relevant Findings: The cross-sectional analysis showed a nearly one to one relationship between the compensation variables and crash probability. For every 10% increase in average driver compensation (including benefits and anticipated raise), the carrier experienced 9.2% less crashes. The presence of a safety bonus was also a significant variable.

Analyses of the J.B. Hunt data corroborated findings from the cross-sectional data. Drivers who experienced a pay raise, or were paid a higher base rate, evidenced a reduction in their crash probability. Findings also showed that driver crash risk decreases until the age of 41, and again increases thereafter. Safer drivers were also shown to have driven more miles and to have longer tenure at the firm than less safe drivers. Additionally, safe drivers were identified, generally, as non-married. The data showed a decrease in crash risk for all drivers over time when all compensation and demographic variables were held constant.

The supply curve derived from analysis of the multi-firm, driver-level data showed that the leisure and income preferences of drivers were consistent with the prevailing economic theory, which postulates that workers, at first, respond to a higher wage rate by working longer hours in order to achieve a higher income. However, at higher levels of pay, the income becomes sufficient enough that workers feel comfortable seeking more leisure time. The shape of the supply curve showed that, at pay rates below 31.4 cents per mile, drivers worked longer hours. For rates above 31.4 cents per mile, drivers worked fewer hours, choosing leisure time over the extra income.

Probit regression results evidenced pay rate and paid time off as the only two significant variables to reliably predict a decrease in crash probability.

Taken together, the three analyses and data sets show that current compensation and increases in compensation both have a negative relationship with crash rates. Crash rates decrease when compensation increases, although demographic variables also account for some of the differences in crash rates among drivers.

Limitations: The series of studies described in this report suggest strong support for the existence of a relationship between compensation and safety. However, the underpinnings behind such a relationship remain unclear. Future research should continue to examine the mechanisms that explain why compensation and safety are related. What is clear is that targeting driver compensation may be an effective way to improve driver safety in the trucking industry.

Categorization: This paper fits within the pre-event timeframe of the driver environment for the Haddon Matrix #2: Compensation. Although compensation policies are set by motor carriers, this study evaluates how drivers behave and respond to different pay rates and raises.

Blower, D.F. (1996). *The accident experience of younger truck drivers* (GLCTTR Publication No. 81-96/1). Michigan University, Transportation Research Institute; Trucking Research Institute

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Age		
Motor Carrier Environment			

Author Abstract: The purpose of this project is to identify the special problems related to the high accident involvement of younger truck drivers and to suggest possible countermeasures. In this project, younger drivers are those in the 18-21 age group and the older drivers selected for comparison are ages 30-49. The project consisted of a driver survey, analysis of traffic violations, analysis of the accident record, and examination of police reports covering selected accident types.

Driver records and accident data from Michigan were used primarily. The survey was done on Michigan CDL holders. Accident data from North Carolina supplemented the Michigan data, and police reports from both Michigan and North Carolina were reviewed.

Young drivers had significantly more traffic violations than older drivers, with higher proportions of unsafe speed, reckless/careless, and failure to yield violations. Accident types with significant younger driver overinvolvement included single vehicle loss of control, rear end truck striking, and truck backed into other. Case review of accident reports showed problems with following too closely; failure to anticipate the actions of other road users; problems with vehicle control, as in low speed offtracking accidents; and possible attentional overload, as in some loss of control accidents.

Industry Sector: Trucking

Purpose: The purpose of this study was to assess differences between younger and older truck drivers in an attempt to explain why younger truck drivers are more likely to be involved in accidents.

Sample: Male holders of Class A or B CDLs in Michigan between the ages 18–24 or 30–49; 4,689 drivers were mailed surveys and over 2,000 responded.

Methodology: This project involved a number of related research efforts, including a driver survey, analysis of driver history files, analysis of accident records, and a detailed examination of individual police-reported traffic accidents. The driver survey was designed to obtain basic information about CDL-holders. Participants were asked if they actively use their CDL, what types of training they have received, the type of truck they drive, and the type of firm for which they drive. Driver history files were used to provide detailed information about accident and violation records. Accident files provided more information about trends in types of accidents, while the individual police reports allowed the researchers access to specific details about the circumstances surrounding accident occurrence.

Drivers were divided into three age groups for analysis purposes. The group of "younger drivers" consisted of drivers between the ages of 18 and 21. A second group of younger drivers, aged 22 to 24, was included because drivers aged 22 to 24 were expected to share similar characteristics with the youngest group of drivers. Finally, the comparison group of "older drivers" included drivers between the ages of 30 to 49.

Relevant Findings: In comparison to older drivers, younger drivers typically drove 30% fewer miles, drove less at night, and were more likely to work for intrastate firms and firms operating fewer trucks. Younger truck drivers were more likely to have experienced a moving violation in the past three years (56% compared with 29% for older drivers), were twice as likely to be cited for unsafe speed (8.2% compared with 4.8% for older drivers), and were more likely to be cited by the police when involved in a traffic accident (70% compared with 55% for older drivers).

Analysis of driver accident records and case studies revealed a number of common themes in accidents involving younger truck drivers. Younger drivers most often exhibited: excessive and unsafe speed; overly aggressive driving, as in following other vehicles too closely; failure to anticipate and provide for the unexpected actions of other road users, as in both rear-end and backing accidents; failure to maintain proper vehicle control, as in low-speed turning and backing accidents; and possible attention overload, as in loss of control accidents.

Although evaluating the means to effectively address the problems of younger truck drivers is outside the scope of this study, the authors suggest increasing practical, real-world training for younger drivers, with special attention given to aggressive driving, accounting for the actions of other road users, and basic vehicle control.

Limitations: This study only examined male truck drivers, more research is necessary to examine differences between male and female truck drivers, especially in the younger age group.

Although particular interest is often devoted to truck drivers under the age of 21, the relatively small population of younger truck drivers made it necessary to expand the sample of younger drivers to those aged 18 to 21 and, in some cases, aged 18 to 24.

Finally, more research is necessary to determine if and what types of training can effectively reduce accident involvement for younger truck drivers.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Age, as it focused on factors related specifically to younger drivers who had been involved in accidents.

Goodwin, D. (1996) Single vehicle accidents: A fleet insurer's perspective. F. Saccomanno & J. Shortreed (Eds.), *Truck safety: Perceptions and reality* (pp. 59–72). University of Waterloo: Institute for Risk Research.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Characteristics		
Motor Carrier Environment			

Author Abstract: Single vehicle accidents (SVAs) involving tractor-trailers pose significant risks to all users of the highway, result in financial losses and may receive hysterical media coverage to the detriment of the trucking industry.

This study considers fleet operating and driver characteristics as well as environmental and road conditions for 40 SVAs reported by 27 Canadian trucking firms April 1989 to April 1990. It identifies the major factors that contribute to the SVAs and provides recommendations for future improvements in trucking safety. Inadequate driver selection, indifferent supervision, and poor driver training appear to be reliable predictors for SVA involvement.

Industry Sector: For-hire trucking in Canada

Purpose: The purpose of the study was to inform motor carriers and insurers of factors that can lead to higher rates of SVA involvement.

Sample: Truck drivers employed by 27 firms and involved in 40 SVAs where the trailer was either severely damaged or demolished beyond repair, as reported by a large Canadian fleet insurer.

Methodology: This study considered fleet operating and driver characteristics as well as environmental and road conditions for 40 SVAs reported by 27 Canadian trucking firms between April 1989 and April 1990. Factors of interest contributing to the SVAs were classified into three categories: operating characteristics, environmental and road conditions, and driver characteristics. The categories were analyzed for frequency of occurrence and compared to the distribution of the characteristics of the entire available driver force and motor carrier population.

Relevant Findings: Driver age was not found to be a significant factor in explaining the frequency of SVAs. However, drivers under the age of 24 tended to be involved in more severe crashes. Drivers with less than seven years of commercial driving experience were responsible for more than half of the

SVAs in the sample. On average, new employees had experienced an SVA within the first five months of driving for a company. Many of the new hires had multiple recorded accidents or violations with previous employers, or were not investigated by employers prior to hire.

The authors recommend that a standard be developed for classifying accident circumstances, using on-board monitoring devices for data collection. They also recommend that motor carriers employ driver trainers to evaluate drivers pre-employment and perform training after hire. Driver performance evaluations should be on-going.

Limitations: The sample size of 27 firms is small and the time period of analysis from April 1989 to April 1990 may be outdated. Furthermore, SVAs accounted for only 2.2% of all trucking accidents in 1990. Thus, the findings of this study may not be applicable to the entire trucking industry.

Categorization: This paper fits within the pre-event timeframe of the driver environment for the Haddon Matrix #2: Driver Characteristics, because the authors sought to extract specific driver characteristics that were linked to higher rates of involvement in SVAs.

Llaneras, R.E., Swezey, R.W., Brock, J.F., Rogers, W.C., & Van Cott, H.P. (1998). Enhancing the safe driving performance of older commercial vehicle drivers. *International Journal of Industrial Ergonomics, 22*, 217–245.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Age and Abilities		
Motor Carrier Environment			

Author Abstract: This research effort involved investigations of fifteen human abilities, their changes which occur with aging, and their effects upon commercial truck driving performance. One-hundred and seven commercially licensed truck drivers, divided into five age cohort groups, participated in the research study. An ability testbed, consisting of laboratory-based assessment devices, was used to measure 15 driving related perceptual, cognitive, and psychomotor abilities. The influence of these functional abilities on driving performance was assessed using an interactive commercial truck driving simulator. Relationships between perceptual, cognitive, and psychomotor abilities and measures of driving performance indicated that functional levels on these tasks and driving performance are significantly related. How well drivers performed on a number of ability tests was predictive of driving performance. However, age, in and of itself, was not predictive of driving performance. Interventions designed to target ability deficiencies were also developed and evaluated during the course of this effort. Four interventions, consisting of three in-vehicle compensatory aids and a single driver training program, were used in the study. The degree to which the interventions enhanced, or otherwise influenced driving performance was examined by contrasting performance with versus without the interventions. Results indicated that all four interventions led to enhanced performance.

Industry Sector: Trucking

Purpose: The primary objective of this research was to identify and reduce risks associated with older commercial drivers, thereby enabling this growing segment of the population to continue to effectively contribute to the workforce, while ensuring safe and productive driving. To meet this objective, a series of empirical research analyses was conducted. These were designed to: (1) examine the effects of increasing age on perceptual, cognitive, and motor abilities by collecting data on ability measures that have been shown to be related to driving; (2) investigate the effects of diminished abilities on direct measures of driving performance in order to determine how age-related ability deterioration affects performance in

commercial vehicle driving; and (3) evaluate methods of compensating for age-related ability changes through vehicle design changes, and/or training-related interventions.

Sample: 107 commercially licensed truck drivers.

Methodology: This study examined important driving-related perceptual, psychomotor, and cognitive abilities associated with commercial vehicle driving. Ability scores were derived from context-free (i.e., non-driving) tests representative of the driving task and were related to age and to driving performance. This approach enabled the researchers to determine the independent effects of each ability on driving performance, as well as provide a way to compare the relative importance and contributions of each ability to overall driving performance and to particular driving maneuvers and tasks. Interventions designed to target ability deficiencies common among older commercial vehicle drivers were also developed and evaluated. Four interventions designed to mitigate age-related problems were evaluated by measuring driver performance, under controlled conditions, with and without the presence of these interventions. A between-subjects design was used to assess the effects of these interventions; subjects assigned to an experimental group received all four interventions, while those in the control group were not exposed to any countermeasures. Thus, two grouping factors were incorporated into the design: Age, expressed across five age groups (under 50, 50–54, 55–59, 60–64, and 65 and older), and interventions, captured by the experimental vs. control group distinction.

Investigations among 15 human abilities, their changes that occur with aging, and their effects on commercial truck driving performance were conducted during this study. Perceptual ability measures included static visual acuity, dynamic visual acuity, contrast sensitivity, useful field of view, field dependence, and depth perception. Cognitive ability measures consisted of decision-making, selective attention, information processing, and attention sharing. Psychomotor ability measures included reaction time, multi-limb coordination, control precision, tracking, and range of motion. The influence of these perceptual, cognitive, and psychomotor abilities on driving performance was assessed using the TT150 Professional Truck Driving Simulator. Simulator-based driving performance variables collected automatically included lane position, gear shifting performance, speed maintenance, and time to complete course. Two trained observers documented driving-related behaviors (e.g., mirror checks, search, speed control, lane position, etc.) at different junctions and various sections of the simulated driving course. In addition, the observers also rated each driver's performance across seven distinct categories, including an overall index of driving performance, using a five-point rating scale ranging from poor to excellent. All participants drove a

standardized 10-mile course that included a variety of road conditions and driving tasks.

Data analyses were structured to address three basic issues: (1) relationships among the various ability measures and age; (2) relationships among the various perceptual, cognitive, and psychomotor abilities and driving performance; and (3) the effectiveness of specific interventions. Analytical techniques included independent Analysis of Variance (ANOVA), bivariate Pearson correlations, and stepwise linear regression.

Relevant Findings: Results relating perceptual abilities to age showed that each of the six measured abilities tended to deteriorate with advancing age. Drivers in the 65 and older age category had significantly poorer static visual acuity, dynamic acuity, contrast sensitivity, useful field of view, field dependence, and depth perception compared to drivers below age 50. With regard to cognitive abilities, the results indicated that drivers 65 and older showed significant deterioration in decision-making, selective attention, information processing, and attention sharing abilities compared to drivers in all other age groups, particularly the below age 50 group. Results of the relationship between psychomotor abilities and age showed drivers under age 50 outperformed drivers age 65 and older in tasks requiring control precision, tracking, and range of motion. Drivers 65 and older also showed significant impairment in the ability to accurately position controls quickly and the ability to track objects. No significant differences were found among the age groups in terms of simple reaction time. In summary, 13 of the 15 abilities tested were found to degrade with age on the basis of one or more of the analyses. It was noted, however, that although an overwhelming number of perceptual, cognitive, and psychomotor abilities were found to exhibit age differences, the degree of deterioration was not the same for all measured abilities.

Correlations between age and driving performance revealed that 10 of the 24 driving performance aspects measured showed significant age relationships; two correlations indicated that driving performance actually improved with increasing age. Specifically, older drivers tended to have better lane position and fuel mileage than younger drivers. The remaining significant relationships were in the expected direction, suggesting that advancing age is associated with poorer driving performance. As indicated by these results, age appears to be associated with some aspects of driving performance. However, given that chronological age is also strongly related to perceptual, cognitive, and psychomotor abilities, it would be misleading to suggest that age, in and of itself, is directly contributing to poor driving performance. This issue was addressed by regressing age and ability scores on driving performance. Results of this analysis provided strong support indicating that driving-related abilities, not chronological age, were critical determinants of driving performance. Age appeared to

indirectly influence driving by affecting basic functional abilities that are related to driving. Consequently, age alone has not been found to be a reliable indicator of driving performance; it appears to function as a moderator variable.

The degree to which the interventions used in this study enhanced, or otherwise influenced, driving performance was also examined. Data generated from this study indicated that interventions might prove to be effective strategies for dealing with declines in driving-related abilities. For example, deteriorating range of motion, control precision, and tracking ability suggested that older commercial vehicle drivers might benefit from automatic transmissions (though the benefits associated with automatic transmission are not limited to older drivers). Also, auditory warning systems offer the capability to further reduce visual demands associated with driving. Although the majority of past studies have emphasized vehicle and roadway accident countermeasures, this research indicated that countermeasures designed to influence the driver directly via training-oriented interventions (e.g., driver education, physical therapy, etc.) might also be an effective strategy for combating age-related ability deficiencies.

Limitations: Given the nature of the study and the requirement for strict environmental controls, driving performance was assessed in a commercial vehicle driving simulator. While this approach maximized the study's internal validity, it also limited its external validity, making it difficult to generalize the findings to actual on-road vehicle driving environments. Time and resource constraints also led the researchers to expose each driver in the experimental group to all four driving countermeasures. Therefore, interventions were not manipulated independently, making it difficult to determine the specific effects associated with a given intervention. Despite these concerns, the researchers pointed out that the results obtained in this study were consistent with many earlier on-the-road studies of older automobile drivers' performance.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Age and Abilities, because the researchers were concerned about how perceptual, cognitive, and psychomotor abilities change with advancing age, what abilities are important to driving, and how results generalize to the commercial driving domain.

Mayhew, C. & Quinlan, M. (2006). Economic pressure, multi-tiered subcontracting and occupational health and safety in Australian long-haul trucking. *Employee Relations, 28*, 212-229.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Characteristics		
Motor Carrier Environment			

Author Abstract: **Purpose**—The purpose of this research is to analyze the relationship between economic pressure, multi-tiered subcontracting and occupational safety and health (OSH) outcomes for employee and owner/drivers in long-haul trucking, using Australian evidence.

Design/methodology/approach—The analysis is based on direct interviews with 300 long-haul drivers, using a structured questionnaire along with an examination of documentary records, statistics and government reports. Qualitative and quantitative data were gathered on self-reported acute and chronic injuries, the incidence of occupational violence, truck crashes, indicators of illicit drug use, hours of work/fatigue and psychological distress.

Findings—Variations between owner/drivers and employees working for small and large firms were investigated. Overall, owner/drivers reported worse OSH than small fleet and, more especially, large fleet drivers. Evidence also indicated a connection between economic pressure, the expansion of contingent work [the use of self-employed subcontractors or owner-operators] and negative OSH outcomes.

Research Limitations/implications—Further longitudinal and comparative research is needed to test the hypothesized link between competitive pressures, supply chain rationalization and OSH outcomes. Research to investigate these issues in other countries is required in order to compare findings with those for Australia and to assess the effectiveness of new enforcement initiatives.

Practical implications—Findings suggest the need for policy interventions aimed at improving OSH to address commercial practices, including elaborate subcontracting chains, more explicitly than is currently the case with road transport regulation. Recent moves in this direction are identified.

Originality/value—Unlike manufacturing, healthcare and the public sector, there have been few studies of the OSH effects associated with contingent work arrangements in transport. In addition to helping to gill this gap the paper provides evidence on the effects of competitive pressure and supply chains on work practices and OSH.

Industry Sector: Long-haul trucking in Australia

Purpose: The purpose of this study was to demonstrate the effect of increasing competition and supply chain dependencies on the OSH of truck drivers. The authors emphasize the OSH research approach and concern with overall driver well-being, as opposed to the more commonly used road-safety approach, which focuses on truck related accidents.

Sample: 300 long-haul drivers.

Methodology: The authors interviewed 300 long-haul drivers over the course of 2 months in 2000. The sample contained owner-operators, small carriers with less than 20 vehicles, and large carriers with more than 20 vehicles. The three types of carriers are represented in almost equal numbers. The survey included closed and open ended questions on acute and chronic injuries, occupational violence, truck crashes, illicit substance abuse, hours of work, fatigue, and levels of stress as measured by the General Health Questionnaire. The survey yielded both quantitative and qualitative data.

Relevant Findings: One in four drivers reported suffering from acute or chronic injuries, a number much higher than the percentage of drivers filing worker compensation claims. Owner-operators were less likely to treat or take time off for their injuries, the majority citing financial pressures as the reason. Drivers working for large firms felt more secure about reporting injuries and being able to take time off for them.

About half the drivers experienced verbal abuse or threats on the job, the majority from other motorists, but some from customers or loading dock employees. A total of 12.5% of the owner-operators, 10.1% of small company drivers, and 5.9% of large company drivers reported having been involved in an accident over the past 12 months. Large company drivers, however, reported a higher occurrence of minor crashes that did not necessitate taking time off from driving. Large company drivers reported being fatigued less frequently than small company drivers or owner operators. They also reported greater compliance with log-book requirements.

Twenty-three percent of drivers reported either using or having observed others use illicit substances, especially amphetamines. Forty percent reported working longer than the legal limit of 72 hours per week. Owner operators were more likely to ignore HOS regulations. Drivers consistently scored above the normal baseline on the health questionnaire, and owner-operator scores were twice as high as that of employee drivers. High scores on the health questionnaire indicate that driver physical and mental well-being is significantly worse than that of the general

population. The drivers with the highest level of stress overwhelmingly indicated financial pressures as the leading cause.

Limitations: The findings of this paper may only be applicable to Australian motor carriers.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Characteristics because it reports differences in driver well-being and accident rates for different types of truck drivers.

McCall, B.P. & Horwitz, I.B. (2005). Occupational vehicular accident claims: A workers' compensation analysis of Oregon truck drivers 1990–1997. *Accident Analysis & Prevention, 37*, 767-774.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Characteristics		
Motor Carrier Environment			

Author Abstract: This study used workers' compensation data from Oregon from 1990 to 1997 to examine workers' compensation claims from vehicular accidents by truck drivers, and to calculate claim rate estimates using baseline data derived from the US Bureau of Census' Current Population Surveys. During this period, 1168 valid injury claims due to vehicular accidents were filed representing an accident claim rate of 50.3 (95% CI: 45.1-55.5) per 10,000 truck drivers annually. There were 19 work-related vehicular accident fatalities recorded in the data over the 8-year period. Of all claimants, males constituted the majority (80.7%), most were 35 years of age or younger (51.4%) and had less than 1 year of job tenure (51.0%). Truck driver claim rates due to vehicular accidents were lowest during the 6 a.m. to 12 p.m. period. The average amount of compensable lost work days per injury claim was 57.8 days (SD = 124.7) and the median claim time was 16.0 days with the inter-quartile range being 53.5 days. The amount of lost work reported increased with the claimant's age. A total of US$ 11,642,635 was paid in claims for vehicular accidents of truck drivers in Oregon over the time examined, which averaged US$ 9966 per claim, with a median claim amount of US$ 2590 and inter-quartile range of US$ 7670. Claims citing sprains were the most frequently recorded injury experienced from vehicular accidents.

Industry Sector: Trucking

Purpose: The purpose of the study was to analyze the characteristics of risky drivers and the causes of truck accidents using a large population of drivers.

Sample: 1,168 accepted injury claims.

Methodology: The study analyzes all injury claims due to vehicular accidents filed by truck drivers in Oregon for the years 1990-1997. Claims data included the age and gender of drivers, time of day and day of the week of the accident, precipitating events, and injuries and compensated days of lost work. Census's CPS was used to establish a baseline of the number of people employed as truck drivers in Oregon. In addition, the CPS Work Schedule

Supplement Survey provided data on the time of day and day of the week worked by a sample of all U.S. truck drivers. The schedule data was used to establish a baseline for Oregon drivers, as they were not found to be statistically different from the general population of U.S. drivers. Although the data was adjusted for the number of truck drivers working during each time of the day and each day of the week, the data was not adjusted for overall traffic volumes.

Relevant Findings: The majority of the claims were filed by drivers under 35 years of age, with drivers under 25 filing 19.5% of the claims, although they constituted only 8.5% of all Oregon truck drivers during that time period. Although women constitute just over 5% of the truck driver population in Oregon, 19.3% of claims were filed by women. Women, however, had shorter time away from work and less expensive claims because on average the female drivers in this sample experienced less severe accidents than the male drivers. The difference in severity may be explained by possible differences in truck types driven by men and women, though no specifics on vehicle types were provided. Fifty-one percent of drivers who filed claims had tenure of less than one year. Only 9% of the accidents occurred at night, with another 9% in the evening. The highest number of accidents occurred during the third hour of work, and the fewest number of injuries occurred on the weekends. The number of lost days of work increased with age, such that those under the age of 25 lost an average of 41.9 days, while individuals over 65 lost an average of 87.0 days.

Limitations: The number of worker compensation claims likely underestimates the total number of truck accidents, particularly less serious accidents.

The data excluded owner-operators.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Characteristics. The study used workers' compensation claims to analyze the characteristics of risky drivers.

[a]Monaco, K. & Williams, E. (2000). Assessing the determinants of safety in the trucking industry. *Journal of Transportation and Statistics, 3*, 69–79.

[b]Williams, E., & Monaco, K. (2001). Accidents and hours-of-service violations among over-the-road drivers. *Journal of the Transportation Research Forum, 40*, 105–115.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Characteristics		
Motor Carrier Environment			

Author Abstract: [a]Using data from the 1997 Survey of Drivers conducted by the University of Michigan Trucking Industry Program, we identify the factors which substantially affect three safety measures: accidents, moving violations, and hours of service violations. The variables used include both operational characteristics (firm size, trailer type) and personal characteristics (age, race, union status). Using both basic descriptive statistics and probit estimation, we find that the variables that have the most impact on the three safety measures are operational in nature, not individual characteristics.

[b]Using data from the 1997 UMTIP's Survey of Drivers, we estimate models of driver accidents and compliance with hours-of-service regulations. We find links between these safety measures and the economic conditions of truck drivers. Drivers who drive more miles have a greater likelihood to be involved in accidents and to violate the federal Hours of Service (HOS) regulations. Rate and method of pay are also significant across the models estimated, suggesting that drivers who are under more economic pressure are more likely to violate regulations and to be involved in accidents.

Industry Sector: Trucking

Purpose: [a]The purpose of the Monaco and Williams (2000) paper was to examine how various individual and work-related driver characteristics influence driver safety. In addition, statistical estimation techniques were used to assess the relative impact of each of these characteristics.

[b]The Williams and Monaco (2001) paper primarily focused on the development of models of driver accidents and compliance with HOS regulations using an updated database and similar estimation techniques as described in the 2000 article. The authors sought to examine the extent to

which demographic and occupational characteristics predict the occurrence of accidents and HOS violations.

Sample: [ab]More than 900 truck drivers were surveyed as part of the UMTIP Survey of Drivers.

Methodology: [ab]Data were collected from truck stops in the Upper Midwest (Ohio, Indiana, Illinois, Michigan, and Wisconsin) throughout 1997 and 1998. The Monaco and Williams (2000) paper used data collected in 1997, and the Williams and Monaco (2001) paper used data from an updated UMTIP database which included information from 1997 and 1998.

[a]For this study, probit regression models were used to estimate the probability of accidents, moving violations, and logbook violations given various driver and operational characteristics. A probit modeling technique is used in cases where the dependent variable is dichotomous. In the current study, all three dependent variables were recorded as a yes or no response. Each driver reported whether he/she had: 1) been involved in an accident reported to the police while on duty in the last 12 months (i.e., accident involvement), 2) been cited for a moving violation while on duty in the last 12 months (i.e., moving violations), and 3) worked more than he/she had logged in the last 30 days (i.e., logbook violations). For each of the three questions, an affirmative response was recorded as a value of one in the model estimation, and a value of zero was recorded otherwise. The driver characteristic variables included in the models were gender, education level, race, ethnicity, veteran status, union status, marital status, job tenure, occupational experience, driver training, trailer configuration, mileage in the last 24 hours, sleep in the last 24 hours, and a calculated mileage pay rate.

[b]In the later study, probit regression models were again tested to determine whether driver and/or firm characteristics explain the probability of accident involvement (as defined in the 2000 study) and HOS violations [Reviewer note: same as the definition for "logbook violations" in the 2000 study].

Relevant Findings: [a]Descriptive analyses revealed that 15% of the sample reported having been involved in an accident, 30% reported having received a moving violation, and 58% reported having worked more than they logged in the last 30 days. Descriptive analyses of driver characteristics showed that white drivers and drivers with less than one year experience reported the highest percentage of accidents (16% and 28%, respectively, versus 15% for the rest of the sample). Drivers paid by percentage of revenue, primarily owner-operators, reported a higher than average percentage of accidents, moving violations, and logbook violations (18%, 38%, and 63%, respectively) than those paid by the mile. Drivers who reported zero

hours of sleep in the last 24 hours were also more likely to have been involved in an accident in the past year (28% versus 15% for the rest of the sample).

Accident Involvement: [a]The probit estimation model of accidents revealed that work-related driver characteristics were more likely to be related to accident involvement than demographic characteristics. Pay rate, method of payment, firm size, region, and source of training were all significant work-related predictors of accidents. Marital status was the only individual characteristic significantly related to accident rate. For pay rate, results suggested that a $0.10 increase in the rate paid per mile would decrease the probability of being involved in an accident by 1.76%. In addition, drivers paid by the hour were 10.2% less likely to have been involved in an accident than those paid by the mile or percentage of revenue. Drivers at firms with 1,000 to 4,999 employees were 11% less likely to be involved in an accident than drivers at firms with less than 25 employees. The authors suggest that this result may indicate that large trucking firms are succeeding in their long-asserted commitment to safety. Northeast and Mid-Atlantic drivers were significantly more likely to have been involved in an accident (56% and 21%, respectively) than those working in the Upper Midwest. This regional finding is consistent with driver reports that driving on the East coast can be more hazardous than other areas, probably due to population density and greater road congestion. Drivers who received training through a trucking company program were 14% more likely to have been involved in an accident than those who learned on-the-job. Unfortunately, it is unknown what type of training (e.g., novice, advanced skills, classroom, etc.) drivers received through their company versus the training drivers received on the job, and whether or not they remained at the company that trained them. Finally, drivers categorized as separated, divorced, or widowed were 8.9% less likely to have been involved in an accident than drivers categorized as single.

[b]Rate and method of pay were again found to be significant predictors of accident involvement in the follow-up study. Drivers who are paid more per mile and those who are paid by the hour, rather than by the mile, are less likely to be involved in an accident. In fact, for every additional 100 miles driven per day, the likelihood of being involved in an accident increased by 1.6%.

Moving Violations:

[a]Union members, drivers at larger firms, and drivers who learned to drive a truck at a private trucking school were significantly less likely to have received a moving violation in the last 12 months. Drivers at smaller firms, owner-operators, drivers who drove more miles in the last 24 hours, and drivers who learned to drive at a public or technical school were all more likely to have received a moving violation. Although it is an important distinction, the authors did not define the differences between public and private trucking schools. Those who responded to the survey were simply asked to check off where they received training on a list of possible places.

Logbook Violations:

[a]Drivers who reported getting greater amounts of sleep in the last 24 hours, hauling a dry van trailer, driving more miles per year, being paid by the hour, and being black or female were less likely to report logbook violations. Drivers who graduated college or had some college experience were more likely to report that they drove more than reported in their logbooks than high school graduates. In addition, married drivers were more likely to report logbook violations than single drivers.

[b]The Williams and Monaco (2001) study found similar results for logbook violations in their model of HOS violations. White drivers and owner-operators were more likely to report logbook violations. In addition, results suggested that driving 100 more miles in a day may increase the probability of logbook violations by 2.6% and sleeping one additional hour may decrease the probability of logbook violations by 3.6%.

Limitations: The authors used an archival dataset, so there is very little information in either article concerning how the data was collected. It is clear that all data were self-report. Thus, there is some concern that drivers may not have accurately reported their involvement in accidents, moving violations, and/or logbook violations due to a social desirability bias (e.g., "They will think I am a bad driver if I tell the truth") or fear of repercussions for rule violations. It is also important to note that most of the results were reported in a descriptive nature, thus more explanation is needed to identify why some of the occupational characteristics identified predict accident, moving violation, and/or logbook violation occurrence.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Characteristics, as it evaluated how various individual and work-related characteristics influence driver safety and, specifically, accident rates.

Murray, D.C., Lantz, B., & Keppler, S. (2006) Predicting truck crash involvement: Developing a commercial driver behavior model and requisite enforcement countermeasures. *Transportation Research Board 85th Annual Meeting* Washington, D.C.: Transportation Research Board.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Characteristics		
Motor Carrier Environment			

Author Abstract: The majority of prior research and analysis, including the Federal Motor Carrier Safety Administration Large Truck Crash Causation Study (LTCCS) points toward driver-related factors as the main cause of most commercial vehicle-related crashes. Therefore, in order to have the most profound impact on the number of crashes, more must be done to understand and mitigate the driver behaviors which lead to crashes.

To do so, the American Transportation Research Institute (ATRI) conducted this research to identify a driver performance-based model for predicting future crash involvement based on prior driver history. ATRI's research team included North Dakota State University Upper Great Plains Transportation Institute (NDSU/UGPTI) and the Commercial Vehicle Safety Alliance (CVSA).

The analysis identifies eight moving violations as significant with an associated crash likelihood increase between 21 and 325 percent. Four driver violations were identified as having a significant associated crash likelihood increase between 18 and 56 percent. Twelve convictions were significant with an associated crash likelihood increase between 24 and 100 percent. Drivers with a past crash were found to have an increased likelihood of a future crash of 87 percent.

In order to address the driver behaviors identified, successful enforcement strategies were identified through interviews and surveys with CVSA members. The CVSA work identified "top-tier" states as those having more traffic enforcement and lower crashes, and from those states, recommended practices have emerged including: focusing on both truck and car driver behavior patterns; conducting highly visible enforcement activities; using a performance-based approach to identify specific crash types, driver behaviors and locations; and, conducting covert enforcement activities.

Industry Sector: Trucking

Purpose: The purpose of this research was to determine whether an overall driver performance-based indicator can be developed that will have the ability to predict accident likelihood. In addition, the research identified the types of driver violations or convictions that are more highly correlated with future crash involvement. The two major goals were to: design and test a model for predicting future crash involvement based on prior driver history information; and, in conjunction with the CVSA, identify effective enforcement countermeasures to address and alleviate the driving behaviors and events that were shown to be predictive of future crash involvement.

Sample: 586,894 CMV drivers for the initial statistical analysis, of which traffic conviction data were available for 540,750.

245,467 CMV drivers for the predictive regression analysis.

Methodology: Data sources for the analysis included the MCMIS and the CDLIS. The main dependent variable in the model was crash involvement, which was also considered the objective measure of driver safety. The independent variables were driver-specific performance indicators mined from available data, including specific violations discovered during roadside inspections, driver traffic conviction information, and past crash involvement information. Driver data were gathered across a several-year time frame, and analyzed across years to determine future crash predictability. Appropriate statistical tests, including chi-square analyses, were used to assess whether a significant difference existed in future crash rates for drivers based on past inspection, conviction, and/or crash information. In addition, logistical regression was used to develop a predictive model with the prior crash status of each driver as the nominal (non-continuous) dependent variable.

In order to identify effective enforcement countermeasures, a survey was distributed to 51 enforcement jurisdictions to identify how enforcement agencies address overall CMV driver behavior and performance issues. A targeted survey was later distributed to those states that had been identified as having a higher level of CMV traffic enforcement and a lower level of crashes. The primary purpose of this targeted survey was to identify preliminary enforcement strategies and best practices among states that appear to be proactive in conducting traffic enforcement and achieving positive results.

Relevant Findings: Statistical analysis of the data showed that the two violations associated with the highest increase in likelihood of a future crash were reckless driving and improper turn violations. When a driver was cited for one of these violations, their likelihood of having a future crash increased 325%

and 105%, respectively. Both log book (i.e., false or no log book entry) and disqualified driver violations were associated with more than a 50% increase in the likelihood of a future crash. An HOS violation and a medical certificate violation were found to increase crash likelihood 41% and 18%, respectively.

The four convictions associated with the highest likelihood of a future crash were improper or erratic lane changes; failure to yield right of way; improper turn; and failure to keep in proper lane. Drivers convicted of one of these types of convictions increased their likelihood of a future crash 91% to 100%. Finally, the results of the crash data analysis indicated that drivers who had prior crash involvement increased their likelihood of having a future crash by 87%.

The targeted survey indicated that successful enforcement strategies for addressing problem driver behaviors are those that exhibit one or more of the following components: creation of aggressive driving apprehension programs/initiatives, a focus on both CMV and non-CMV behavior patterns, highly visible enforcement activities, use of a performance-based approach to identify specific crash types, driver behaviors, and locations, and covert enforcement activities. The states identified as having a higher level of traffic enforcement and a lower level of crashes were found to be significantly more likely to compare traffic enforcement programs with crash data and other information in order to monitor the program's effectiveness.

Limitations: No goodness-of-fit statistics were provided for the predictive regression model. Thus, it was difficult to judge the robustness of the model for predicting the likelihood of future crash involvement based on the explanatory variables.

Categorization: This study fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Characteristics, as the research focused on driver-specific behaviors and events and their relationship to future crash involvement.

[a]Nafukho, F.M. & Hinton, B.E. (2004). *A model for predicting tractor-trailer truck drivers' job performance related to highway safety* (Publication No. MBTC2043). University of Arkansas, Fayetteville, Research and Special Programs Administration.

[b]Nafukho, F.M., Hinton, B.E., & Graham, C.M. (2007). A study of truck drivers and their job performance regarding highway safety. *Performance Improvement Quarterly, 20*, 61–74.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Characteristics		
Motor Carrier Environment			

Author Abstract: [a]A number of factors may contribute to road traffic accidents, namely: reckless driving, having un-road worthy vehicles on the road, and poor conditions of the roads. However, this study examined the performance of tractor-trailer truck drivers in a leading transportation company in the United States of America. Limited research has addressed the issue of working conditions of the drivers, especially incentive, compensation, and workplace variables and how these variables affect job performance in terms of reduced accidents. Therefore, the primary purpose of this study was to determine how tractor-trailer truck drivers' job performance could be improved while at the same time ensuring increased revenue for the transportation companies employing them. The target population for the study comprised of tractor-trailer truck drivers employed by a major transportation company in the U.S. The researchers obtained data on the drivers from the database maintained by the company. Data were obtained for 14,340 drivers. The data used in the study included demographic, incentive, compensation and workplace variables. The results of the study showed that a statistically significant model did exist that explained the variance in the dependent variable, the number of accidents, which was used as a measure of driver performance. The variables cost of accidents, miles driven per month, safety bonus, pay time off, drivers' age and salary earned combined explained 3.2% of the changes in the dependent variable (number of accidents) in the study. The demographic variables miles driven and age of the driver had linear and positive relationship with the dependent variable, number of accidents. Based on the results of the study, several policy implications and recommendations for further studies are made.

[b]Limited research has addressed the issue of truck drivers and their performance regarding highway safety in terms of reduced number of crashes per driver. The primary purpose of this study was to determine how tractor trailer truck drivers' job performance could be improved while

at the same time ensuring increased revenue for transportation companies employing them. The target population for this study comprised of tractor-trailer truck drivers employed by a leading transportation company in the United States. The data used in the study included demographic, human capital, compensation and workplace variables. The results of this study should be useful to several individuals, organizations and the entire U.S. economy. The transportation companies should benefit by knowing the factors that predict good job performance for the drivers. This should assist management in designing work conditions or other activities that promote good performance in terms of reduced crashes and improved productivity of drivers.

Industry Sector: [ab]Trucking

Purpose: [a]The purpose of this study was to evaluate the effect of driver characteristics, driver compensation, and workplace variables on safety outcomes as measured by accident rate per driver.

[b]The later paper reports on the same study and explains the link between workplace variables and the crash rate per driver. This paper also makes recommendations for further study.

Sample: [ab]14,340 tractor-trailer drivers.

Methodology: [ab]The authors obtained data for 14,340 drivers from a major motor carrier for the year 2002. Standard regression analysis was used to determine the relationship between driver characteristics and the dependent variable (number of accidents per driver). The independent variables included were cost of accident, salary, gender, marital status, age, race, miles driven per month, times of dispatching, miles, paid time-off, and safety bonus provided by employer. All drivers in the company had received an equal amount of training, and 19.2% or 2,754 of the drivers in the sample had been involved in at least one accident.

Relevant Findings: [ab]The drivers who had been involved in at least one accident were, on average, one year older, earned about $20 less paid time off during 2002, and drove, on average, 630 miles more in 2002 than the drivers with no accidents. In 2002, this group of drivers also earned a smaller average safety bonus, but only by approximately $10.

Six variables were found to be significant in the regression model and together explained 3.2% of the variance in driver accident rates. The variables included cost of accident, miles driven per month, safety bonus amount, paid time off, age, and salary. Incentives thus have a positive effect on driver safety. b. While the model explains only 3.2% of the

variation in crashes, a 3.2% reduction in total crashes could have a significant effect on a company's bottom line.

[b]The authors performed further analysis of the miles driven per month and age variables. Within the sample of drivers with crashes, drivers with three crashes had the highest mean of miles driven and drivers with one crash had the lowest mean of miles driven. Older drivers experienced more crashes than younger drivers.

Since the average miles driven per month correlated highly with the crash rate, the authors recommend that companies revisit their compensation schemes, perhaps compensating drivers based on the value of the goods transported instead of the miles driven. They also recommend further qualitative study focusing on the factors that drivers think can make them more efficient and effective at work. Lastly, the authors recommend a study focusing on drivers above 50 years of age.

Limitations: [ab]The authors acknowledge that other variables shown to affect driver safety such as experience, and use of alcohol, are not included in this study.

Categorization: These papers fit within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Characteristics, as they examine the characteristics of both risky and safe drivers.

Report to congress on the large truck crash causation study. (2006). (TRIS No. 01023450). Federal Motor Carrier Safety Administration.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Characteristics		
Motor Carrier Environment			

Author Abstract: No author abstract

Industry Sector: Trucking

Purpose: The purpose of the LTCCS was to conduct a comprehensive examination into the causes of, and contributing factors to, crashes involving CMVs. This study was designed to permit consideration of a broad range of factors that could be used to guide development of crash countermeasures. The LTCCS collected the same type of descriptive data as other national traffic safety databases such as the Fatality Analysis Reporting System (FARS), the General Estimates System (GES), and the MCMIS, but it also focused on pre-crash factors such as driver distraction and fatigue, vehicle condition, weather, and roadway problems. This makes the LTCCS the only national examination of all factors related to causation in large truck crashes.

Sample: 967 crashes involving large trucks.

Methodology: The LTCCS collected data on crashes at 24 sites in 17 states during the period 2001 through 2003. An attempt was made to ensure that each crash involved at least one truck with a gross vehicle weight rating of more than 10,000 pounds and also resulted in at least one fatality, incapacitating, or non-incapacitating but evident injury. Data were collected on up to 1,000 elements in each crash. The factors coded were selected from a broad range of factors thought to contribute to crash risk. These include, for example, vehicle factors such as brake failure, environmental factors such as roadway and weather conditions, and driver factors such as fatigue, distraction, speeding, and making an illegal maneuver. To ensure high data quality, onsite investigations began as soon as possible after a crash occurred.

The coding of the events surrounding the crash began with the "critical event" (the event that immediately led to the crash), the "critical reason" (the immediate reason for the critical event or failure leading to the critical event; the critical reason describes why the critical event occurred), and

the "associated factors" (any of approximately 1,000 conditions or circumstances present at the time of the crash that could possibly contribute to the crash).

Relevant Findings: In the 967 crashes that comprise the LTCCS database, there were 1,127 large trucks, 959 non-truck motor vehicles, 223 fatal crashes resulting in 251 fatalities, and 744 injury crashes resulting in 1,408 injuries. Thus, 23% of the LTCCS cases resulted in at least one fatality. One-fourth of the cases involved only one vehicle, including a truck that rolled over, struck an object, hit a pedestrian, or collided with a non-motorized vehicle such as a bicycle. Over 60% of the 1,127 trucks involved in the crashes were tractors pulling a single semi-trailer.

The remaining results discussed in this section are national estimates based on weighted data. During the 33-month study period of the project, FMCSA estimated that there were approximately 141,000 large trucks involved in fatal, incapacitating, and non-incapacitating injury crashes. Almost one-fourth of the crash involvements consisted of rear end collisions, about 18% represented a truck either running off the road or out of its lane, and almost 27% of all large trucks were involved in crashes where they were the sole motor vehicle.

Trucks were assigned the critical reason for the crash in 77,000 (55%) of the estimated 141,000 cases of large trucks involved in fatal, incapacitating, and non- incapacitating injury crashes. For those 77,000 cases, the driver accounted for 87% of the critical reasons, and most involved failure to correctly recognize the situation or poor driving decisions. The critical reason was assigned to environmental conditions (roadway or weather) in only 2% of the cases. In addition, the most common associated factors recorded were driver factors, such as legal drug use, traveling too fast for conditions, unfamiliarity with the roadway, inadequate surveillance, fatigue, and feeling under pressure from motor carriers. For two-vehicle crashes involving a truck and a passenger vehicle, trucks were assigned the critical reason in 44% of the crashes and passenger vehicles in 56%. Driver recognition and driver decision errors were the most frequently cited critical reasons for both types of vehicles.

Limitations: The LTCCS contains a large amount of descriptive data. It was never the intent of the study to perform crash causation analyses. Thus, additional analyses must be conducted in order to identify specific risk factors for large truck crashes. Another limitation is the results of the weighted estimates may differ from true values, as they are based on a probability sample of crashes and not a census of all crashes.

Categorization: This study fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Characteristics, as the study focused on determining the causes of, and contributing factors to, crashes of CMVs.

Rodriguez, D.A., Rocha, M., Khattak, A.J., & Belzer, M.H. (2003). *Effects of truck driver wages and working conditions on highway safety: Case study* (TRIS No. 00965381). Transportation Research Board.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Compensation		
Motor Carrier Environment			

Author Abstract: The role that driver compensation and work conditions play in influencing driver safety outcomes has gained increased attention from trucking firms and policy-makers. This paper examines the role of these factors, in addition to driver behavioral and demographic factors in influencing crash frequency at the driver level. A unique driver-level dataset from a large truckload firm collected over a period of 26 months is used for estimating regression models of crash counts. Based on estimates from a zero inflated Poisson regression model, results suggest that occupational and labor market factors, such as pay, tenure at the job, and percent of miles driven during winter months, have a significantly better explanatory power of crash frequency than demographic factors. Taking into account both the inflation and the count model, results suggest that higher pay rates and getting a pay raise are related to lower expected crash counts and to a higher probability of zero crash counts, ceteris paribus. Although a partial equilibrium approach is followed, the evidence provided is a first step in examining the structural causes of unsafe driving behavior, such as driver economic rewards, and crash outcomes. These results can motivate firms in modifying operations and driver hiring practices. They also support the need for a general equilibrium examination of the relationship between driver compensation and driver safety.

Industry Sector: Trucking

Purpose: The purpose of this paper was to add to the literature examining the effect of behavior on safety outcomes by examining some of the factors that motivate driver behavior, particularly compensation and occupational factors.

Sample: 11,540 unscheduled over-the-road, dry-van, tractor-trailer drivers from JB Hunt.

Methodology: This paper used regression models to estimate driver level truck crash counts. The data used in this analysis were driver-level HR, operations, and safety records from JB Hunt, whose drivers were shown to be

comparable to industry-wide drivers in terms of demographic and occupational characteristics. Accident data were collected over a 26 month period, with each driver being observed on average for 9.2 months. The regression model included driver socio-demographic characteristics, occupational factors, and individual exposure as explanatory variables. For example, driver compensation per mile, tenure in years, total number of miles driven during period observed, percentage of miles driven during winter, age, gender, race, and marital status. The dependent variable was total number of crashes costing the firm $500 or more during the period of observation. The data included drivers who received a pay raise, and drivers who did not receive one, either because they left the firm prior to the raise or were hired at a higher pay rate.

Relevant Findings: Higher pay rates, as well as pay raises, were shown to lower expected crash frequency. The model estimated that, on average, a one cent per mile raise in pay resulted in a 2.27% reduction in crash frequency, which is known as the elasticity of the crash rate with respect to the pay raise. This result translates into a less than 50% probability of having no crashes at a pay rate of 16 cents per mile and a more than 95% probability of having no crashes at a pay rate of 49 cents per mile. A higher pay rate lowered crash frequency even for drivers with many years of experience. Crash probability, at first, declines with tenure, and then begins to increase after about six years. While crash frequency decreases with driver age, it is at a decreasing rate. Policies that allow drivers opportunities for pay raises or higher rates of pay when hired may contribute to better safety outcomes.

Limitations: This study uses a firm-specific data set from a very large firm that implemented significant pay raises. The same results may not hold for smaller firms or firms implementing smaller pay raises.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Compensation. The study primarily looked at the effect of compensation on safety outcomes, but also looked at driver demographic and occupational characteristics.

[a]Staplin, L. & Gish, K.W. (2005). Job change rate as a crash predictor for interstate truck drivers. *Accident Analysis & Prevention, 37*, 1035–1039.

[b]Staplin, L., Gish, K.W., Decina, L.E., & Brewster, R.M. (2003). *Commercial motor vehicle driver retention and safety* (FMCSA-RT-03-004). ATA Foundation, Alexandria, VA.; Federal Motor Carrier Safety Administration, Washington, DC. Office of Research and Technology.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Characteristics		
Motor Carrier Environment			

Author Abstract: [a]This research analyzed the Motor Carrier Management Information System (MCMIS) database to develop estimates of the increased risk of crash involvement experienced by commercial drivers who change jobs frequently. These analyses quantified the risk of single- and multiple-crash involvement as a function of annual job change rate, and expressed the relative risk for drivers with more versus fewer job changes through calculation of the odds ratio statistic. Significant odds ratio values were found, indicating that crash risk begins to rise when a driver has averaged more than two jobs with different employers each year for 2 years or longer, and that the odds of being involved in multiple crashes more than doubles for drivers with three or more jobs per year during this same interval. Opportunities for further research, focusing on variables that could be extracted from existing data sources to further enhance the validity and predictive value of the relationships found in this study, were also identified.

[b]Within this research, the study team analyzed the MCMIS database to develop estimates of the increased risk of crash involvement experienced by commercial drivers who change jobs frequently, conducted a literature review, and contacted industry experts to identify strategies with the best potential to improve trucking companies' retention of safe drivers.

The database analyses quantified the risk of single- and multiple-crash involvement as a function of annual job change rate, and expressed the relative risk for drivers with more versus fewer job changes through calculation of the "odds ratio" statistic. Significant odds ratio values were found, indicating that crash risk begins to rise when a driver has averaged more than two jobs with different employers each year for two years or longer, and that the odds of being involved in multiple crashes more than

doubles for drivers with three or more jobs per year during this same interval.

The literature review coupled with contacts with drivers, motor carrier management, motor carrier insurers, and other groups and associations supported recommendations in the areas of selection and hiring of new driver applicants; new driver orientation; driver training, including refresher training; driver-dispatcher operations; the measurement and recognition of safe driving performance by trucking companies; scheduling and hours-of-service compliance; and the needs of industry to improve perceptions of the profession and to convey respect for and a commitment to its drivers.

Industry Sector: [ab]Trucking

Purpose: [ab]Previous research suggests that motor carriers with higher driver turnover rates have higher crash rates than their counterparts with lower turnover rates. This study sought to expand upon previous findings by determining if drivers with higher rates of job change were also involved in more crashes than drivers with lower job change rates. The 2003 FMCSA report and 2005 journal article both outline the same study.

Sample: [ab]25,609 truck drivers.

Methodology: [ab]Job change and crash rate data were obtained from the MCMIS, operated and maintained by the FMCSA. Data were gathered specifically from the Crash File, Census File, and the Inspection File, with all driver information being recorded during roadside inspections. Drivers were included in the sample if they were involved in at least two inspections during a two year period. Relative crash risk was then identified using the calculation of an odds ratio.

Relevant Findings: [ab]Of the 25,609 drivers included in the sample, 16,249 had no crashes, 8,797 had one crash, and 563 had two or more crashes. Drivers who had more than six jobs in the given sampling period of 2 or more years, depending on the data available, were 1.6 times more likely to have been involved in at least one crash, and 2.2 times more likely to have been involved in multiple crashes.

Additional analyses examining rates of job change, or number of jobs per year, revealed similar results. The odds of being involved in at least one crash significantly increased for drivers who had changed jobs more than two times per year. An examination of drivers involved in multiple (two or more) accidents revealed that drivers who had changed jobs three or more times per year were over twice as likely to be involved in multiple crashes than drivers who changed jobs less frequently. The relationship between

turnover and crash risk suggests that frequent turnover may serve as a potential indicator of risky drivers. In other words, those who job-hop between motor carriers more often may also be the more risky drivers.

Limitations:

[ab]The inspection sampling period for drivers included in the study varied markedly, although all drivers had a sampling period of at least 24 months, many drivers had a much longer sampling period. Thus, the results examining job change rate are more stable because they standardize the count of the total number of unique jobs held in the total sampling period to a measure of unique jobs held per year. Restricting the dataset to include only a common sampling period would have dramatically decreased the number of data points available. Causal inferences cannot be made about the identified relationships because of the cross-sectional nature of the dataset and the retrospective analyses. Other variables, such as age, education, and personality factors may also be involved and warrant further research. Unfortunately, raw numbers were not available in the article, and actual percentages were not reported. It would be necessary to contact the authors in order to further investigate these other variables.

Categorization:

These papers fit within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Characteristics, because they identify characteristics of drivers that may indicate more frequent accident involvement. This could aid motor carriers in identifying risky drivers within their organization.

Sumer, N., Ayvasik, H.B., & Er, N. (2005). Cognitive and psychomotor correlates of self-reported driving skills and behavior. *Third International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design* (pp. 96-103).University of Iowa, Iowa City.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Abilities		
Motor Carrier Environment			

Author Abstract: No author abstract

Industry Sector: Trucking and motor vehicles in Turkey

Purpose: The researchers developed a computerized psycho-technical assessment system that included a number of tests to measure cognitive and psychomotor performance (e.g., driver attention and reaction time). The purpose of this study was to examine cognitive and psychomotor correlates of self-reported driving skills and behaviors.

Sample: 716 non-professional passenger car and professional drivers.

Methodology: Participants were administered computer-based cognitive and psychomotor tests in a research center established to investigate the validity of a psycho-technical driver assessment system. The computerized test battery consisted of the following: Traffic Monotonous Attention Test; Selective Attention Test; Visual Pursuit Test to assess drivers' visual plasticity and tracking ability; Eye-Hand Coordination Test; Reaction Time Test; and Peripheral Perception Test to measure drivers' ability to pay attention and detect stimuli coming from peripheral panels of the monitor while simultaneously attending to a demanding task on the screen. After completing these computerized tests, participants completed a Driver Behavior Questionnaire (DBQ) that assessed driver behaviors, specifically driving violations and inattention errors. They also completed a Driver Skill Inventory that provided a self-reported measure of driving (perceptual-motor) and safety skills.

Relevant Findings: This study revealed that self-reported driving skills, as well as driving behaviors, could be systematically predicted by the computerized measures of cognitive and psychomotor performance. Correlations between driving skills and behaviors and both peripheral perception and reaction time were moderately strong. Drivers with higher levels of peripheral perception ability and quicker reaction time tended to report

that they had a higher level of perceptual-motor performance, better safety skills, fewer driving violations, and made fewer inattention errors. It was also found that, as expected, both cognitive and psychomotor performance deteriorated as age increased.

Regression analysis showed that the drivers' level of education was a significant predictor of all driving skill and behavior variables. Driving exposure was also significantly related to driving perceptual-motor skills, but was not associated with safety skills or driving behaviors. The study revealed that higher levels of selective attention were associated with diminished skills and increased violations and errors. This suggested that high levels of selective attention, in fact, create a proclivity for unsafe driving and aberrant behaviors. Peripheral perception, on the other hand, was found to be a critical element of safe driving, as evidenced by a positive correlation with safety skills and a negative correlation with violations and errors. Finally, a decline in both reaction time and visual pursuit seemed to be linked with unsafe driving.

Limitations:

Very high correlations were observed between the driving skills and safety skills measured with the Driver Skill Inventory and between the driving violations and attention errors assessed using the DBQ. As a result, the researchers' expectation that computerized measures of cognitive and psychomotor abilities would be mainly linked with driving skills and attention errors, but not with safety skills and driving violations, was not supported.

Another limitation concerns the nature of self-reported survey instruments; past studies have demonstrated that both young and old drivers tend to overestimate their driving skills and underestimate their limitations and may, therefore, bias the results. The majority of the 716 study participants in this study were young and middle-aged, with older drivers not well represented (mean age was 36.59 and the oldest driver was 61; however, this is nevertheless a representative sample of the CMV operator population, at least within the United States).

Categorization:

This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Abilities, because the researchers focused on predicting driving skills and behaviors that affect safety on the basis of the driver's cognitive and psychomotor abilities and characteristics.

Walton, D. (1999). Examining the self-enhancement bias: Professional truck drivers' perceptions of speed, safety, skill and consideration. *Transportation Research Part F: Traffic Psychology and Behaviour, 2*, 91–113.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment	Driver Perceptions of Self and Other		
Motor Carrier Environment			

Author Abstract: A sample of 1,006 professional truck drivers were surveyed on their perceptions of self and average other speeds, consideration, relative safety, and relative skill. A disproportionate frequency of responses is found in the measures of speed, safety, and consideration, but not skill. In the measures of speed and consideration this bias is found to operate in a negative direction. Truck drivers are found to evaluate other road users negatively, they do not demonstrate 'self-enhancement' indicative of driver overconfidence. Drivers responsible for the biases are isolated from the sample using a method of triangulation. Background factors relating to driver characteristics and employment conditions are examined. Characteristics of the drivers' employment indicate the perceptions are related to factors external to the drivers' self-conceptions. These contrasts provide further support for the contention that the 'self-enhancement bias', as it appears in this sample, operates as a negative-other rationalization.

Industry Sector: Trucking in New Zealand

Purpose: The purpose of this study was to examine whether or not 'self-enhancement bias' was present in a sample of truck drivers. This bias posits that drivers overestimate their own skill and safety, as compared with others, and regard the average driver as more likely to be involved in an accident than they are. Further, the authors sought to determine whether the bias was related to an inflation in perception of one's own ability ('positive-self') or a negative evaluation of others' abilities ('negative-other').

Sample: 1,006 professional truck drivers in New Zealand.

Methodology: Researchers contacted 680 transport firms located on one island of New Zealand. They distributed 1,995 surveys to drivers who worked for, or through, these companies. At total of 1,013 surveys were returned by the due date, and 1,006 were deemed usable. Respondents were nearly all

male, 25.5% were owner-operators, and the mean, median, and mode of the age distribution all fell within the category 41–48 years.

The survey consisted of 25 items, including measures from previous studies on self-enhancement bias. The pre-existing scales for self-enhancement bias measured speed (Walton & Bathurst, 1998), consideration (McCormick, Walkey, & Green, 1986), and safety and skill (Svenson, 1981). Additionally, there were questions regarding typical type of truck driven, type of load hauled, driver-firm relations, pay, and safety equipment. In New Zealand speed limit varies by trailer type, so, drivers were also asked to provide the speed limit of the vehicle they reported operating on a regular basis. While the author did not provide explicit examples of survey item wordings, it was explained that speed was measured using continuous scales with a range from 70–130 km/h; consideration was measured using scales that each ranged from 0–6; and safety and skill were assessed using 'forced-choice' items that asked, for each dimension, whether drivers considered themselves better than the average truck driver.

Relevant Findings: The professional truck drivers in the current sample exhibited a self-enhancement bias on measures of speed, safety, and consideration. Largely independent of the type of truck driven and whether or not drivers considered themselves to be safer or more skilled than the average truck driver, they believed that other drivers traveled at speeds that were higher than they actually traveled. This indicates a negative-other bias, where the thinking is that 'others drive faster than me' rather than 'I drive slower than others.' Despite being experienced drivers, logging approximately 100,000 km per year, this sample reported inflated speeds for others on the road. At the same time, they were very accurate when self-assessing their own speed, as compared with data records collected by Land Transport Safety Authority (LTSA) regarding the actual average speeds of different vehicle classifications.

Results also indicated a negative bias for the measure of consideration, where survey respondents reported other truck drivers to be less considerate than themselves, and car drivers as far less considerate than other truck drivers.

Findings for the measure of skill did not reflect a self-enhancement bias, as younger drivers (< 28 yr) accurately deferred to more experienced drivers when rating their assessments of skill; indeed younger drivers are generally not as skilled as older drivers. Additional support for lack of bias on this measure was found in that older drivers (> 55 yr) more frequently claimed to be less skilled than the average truck driver, recognizing that age can have a deleterious impact on skill.

Background variables external to driver characteristics especially impacted reports on the safety measure. In particular, drivers who claimed they were less safe than the average driver reported more frequently that their employer had less regard for their safety as an employee. Additionally, these drivers also claimed more frequently that their employer had no concern for their work hours. They were more likely to be employed at a large company, and less likely to indicate that they would be trained to drive a new type of vehicle. These findings suggest the importance of large companies emphasizing and attending to safety, training employees, and adhering to HOS limits. The sample subset of owner-operators also more frequently reported driving less safely than the average truck driver. The authors indicated that this may be related to the fact that the owner-operator is solely responsible for his/her truck, including all maintenance (or lack thereof), and thereby possesses detailed knowledge regarding its mechanical condition. For some drivers, then, factors *external* to their control were influential, which is not consistent with an overly positive self-conception of their driving.

An explanation of the negative-other rationalization may be found in Wills' (1986) downward comparison theory, which suggests that drivers may justify their own non-compliant behavior by "reporting as 'average' those who are more extreme than themselves" (p.111). A negative regard for average allows for the driver to consequently perceive his or her own speed as slower, and levels of consideration as higher, in comparison. Regarding skill level, where no measure of bias was found, the authors purported that justification was not necessary because skill level does not have implications for external standards of conduct. Rather, it is the acting out of that skill on various measures (e.g., speed and consideration) that is negatively evaluated.

Limitations: There are certain operational variations in truck driving in New Zealand compared with the United States that likely differentially impact safety outcomes. For example, in New Zealand, seat belt use is not required by law, speed limits differ depending on the type of trailer being hauled, and HOS regulations are not in parallel with the United States. Caution should therefore be exercised regarding the generalizability of the findings in this study.

Categorization: This paper fits within the pre-event timeframe of the driver environment for Haddon Matrix #2: Driver Perceptions of Self and Other, in that it evaluates perceptions of 'self' and 'other' on various measures and in light of background factors relating to driver characteristics.

Motor Carrier Environment: What motor carrier practices affect safety?

American Trucking Associations. (1999). Safe returns: A compendium of injury reduction and safety management practices of award winning carriers.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Safety Management Practices		

Author Abstract: No author abstract

Industry Sector: LTL, TL, and private trucking

Purpose: The purpose of this project was to: identify and document highly effective motor carrier safety management practices; identify and document successful approaches to reducing the risk and cost of workplace injuries; and share this information with industry and the general public.

Sample: Phase I interview: 48 award winning motor carriers; Phase II interview: 1 carrier from the Phase I, and 10 additional carriers.

Questionnaire: 200 motor carriers in California, Washington, and Oregon.

Methodology: The American Trucking Association Foundation (ATAF) identified a stratified sample of award winning carriers based on carrier type, operation type, and size. Carriers were selected based on having exemplary safety performance records and/or injury rates that were significantly lower than the industry average. Interviews were then conducted with safety management directors, personnel directors, owners, and/or other staff responsible for safety. The interviews included questions about the integration of the safety function within the organization, employee hiring, employee training, employee award and incentive programs, equipment specifications and maintenance, safety policies and meetings, injury prevention, accident and injury investigation, claims management, monetary investment in safety, and other factors critical to safety success as identified by interviewed carriers.

In addition, a survey was administered to 200 motor carriers in order to determine benchmarks for typical practices in the trucking industry. Survey questions requested information regarding safety-related hiring criteria, driver training, award and incentive programs, safety meetings,

accident review, key factors in effective safety management program implementation, and general information about the respondent carrier.

Finally, an additional sample of motor carriers was selected based on recommendations from insurance providers. Carriers participating in the Phase II interviews were asked more detailed information concerning their injury prevention practices.

Relevant Findings: Four factors were highlighted as critical to successful safety management: 1) Top management must support and be committed to safety; 2) Employees must be included in safety management by keeping lines of communication open, encouraging employee feedback, and rewarding employees with bonus, incentive, and recognition programs; 3) Safety must be a focus in all aspects of operations and at all levels of the organization, including hiring, compensation and benefits, and day-to-day protocols; and 4) Safety management should be on-going and comprehensive to identify and address problems before an event occurs.

While employee retention is a serious problem in the trucking industry, most of the award winning carriers interviewed had lower than industry-average annual turnover rates. Participants stressed treating their employees with respect as critical to successful retention. In addition, some firms had developed programs designed to increase retention of new hires during the first four months of employment by pairing new hires with more senior employees using a "buddy" support system.

All of the participating companies used merchandise incentive or recognition programs where employees could earn points toward rings, belts, jackets, or vacations for safety-related performance. Over two-thirds of the companies also provided cash incentive programs, with safe performance awards ranging in value from several hundred to several thousand dollars.

All of the participating firms reported holding regular safety meetings. Attendance was typically mandatory and employees were paid for attendance. In addition, the use of employee-staffed safety subcommittees, responsible for accident investigations, work environment safety, and training needs assessment, was reported to help make employees feel more involved in safety management.

Most of the training and safety programs identified consistently tracked and analyzed all accidents and incidents, regardless of severity. Monitoring even the most minor of events allowed the companies to develop more effective tools for accident and injury prevention to prevent minor events from becoming major events in the future.

Finally, participating companies reported spending an average of $2,500 per power unit per year on direct safety expenditures, such as safety administration, awards and bonuses, safety meetings, and training expenses. This figure is almost $1,500 higher than what is spent by the average motor carrier and demonstrates a clear investment in safety through out-of-pocket costs. Safety is viewed as an investment that more than pays for itself through reductions in insurance premiums and accident costs, and increases in productivity and employee retention.

Limitations: This report provides a general overview of the best practices employed by award winning motor carriers. A more detailed analysis, broken down by carrier type, operation type, and/or size may be helpful in assessing best practices and developing training programs for different types of motor carriers. In addition, the researchers primarily focused on interviewing management to determine best safety practices. It may also be informative to interview drivers working for award winning motor carriers to determine what policies and practices they believe assist them in being safer drivers and if there are any differences between drivers at award winning motor carriers and drivers employed by carriers with poor safety performance records.

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Management Practices, because the purpose of the study was to gain a better understanding of the management practices that can lead to safer fleet performance.

Arboleda, A., Morrow, P.C., Crum, M.R., & Shelley, M.C.I. (2003). Management practices as antecedents of safety culture within the trucking industry: Similarities and differences by hierarchical level. *Journal of Safety Research, 34*, 189–197.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Safety Management Practices		

Author Abstract: Problem: A homogeneous perception of safety is important for the achievement of a strong safety culture; however, employees may differ in their safety perceptions, depending on their position and/or hierarchical level within the organization. Moreover, there is limited information on the antecedents of safety culture. This study examines how safety training, driver scheduling autonomy, opportunity for safety input, and management commitment to safety influence individuals' perceptions of safety culture. Method: Data for this study were drawn from 116 trucking firms, stratified by three safety performance levels. The data were collected from drivers (lowest hierarchical level), dispatchers (medium hierarchical level), and safety directors (highest hierarchical level), regarding their perceptions of their respective corporate safety cultures. Perceptions of safety culture were analyzed through a linear regression using dummy variables to differentiate among the three hierarchical groups. The resulting model allowed for examination of the specific antecedents of safety culture for the three employee groups and the extent to which the hierarchical groups were in agreement with each other. Results: Driver fatigue training, driver opportunity for safety input, and top management commitment to safety were perceived to be integral determinants of safety culture in all three groups. Impact on industry: Trucking firms seeking to strengthen employees' perceptions of safety culture might begin by improving these safety management practices while appreciating that they may have a different impact depending on the employee's hierarchical position (e.g., drivers' perceptions of safety culture are more influenced by top management commitment and driver fatigue training). A fourth safety practice examined, driver scheduling autonomy, was not found to be instrumental in shaping safety culture for any of the three hierarchical levels. Consistent with previous research, implementation of stronger safety cultures should result in fewer accidents.

Industry Sector: Trucking

Purpose: The purpose of the current study was to examine management practices as predictors of safety culture in the trucking industry. In addition, the perceptions of drivers, dispatchers, and safety directors were explored to determine if management practices could predict safety culture at different levels of the trucking industry's hierarchy.

Sample: 116 firms (32 top safety-performing firms, 53 average firms, and 31 poor performing firms), yielding individual responses from 113 drivers, 98 dispatchers, and 109 safety directors.

Methodology: The authors sampled from trucking firms listed in the federal government's Motor Carrier Census file that had also been rated for safety in the SafeStat. A total of 77,216 motor carrier firms exclusively engaged in trucking (i.e., no passengers) were eligible for selection in the study, based on their inclusion in the aforementioned databases. The population of firms was then divided by quartiles into three safety performance categories based on SafeStat ratings (numerical thresholds not provided): top safety-performing firms, average firms, and poor performing firms. Motor carriers were randomly selected from within each category and contacted to participate. Of the 566 firms contacted, 374 agreed to participate and 116 returned usable surveys.

The authors then administered a survey to drivers, dispatchers, and safety directors at the participating firms concerning management practices at their organization and perceived safety culture. Management practices were measured by asking participants to report the extent to which they thought: 1) drivers in their firm were trained about driver fatigue issues (driver safety training); 2) drivers in their firm were the best judges of whether they were too tired to driver (driver autonomy); 3) drivers in their firm had opportunities to make suggestions and voice complaints regarding safety and fatigue (driver safety input); and 4) top management in their firm was committed to driving safety (top management commitment).

Safety culture was measured by asking respondents to indicate their level of agreement (strongly agree to strongly disagree) with four statements: 1) our company makes driving safety a top priority; 2) driving safety is an important concern at this company; 3) I am satisfied with the amount of emphasis this company places on driving safety; and 4) drivers and management openly discuss issues related to driver fatigue. A multiple linear regression model was then used to estimate the effect that management safety practices had on individuals' perception of safety culture.

Relevant Findings: Driver safety training was a significant predictor of safety culture for drivers, dispatchers, and safety directors. In addition, drivers' opinions regarding their own training were the most influential predictors of safety culture. Thus, when drivers receive safety-related training, all employees (and particularly drivers) may be more likely to perceive a strong, positive safety culture in the organization.

Driver autonomy was not a significant predictor of safety culture for any of the three groups of employees. Drivers, dispatchers, and safety directors did not view driver scheduling autonomy as an important contributor to safety culture in their organizations.

Driver safety input was a significant predictor of safety culture for dispatchers and safety directors, but was not a significant predictor of safety culture for drivers. However, a comparison between drivers, dispatchers, and safety directors revealed no statistical differences in effect sizes, suggesting that all employees agreed about the extent to which driver input is important in regards to safety culture. In effect, driver input may be a predictor of safety culture, but it is not as strong a predictor of safety culture as driver training.

Top management commitment to safety was a significant predictor of safety culture for all three groups of employees. When employees believe that top management values safety, they are more likely to perceive a strong safety culture in the organization. Results also indicated that drivers' perceptions of top management were significantly more important in predicting safety culture than were dispatchers' or safety directors' perceptions. Therefore, it is most important that drivers perceive top management as safety-conscious when fostering a strong safety culture.

Limitations: This research is limited by its reliance on self-report data, potentially resulting in artificially inflated relationships between variables. However, self-report methodologies are often the only practical means of gathering information on employee perception, and recent research suggests that the problem of inflation in self-report data is often over-emphasized.

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Management Practices, as it examined driver, dispatcher, and safety director perceptions of safety culture as a function of management practices.

[a]Barton, R., Tardif, L.P., Wilde, G., & Bergeron, J. (1998). *Incentive programs for enhancing truck safety and productivity: A Canadian perspective* (Publication No. TP 13256E). Transport Canada; Canada Safety Council.

[b]Barton, R. & Tardif, L.P. (2002). Implementing successful incentive programs within transport fleets. In Z.G. Zacharia (Ed.), International Truck and Bus Safety Research and Policy Symposium (pp. 45–55). University of Tennessee, Knoxville: National Safety Council.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Incentive Programs		

Author Abstract: [a]No author abstract

[b]Incentive programs strengthen the motivation to be safe and, combined with proper tools and knowledge, will result in improved safety. An estimated $30 to $50 million is spent annually by Canada's trucking industry on this type of program.

A review of theoretical considerations respecting safety incentive programs is provided. Forty trucking companies across Canada are interviewed regarding their use of incentive programs, and findings of the interviews summarized. Guidelines for developing and evaluating safety incentive programs are provided along with a series of factors for enhancing the effectiveness of these programs.

A two-year pilot program is recommended to develop and validate a procedures manual for companies to follow when designing, implementing and administering a safety incentive program. This would include detailed benefit-cost analyses of these programs within a minimum of four trucking companies. A nationwide recognition-based incentive program is recommended. The framework and organizational structure for this program would be developed as part of the pilot program.

Industry Sector: Long-haul trucking in Canada

Purpose: The purpose of both articles was to identify what programs are currently in place in the industry, their strengths and weaknesses, and make recommendations for adopting industry best-practices.

[b]This article also documents the results of three pilot tests of a manual developed to help motor carriers design and implement incentive programs.

Sample: 40 Canadian-based firms, including companies of various sizes and types (private for-hire, LTL, and bulk).

Methodology: [a]The authors initially conducted on-site personal interviews at 40 carriers. Managers were interviewed at all 40 firms, while drivers were interviewed at 2 of the firms and at 1 truck stop.

[b]The results were later compiled into a manual describing the implementation of successful incentive programs. The manual was evaluated in a pilot study of three different carriers that implemented safety, driver retention, performance and fuel economy programs. The pilot studies documented the implementation steps taken by each company and assessed their success. Results were used to further develop the incentive program implementation manual.

Relevant Findings: Safety technologies and vehicle engineering provide the tools needed to drive safely. Safety training provides the knowledge to drive safely. Incentive programs then provide the motivation to use safety technologies, tools, and knowledge. It is necessary to use incentives, education, and safety engineering in conjunction with each other in order to produce positive safety outcomes. Incentive programs can be effective at improving safety, with some motor carriers achieving reductions in negative safety events of up to 80% when combined with safety engineering and training. Motor carriers recoup the costs of incentive programs through reduced crash rates and rebates on reduced insurance claims. In the literature reviewed by the authors of both studies, the majority of motor carriers that have evaluated their incentive programs report benefit-cost ratios exceeding two to one.

However, motor carriers lack a reference point for developing incentive programs. Thus, many are unable to implement successful programs. Existing programs vary widely in the type of reward given, the timing of the reward and reward eligibility. The authors list a number of criteria that must be met in order for an incentive program to be effective:

- Management must be committed to the program. A budget should be set aside and a coordinator and incentive planning team named. The firm should promote a strong safety culture among all employees.
- Incentives should be attainable and awarded fairly, of high perceived value, and increase with long-term performance. Recognition programs, such as driver of the year, are highly effective as an addition to a cash bonus.

- Graduated rewards tend to be more successful than all-or-nothing rewards.
- Management should evaluate the plan regularly for costs, benefits, and effectiveness. A successful incentive program changes over time and incorporates employee feedback. A time lag of about one year from the time a program is introduced or substantially modified should be expected for results to appear.
- The program must be clearly communicated to employees through an initial manual and regular follow-up communications.
- New drivers must be trained for safety habits.

The pilot study findings of one LTL carrier showed successful implementation of safety and driver retention programs. First, the company appointed a safety director who met with each employee. The company then implemented a bonus which all drivers received after six months, provided they had not been involved in an adverse safety event. This six month period was chosen because the majority of company turnover happens during the first six months of employment. After implementation, driver turnover for new employees fell from 98% to 20%. A recognition incentive, which was not specified, decreased adverse events by 35% per vehicle and per million vehicle mile. Other pilot studies have shown that incentive programs targeted at fuel economy, safety, or performance indirectly reduce turnover by increasing job satisfaction.

The authors also recommend an industry-wide, recognition-based safety program for both companies and drivers.

Limitations: Small sample size.

Categorization: These papers fit within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Incentive Programs, as these articles discuss the development and implementation of safety incentive guides and programs.

Dammen, S.J. (2005). The effects of safety practices, technology adoption, and firm characteristics on motor carrier safety. *Journal of the Transportation Research Forum, 44*, 103–20.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Safety Management Practices		

Author Abstract: The theory of the firm suggests that firms should maximize profit by investing in safety until marginal cost is equal to the marginal benefit. This paper addresses motor carrier safety from the perspective of the firm, developing the theoretical framework for firm safety decisions. Additionally, this paper tests the relationship between firm safety performance and safety practices, new safety technologies, and firm marketing strategies. By testing the impact of the safety performance marketing strategy on carrier accident rates, it can be shown that firm managers have control over the safety performance of their firms through management decisions.

Industry Sector: Trucking

Purpose: The purpose of this paper was to empirically evaluate the effect of firm safety practices, characteristics, and technology use on accident rates and to demonstrate that a motor carrier's management can impact the fleet's safety performance.

Sample: 516 Class I and Class II motor carriers.

Methodology: This study tested the effect of safety practices, technologies, and firm characteristics on carrier injury and fatality rates. Safety practices measured included safety meetings, firm speed limit, motorist "call-in" numbers, and apprenticeship training programs. The firm characteristics included size, LTL or TL industry sector, use of owner-operators, unionization, and marketing strategies that emphasize either on-time performance or safety performance. These practices and characteristics were analyzed in the context of the theory of the firm.

The theory of the firm broadly stipulates that firms are profit maximizers and make all decisions, including safety decisions, in order to maximize profit. Firms thus make investments in both safety and non-safety inputs to maximize the profit of their output. When making these decisions, they also face uncertainty, which in this model is the probability of having an

accident. The firms final profit is thus its revenue, less the cost of safety and non-safety inputs (such as wages), and less the cost of accidents.

The study uses firm-level data from the 1996 Motor Carrier Safety, Operations and Technology (MCSOTS) survey, and also from annual financial and operating statistics. Only Class I and Class II for-hire motor carriers were included in the study sample. [Reviewer note: As of January 1, 1994, the ICC defined Class I carriers as those establishments with annual revenues greater than $10 million, Class II carriers with annual revenues between $3 and $10 million, and Class III carriers with annual revenues of less than $3 million.] Data from the MCSOTS survey contained information regarding firm operating characteristics, safety practices, use of technology, and carrier safety performance. The technologies included for analysis were collision avoidance systems, automated vehicle diagnostics, and on-board computer monitors. Fatality and injury accident rates were taken from the SAFER system 1996 database. The SAFER system provided profiles of carriers' safety, and captured information regarding inspections, OOS rates, accidents, and their FMCSA safety rating. It was the precursor system to SafeStat.

Relevant Findings: As hypothesized, firms that utilized technology and safety practices had lower accident rates with fatalities and injuries, showing that managers can control the safety outcomes at their firms. The one unexpected result was that safety meetings were one type of safety practice that actually correlated with higher accident rates. One possible explanation for this result may be that firm safety meetings are an Occupational Safety and Health Administration (OSHA) work rule. Firms may implement the meetings to satisfy these regulations, even if they do not decrease the firm accident rate.

The most significant factors shown to affect a firm's accident rate were the firm's characteristics, particularly safety performance marketing strategies, use of owner-operators, and unionization. Unionized firms and firms that used owner-operators had significantly lower accident rates. Firm size was also shown to be inversely related to accident rate. LTL firms did not have an accident rate that differed statistically from that of TL firms. Unionized firms and firms with speed limit policies reduced their accident rate by roughly 30% relative to their peers. Collision avoidance systems were also shown to significantly reduce accident rates.

Limitations: Additional firm characteristics and safety practices, such as training and recruiting, should be added to the analysis, since their omission may bias the included variables. The firm characteristics and technology variables are all dichotomous variables; they indicate whether or not a firm uses a certain practice or technology, but not its use intensity or quality.

The author also acknowledges that the paper does not test for causality, and it is possible that firms with high accident rates adopt safety practices retroactively in order to decrease the future accident rate.

The study uses data from 1996. Since then, the role of LTL carriers and their share of the motor carrier industry have changed considerably.

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Management Practices. The premise of the paper is the assumption that firms impact their accident rate through safety management practices and safety technology adoption.

Dobie, K. & Glisson, L.M. (2005). *Investigation of the safety training of motor carrier drivers*. Greensboro, NC: Southeastern Transportation Center.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Safety Management Practices		

Author Abstract: No author abstract

Industry Sector: Trucking

Purpose: Researchers surveyed motor carrier managers and operators to examine the state of the relationship between on-going motor carrier safety training and reports from their respective drivers. The survey also assessed the benefits of training, with a goal of improving training programs, carrier safety and driver retention.

Sample: 60 motor carrier operators.

47 motor carrier managers.

Methodology: Researchers distributed tailored surveys each to motor carrier managers and drivers. The surveys solicited information regarding the current state of training within the motor carrier industry. Specifically, managers were asked about available training opportunities for their drivers, and operators were asked to provide information regarding the value they place on the different types of training available to them.

Relevant Findings: The types of training which drivers reported as being most useful and beneficial largely mapped to the training that motor carriers indicated would most benefit their organizations in terms of profits and competitive position. For instance, a vast majority of drivers and managers (86.7% and 93.6%, respectively) responded that training to keep drivers "up-to-date regarding laws and company rules" is important. Additionally, both agreed that training with respect to personal safety was important and desirable.

In general, although management and operators tended to agree regarding the information and skills training should provide, drivers did not uniformly indicate that availability of this training would persuade them to stay at a company. When asked, 50% of drivers reported that it did not matter whether or not the company they worked for offered training. Additionally, 73.3% of the drivers indicated that availability of training

would not affect their decision to stay at a company. This may be due to an apparent lack of tangible benefits for drivers as a result of training. With regard to financial compensation, 61.7% of drivers reported receiving no compensation for time spent in training, nor benefits with regard to pay, job assignments, route assignments, or promotions. Management responses corroborated driver perceptions. The authors concluded that without such incentives, it is clear as to why training opportunities alone are not enough to keep drivers at a company. Rather, participation in training must also benefit drivers in tangible ways, such as increased level of responsibility and pay.

Despite that motor carriers reported having instituted various programs to help improve their drivers' safety performance, the incidence of crashes involving large trucks increased between 2002 and 2003 according to the FMCSA. As a partial explanation, the authors suggested that driver turnover may be a confounding factor, in that potential benefits from targeted safety programs, as individually developed by carriers, are lost on drivers who leave their company before completing such programs.

Limitations: The suggested link among safety training, driver turnover, and FMCSA accident rates involving large trucks is speculative and was not systematically evaluated; as such, it must be interpreted with caution. Additionally, a small sample of convenience was used for this research and procedural details regarding methodology were not provided. As reported by the authors, the majority of drivers they received data from were owner/operators.

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Management Practices, as this study assessed the state of safety training programs in the trucking industry.

LaMere, J.M., Dickinson, A.M., Henry, M., & Henry, G. (1996). Effects of a multicomponent monetary incentive program on the performance of truck drivers: A longitudinal study. *Behavior Modification, 20*, 385–405.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Incentive Programs		

Author Abstract: A multiple-baseline experimental design across two groups was used to examine the effects of a multi-component individual system on the performance, safety, and satisfaction of 22 truck drivers. The intervention included incentive pay, which was increased twice; individual and group feedback; and loss of incentive pay for accidents. Drivers earned points for completing various types of jobs. The primary measure was the percentage of job points earned in less time than the baseline average, which controlled for number of hours worked and miles driven. After intervention, performance increased and remained high for nearly 4 years. Accidents did not increase when the intervention occurred, and satisfaction with pay and work were not affected by it. Labor cost savings averaged more than $5,000 a month while the incentive program was in effect, and drivers' pay increased. These results add to the substantial literature on individual incentives by documenting increased productivity sustained over a long period without accompanying increases in accidents or decreases in workers' satisfaction.

Industry Sector: Waste disposal trucking

Purpose: Researchers were asked by a waste management company to develop an incentive system that would increase driver productivity without increasing accidents or producing driver dissatisfaction. The study also sought to examine the long-term effects of performance incentives.

Sample: 22 drivers at a single waste management company.

Methodology: The incentive program was implemented over the course of 78 weeks with follow-up data collected during an additional 116-week period. Drivers were divided into two groups, with baseline data collected for both groups. The baseline period began on October 29, 1989 for both groups of drivers, and lasted 20 weeks for Group 1 and 34 weeks for Group 2. Thus, incentives for Group 1 began 14 weeks prior to the incentives for Group 2. Both groups were first observed for 20 weeks in order to obtain baseline

data. This data provided information across time and between the two groups.

Incentive-based pay was increased during two phases, first by 92% and then by 57%. The incentive program did not change the drivers' base pay, which was equal among all drivers at the beginning of the study. Drivers received awards when their weekly performance exceeded the baseline average. Performance was measured as a ratio of "job points" (the number of jobs weighed by job type) to the number of hours worked, given the number of miles driven. However, drivers lost their week's award if they had a chargeable accident, defined as accidents in which the driver was found at fault by either police or management. This was done to discourage improving productivity at the expense of safety. Drivers were taught to record and calculate their own performance, which supervisors later verified.

Researchers then compared the number of chargeable accidents for the same time period of October 8 through March 17 during the baseline and one year later during the first incentive increase phase. Only changes in productivity, measured as the number of "job points" completed per day given miles driven, were closely compared to the baseline in the second phase. Changes in chargeable accidents were not analyzed. Net labor cost savings were calculated on a weekly basis during the incentive phases. Labor cost savings resulted from more work being done in the same amount of time. The data was analyzed using an ANOVA.

Relevant Findings: The percentage of jobs completed, given number of miles driven, increased with the introduction of incentives relative to the baseline. Thus, drivers were completing more jobs given the number of miles driven in the same amount of time as before the incentives were implemented. The increase was substantial during the initial introduction of incentives, though subsequent raises in the reward rate did not produce a statistically significant effect on productivity. Nevertheless, the increase in productivity resulting from the first introduction of incentives was sustained over a period of four years.

Since drivers were paid per hour, the company also saw labor cost savings, which were larger than the cost of the incentive program. The company had a return on investment (ROI) ratio of 2.8 during the first incentive phase, meaning that for every dollar invested in the incentive program, the company saved $2.80 in labor costs and increased business.

Three fewer accidents were reported during the incentive phase than during the baseline period, but the authors did not calculate the change in accident rates. There were no statistically significant changes in the level of job satisfaction.

Carefully designed incentive programs have the ability to increase productivity without diminishing safety performance. In this study, a safety incentive was built into the productivity incentive. Drivers were active participants in program design, implementation, and operation.

Limitations: This paper documents the implementation of one successful incentive program. Although many of the features of this specific program may be transferable to other trucking companies, in all likelihood, incentive programs need to be tailored to fit the unique characteristics of each organization.

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Incentive Programs, because the study evaluates changes to accident rate and job productivity after the introduction of incentives.

[a]Mejza, M.C., Barnard, R.E., Corsi, T.M., & Keane, T. (2003). Driver management practices of motor carriers with high compliance and safety performance. *Transportation Journal, 42*, 16–29.

[b]Corsi, T.M., & Barnard, R.E. (2003). *Best highway safety practices: A survey about safety management practices among the safest motor carriers*. Washington, D.C.: Federal Motor Carrier Safety Administration: Data Analysis Division.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Safety Management Practices		

Author Abstract: [a]This article reports findings from a survey conducted in order to characterize the driver management practices of trucking companies that are recognized as being among the safest companies in the motor carrier industry. Using primary data collected from a geographically stratified judgment sample of the safest U.S. motor carriers, we present observations and analysis of aspects of the driver hiring, driver training, and driver reinforcement activities of the "best safety performers" in the trucking industry. The findings imply that the safest trucking firms apply screening criteria consistently in all driver-hiring situations; emphasize pre-service and in-service training for company drivers and owner-operators alike; cover a broad scope of topics in several venues during their training programs and use several methods to evaluate drivers in those programs; and use an array of different types of rewards to support drivers who demonstrate safe driving performance. The information developed in this study could be useful to managers of new entrant carriers who are still developing their safety management programs, to managers of established carriers who might wish to compare or benchmark their existing driver hiring, training, and reinforcement practices to those of the safest trucking companies, and finally, to public safety agencies that might use the results as input to the development of educational components of their motor carrier safety programs.

[b]No author abstract

Industry Sector: Freight trucking

Purpose: [ab]These studies sought to address the lack of data regarding carrier management practices, as this has hampered past studies of carrier safety. Unlike data on carrier safety performance or compliance, data on management practices is more limited. The authors thus sought to

systematically characterize the safety management programs and policies of the best performing carriers so that other carriers and regulators will have a point of reference when designing their own programs and policies.

Sample: [ab]148 freight carriers from the 48 continental states. The sampled group was heterogeneous in size and commodity carried.

Methodology: The papers in this annotation report on the same study. The Mejza et al. (2003) paper is a shortened version that covers only driver-related management policies. The Corsi and Barnard (2003) report includes survey results on vehicle-related management policies as well as a detailed appendix on the questionnaire and survey results.

[ab]The authors used a three-stage process to select the "best performing" motor carriers in each continental state. First, the authors used FMCSA's September 2000 SafeStat compilation to divide carriers into 12 commodity categories, with 3 equal-sized groups within each commodity category. The carriers in each commodity and size group were rank ordered from best to worst, based on the sum of their scores for the following SafeStat performance indicators: temporary accident involvement indicator, temporary vehicle inspection indicator, and temporary driver inspection indicator. The 20 safest large, and the 20 safest medium-sized carriers in each commodity group were then selected for a total of 440 freight and 40 passenger carriers. Second, these selected carriers were grouped by state, and lists consisting of 10 firms each were sent to their respective state safety directors, who then selected four freight and one passenger carrier for administration of the questionnaire. Safety directors were also given the choice to select carriers not on the original list of 10 firms. The authors then surveyed those motor carriers, receiving usable responses from 148 freight carriers.

The survey assessed three driver-related activities that managers perform, to varying degrees, in an attempt to improve their firm's safety outcomes. The three areas were selection, training, and reinforcement.

[b]The survey also asked managers about their general attitudes towards safety and the safety culture at each firm, but the results of these questions was reported only in the second study. In addition, the practices of the responding carriers were examined based on size to determine if management practices differed for large, medium, and small firms. Researchers segmented, by size, the responding 148 firms into three groups, with the smallest group comprised of firms with less than 25 power units, the medium group having between 25 and 94 power units, and the largest group having 95 or more power units. Each size group contained 33% of the responding firms. Results in the second study are reported based on these size delineations.

Relevant Findings: [ab]The safest firms, as identified by these studies, strongly and widely exhibited three main driver-related management practices. The first was driver selection. These firms chose drivers without prior alcohol or drug-related violations, without chargeable crashes, without speeding tickets and traffic violations and with driving experience. Over 90% of the firms used drug testing, past traffic records, on-road tests, and license qualification checks to assess potential hires. The same criteria were applied to owner-operators, although only one third of surveyed firms actually considered owner-operators for employment. Age was a significant consideration only when contracting with owner-operators. So, motor carriers were more willing to hire employees than owner-operators between the ages of 21 and 25, as long as they had a good driving record, recommendations, and adequate driving experience.

The second driver-related management practice was driver training. Most firms required both pre-service and in-service training. The five most popular training topics were reported as HOS regulations, pre-trip inspection, accident notification, federal safety regulations, and post-trip inspections. The carriers reported using a combination of classroom, on-road vehicle, and off-road vehicle training. Most carriers reported utilizing both written or oral examinations and in-vehicle tests. Computer evaluations were reported to be used less frequently.

The third driver-related management practice most commonly utilized by the firms in this study was reinforcement. The most commonly reported safety incentives were recognition rewards, such as letters or plaques. Two thirds of the companies reported giving cash rewards, and the majority utilized a combination of both recognition and compensation rewards. Most rewards were given after a driver was accident-free for a specified time period. It is evident that safe motor carriers have strict selection criteria, multi-faceted training, and broad safety incentive programs.

The surveyed firms also indicated a dedication to deploying a defect-free fleet, with over 80% reporting that they rarely need to conduct unscheduled maintenance as a direct result of their strict preventive maintenance policies. A majority of the firms used computerized equipment maintenance, although less than one fourth of the smaller firms reported investing in such systems. Maintenance schedules were typically time-based and frequent, depending on the part of the truck being maintained. For example, brakes are maintained on average every 10,000 miles by the majority of the carriers.

[b]The respondents to this survey also reported using disciplinary actions as repercussions for safety violations, with larger carriers being more likely to terminate or suspend than smaller carriers. Researchers also found that,

regardless of firm size, many of the surveyed firms monitored their drivers using various technologies. The most common were speed regulators and engine diagnostics.

Larger carriers were more likely to utilize strict selection criteria, conduct thorough training, and offer incentives to drivers than were smaller firms. For example, a higher percentage of large carriers reported hiring drivers only over the age of 25, requiring driving experience with other carriers and a lack of prior speeding tickets. A higher percentage of large firms also performed license qualification checks, required both pre-service and in-service training, and provided individual driver safety incentives. Although the percentages were higher for large firms, over 50% of best performing carriers in all size categories demonstrated strict selection criteria, thorough training, and the use of incentives.

Limitations:

[ab]These papers did not test for causation or significance. It is unclear whether the practices identified in this study lead to safer motor carriers, or if other, unidentified, factors contribute to the safety rankings of these firms. As these papers report only on a characterization study, the authors recommend that similar data be collected, compared, and tested for statistically significant differences between the practices of the safest motor carriers to the practices of less-safe carriers.

Categorization:

These papers fit within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Management Practices, taking a holistic approach in considering a broad range of factors that motor carriers employ to improve safety. This includes driver selection, retention, and reinforcement practices.

Mejza, M.M., & Corsi, T.M. (1999). Assessing motor carrier potential for improving safety processes. *Transportation Journal, 38*, 36–50.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Safety Management Practices		

Author Abstract: No author abstract

Industry Sector: Trucking

Purpose: The majority of federal programs seek to identify the riskiest motor carriers by evaluating negative safety outcomes. The purpose of this study was to develop a technique for identifying positive safety outcomes as well as the management practices that led to them. These identified practices can then be used to improve safety at problem carriers.

Sample: 52 Class I carriers and 41 Class II carriers.

Methodology: Motor carrier safety was modeled as a process with a set of safety inputs that are used to generate safety-related outcomes. Inputs were vehicle and driver safety management activities and outputs were defined as driver and vehicle compliance with Federal Motor Carrier Safety Regulations (FMCSR). Management inputs were categorized into planning, implementation, and control, taken from the ATA's 1995 Motor Carrier Annual Report for Class I and Class II freight carriers. Inputs included driver compensation, driver exposure, vehicle exposure, and vehicle servicing. Safety-outputs were taken from SafeStat.

These inputs and outputs were then used in a linear programming technique called data envelopment analysis (DEA). The model in this paper measured compliance efficiency relative to the performance of other motor carriers in the sample by determining the maximum levels of output (compliance) that motor carriers could have achieved from the management inputs that were utilized. Motor carriers in the sample were ranked according to their efficiency scores, slack (the difference between potential and observed output given a set of inputs), and excess values (the amount of inputs used in excess of the amount necessary to achieve a given level of output).

Relevant Findings: The study does not identify specific management practices that lead to either good or poor performance. Instead, the authors demonstrate a model

that can provide a basis for regulators to identify the best and worst performing carriers, for carriers to develop carrier-specific safety improvement objectives, and for carriers and shippers to facilitate the carrier selection decision.

Rankings resulting from a DEA model can be used by regulators to identify best and worst performing motor carriers and to develop benchmarks. The DEA model in this paper identified 27 carriers as having achieved maximal compliance with both vehicle and driver regulations in an efficient manner relative to their combination of safety inputs. The paper also demonstrated how to measure the degree of underperformance for inefficient carriers relative to their efficient peers.

Limitations: Data were not available for the authors to include driver training, driver reinforcement, and vehicle evaluations performed by motor carriers as variables in the DEA model. Other variables used in the model were proxy variables. For example, driver compensation was used as a proxy for driver skill under the assumption that drivers with more skill receive higher pay.

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Management Practices. The study takes a holistic approach in considering a broad range of factors that motor carriers employ to improve safety, including driver selection, retention, and reinforcement practices.

Naveh, E., Marcus, A., & Allen, G. (2003). *ISO 9000's effects on accident reduction in the U.S. motor carrier industry* (Publication No. MN/RC 2003-29). University of Minnesota, Minneapolis; Minnesota Department of Transportation.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Safety Management Practices		

Author Abstract: This report aims at establishing a correlation between the voluntary ISO 9000 certification by motor carriers and traffic safety. The report shows that improvement of operating and quality performance improved safety performance. As part of the analysis, several ISO 9000 certified and non-certified motor carrier companies were compared based on their social and financial performance prior to, during and after the certification process. The authors have shown that there is a positive increase in performance during and after the certification process. The number of motor carrier companies certified by ISO 9000 is limited and unique. The uniqueness arises from the fact that the certified organizations haul specialized products such as automobiles and hazardous materials. That shows that most organizations are certified due to mandatory reasons.

In conclusion, the observations and results have thrown light in a new direction that indicates that there exists a significant relationship between the quality assurance and safety performance of a motor carrier organization. The authors feel that further research is necessary to investigate the circumstances under which ISO 9000 and other programs for upgrading motor carrier performance help lead to an increase in safety.

Industry Sector: Specialized trucking (trucks over 10,000 pounds in gross vehicle weight rating)

Purpose: The purpose of this study was to see if a voluntary ISO-9000 certification program, or a similar program, can complement safety regulation and contribute to an improvement in motor carrier safety.

Sample: 40 ISO-9000 certified U.S. motor carriers and 20 similar, non-certified U.S. motor carriers.

Methodology: ISO-9000 certification is a set of audited quality assurance standards covering service, processes, and delivery that allow customers to choose certified suppliers. For the motor carrier industry, the practices include driver hiring, licensing procedures, work hours, training, safety programs, and driver and vehicle monitoring.

The study compared certified and uncertified motor carriers. McGraw-Hill provided the list of ISO-9000 certified carriers, from which 40 were selected. Twenty uncertified carriers were chosen that were similar to the certified carriers with respect to miles driven and goods hauled. The return on assets (ROA) ratio was chosen as the independent variable. The ratio was taken from the ATA data set, which includes financial data on all U.S. motor carriers. The US-DOT SAFER data set provided the dependent variables which included safety performance data, the number of injuries, fatalities and tow accidents. Driver, vehicle, and management SafeStat scores were also used as control variables. Data was taken from a five year period, with two years prior to ISO registration, one year during ISO registration and two years after ISO registration. The authors also performed a more in-depth case study of a single hazmat carrier.

Relevant Findings: The results show that ISO 9000-certified carriers had significantly better safety performance, as measured by number of accidents, than similar carriers without this certification. The study also found that a carrier's profitability, as measured by its ROA ratio, is highly correlated with a good safety record. Firms that became ISO 9000-certified improved both their safety and financial performance.

As a component of this research, the in-depth case study of a hazmat hauler revealed that the company was under pressure from its insurer to reduce accident rates or face higher fees. It was already implementing safety changes prior to beginning the certification process including driver background checks, additional training, performance monitoring and the establishment of safety goals and a safety committee. To become certified, the company involved employees in the production of a safety and operations manual. The company thus used ISO-9000 certification as part of a broader commitment to a safety culture.

Limitations: The performance of the certified firms may, however, differ from their peers for other reasons. These firms tended to be automobile or hazardous materials haulers, and early adopters of the certification. In addition, the reason that firms seek certification is important, since voluntary certification indicates a desire to improve performance in a verifiable manner. Mandatory certification may not produce the same positive results on safety and performance. The conditions under which certification has the ability to enhance safety need to be further investigated.

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Management Practices. The study examined the effect of voluntary quality certification on safety and performance.

Shaw, J.D., Gupta, N., & Delery, J.E. (2002). Pay dispersion and workforce performance: Moderating effects of incentives and interdependence. *Strategic Management Journal, 23*, 491–512.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Incentive Programs		

Author Abstract: The compensation literature is replete with arguments, but lacking in empirical tests, regarding the effects of pay dispersion on organizational outcomes. Pay dispersion may increase effort and provide incentives for high workforce performance levels, but may also inhibit cooperation and goal orientation among employees. Drawing on several theoretical perspectives (individual motivation, institutional theory, organizational justice, and neoclassical economics), this study predicts that pay dispersion will be associated with higher levels of workforce performance when accompanied by formal individual incentive systems and independent work, while pay compression is desirable in the absence of individual incentive systems and when work is interdependent. Survey research studies in two industrial sectors (the motor carrier and concrete pipe industries) were conducted to address these issues. Interactive regression results were generally supportive of the predictions across several measures of workforce performance (accident rates, safety violations, and productivity). Implications of these studies for strategy implementation in terms of compensation theory and practice are addressed.

Industry Sector: Trucking

Purpose: The purpose of this study was to explore the fit between an organization's compensation structure and its business strategy and performance. In particular, the authors tested the effects of compressed and dispersed compensation structures on organizations. In a compressed structure, salaries do not vary greatly among employees across positions, as opposed to a dispersed structure where compensation can vary widely. Previous studies have found conflicting results, showing that pay dispersion can both benefit and hurt worker performance. The authors performed this study to show that the effect that dispersion has on productivity depends on whether incentives are targeted at individuals or teams, and on whether the nature of the work performed by employees is independent or interdependent.

Sample: 379 trucking firms with more than 30 employee drivers per company.

Methodology: This study focused on the effect of horizontal pay dispersion (the degree of difference in pay within a group of employees at the same level) on workforce performance, as opposed to vertical pay dispersion (the degree of difference in pay among employees at different levels of an organization). To measure the effect the authors use two empirical case studies.

The study used the TTS Blue Book of Trucking Companies data gathered between the years 1994 and 1995 to select motor carriers with more than 30 company drivers. The heads of HR at the chosen firms were surveyed about driver compensation practices, and 379 replied. Organization and financial data were taken from the Blue Book and safety data were taken from SAFER (the precursor to SafeStat). Independent variables resulting from this data include pay dispersion (difference between the annual pay of new hires and the annual pay of senior drivers) and four types of individual incentives such as on-the-spot bonuses for exceptional performance, and the use of a merit pay system. The dependent variables were the accident frequency ratio, driver-related OOS percentage, and a company's relative performance as measured by on-time deliveries, on-time pick-ups, and other measures over which the driver has at least partial control. Control variables included company size, company age as determined by year founded, percent of drivers unionized, carrier type (i.e., TL or LTL), driver tenure (i.e., percentage of drivers employed at the company for more than 24 months), the extent to which pay is based on seniority, average annual pay level, level of communication about pay at the company, and the average value of benefits paid by the company.

The second study performed similar regression analysis on the concrete pipe production workers; however, as its sample falls outside the scope of this review, results will not focus on this study.

Relevant Findings: The use of individual incentives and dispersed wages was associated with better performance in an organization environment where work was independent (i.e., the trucking industry). Workers can perceive the existence of wide differences in pay as a motivating factor, as long as the differences result from fair and consistent management policies.

This study of the motor carrier industry revealed that accident rates can be explained by the interaction between individual incentives and pay dispersion. The accident frequency ratio was lowest when individual incentives were high, but especially with high pay dispersion. The highest accident rates were seen when pay was dispersed, but individual incentives were low. Thus, dispersed pay was not a motivating factor for drivers because it did not result from the presence of individual incentives.

The same pattern was seen with the percentage of driver-related OOS occurrences. Driver-related OOS rates were lowest in the presence of wage differences together with the use of individual incentives. However, company performance variables had a negative relationship with pay dispersion. Performance was always better with compressed wages than with dispersed wages. However, company performance was better if dispersed wages were used with individual incentives than when dispersed wages were not accompanied by individual incentives.

Limitations: The authors do not explore the effect of pay progression over time on motivation and workforce performance. Studies have shown that workers compare their income to that of their colleagues and to their past income. Some of the negative effects of pay dispersion can be offset for an individual worker by growth in his/her compensation over time. In addition, it is unclear whether drivers at each of the carriers sampled were paid by the mile or by the hour, as pay dispersion was calculated using average annual earnings for entry-level and senior drivers. It would be interesting to examine whether the effects of pay dispersion differ based on method of payment (i.e., by mile, hour, or another method, such as revenue-based pay).

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Incentive Programs. The study primarily looked at the effect of incentives on organizational performance and used the motor carrier industry as one case study, where safety is a performance measure.

Wright, I.D., Veith, G., & Tsolakis, D. (2005). *Productivity implications of heavy vehicle safety programs* (Austroads Publication No. Ap-R263/05). Austroads.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment	Safety Management Practices		

Author Abstract: No author abstract

Industry Sector: Trucking in Australia

Purpose: This study evaluated the information available through previous literature and company evaluations regarding the link between safety programs and productivity. The purpose is both to report available information and to identify data gaps.

Sample: 12 Australian companies provided information on their safety programs for a total of 20 different firm safety programs.

Methodology: The authors first performed a literature review to identify studies that link motor carrier productivity and safety programs. The authors then contacted companies to identify those with safety programs. Managers at twelve companies were interviewed in person with the aid of a questionnaire. All companies provided a qualitative assessment of their safety programs and associated costs and benefits. Only a few companies were able to provide a limited amount of quantitative data, showing that rigorous safety program evaluation is lacking among Australian motor carriers.

Relevant Findings: The literature review showed that the incentive programs developed by the Canadian Safety Council were the only programs where the relationship between productivity and safety had been comprehensively evaluated. Australian firms and state road transport agencies have implemented the Trucksafe and National Heavy Vehicle Accreditation Schemes, respectively. Both of these recent programs are truck driver accreditation schemes, and neither program had been systematically evaluated at the time of this study.

Three of the 12 companies examined in this study had a fatigue management program, half focus on driver training, drug testing, and medical examinations, and three companies had systematic driver selection procedures. Half of the 12 companies conducted drug tests and

medical examination on current drivers and provided driver training. Companies also reported encouraging driver involvement in vehicle selection, vehicle management, and maintenance.

Interviews and surveys revealed significant gaps in data on the costs, benefits, and effectiveness of safety programs. Trucking firms in Australia are not collecting extensive quantitative data on their programs. It is therefore not possible to draw authoritative conclusions from the data collected. However, the authors report all qualitative information gathered during the interviews as a case study of each of the 12 firms.

Of the qualitative benefits reported, nine companies claimed overall improved safety. All of these companies had a considerable degree of similarity across some of their programs, particularly in relation to the benefits of employee selection, induction, and training. There were also similarities with regard to utilizing employee knowledge and input to improve vehicle selection and maintenance. Firms that encouraged involvement of their workers in vehicle management, including selection and maintenance, reported lower maintenance costs, less accidents, and less time spent by drivers away from work due to injuries. Four companies experienced reduced insurance costs and improved vehicle utilization through less OOS time.

Limitations: The small sample size and lack of quantitative data prevented the authors from making firm conclusions. The purpose of this study, however, was to demonstrate the lack of data on the effect of safety programs on firm productivity.

In addition, the study only examined safety programs in Australia, thus any conclusions may only be generalizable to Australian carriers.

Categorization: This paper fits within the pre-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Management Practices. The paper analyzed the existence and benefits of safety programs used by Australian motor carriers.

Event

Driver Environment: How are driver behaviors related to event occurrence?

[a]af Wahlberg, A.E. (2000). The relation of acceleration force to traffic accident frequency: A pilot study. *Transportation Research Part F: Traffic Psychology and Behaviour, 3*, 29–38.

[b]af Wahlberg, A.E. (2004). The stability of driver acceleration behavior, and a replication of its relation to bus accidents. *Accident Analysis & Prevention, 36*, 83–92.

[c]af Wahlberg, A.E. (2006). Speed choice versus celeration behavior as traffic accident predictor. *Journal of Safety Research, 37*, 43–51.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment		Unsafe Driving Behaviors	
Motor Carrier Environment			

Author Abstract: [a]Acceleration- (g-) force and mean speed are measured onboard city buses in regular traffic. The means of Right/Left, Gas/Brake, the composite g-force and speed are correlated with drivers' frequency of (bus) accidents for different time periods. No stable relationship is found, only a weak tendency for the dimensions of mean speed and Right/Left to predict bus accidents when time periods of one to five years are used. The many problems inherent in this kind of field research are discussed and some remedies proposed.

[b]The reliability over time of a method for measuring driver acceleration behavior was tested on bus drivers in regular traffic. Also, a replication of an earlier finding of a correlation between driver acceleration behavior and accident frequency for the individual drivers was made. It was found that the split-half correlation is probably around 0.50 for the mean (of accelerations) of a 30-min drive, and similar for the test-retest of 2.5 h measured about a month apart. With such reliability, the sample was probably too small to reliably determine any association with accidents, but some significant correlations were found. Some ways of holding constant the differences in exposure and driving environment were tried with mixed success. Alternate ways of analyzing the data and several methodological problems were briefly discussed. It was concluded that the measurements of acceleration behavior, for bus drivers, are fairly reliable over at least a few months. However, some strange discrepancies between samples make all interpretations concerning the link to accidents tentative.

[c]*Introduction*: The driver celeration behavior theory predicts that this variable is superior to all other variables as a predictor of individual traffic accident involvement, including the ever-important speed parameter. [Reviewer note: celeration refers to speed variability during driving (i.e., speeding up and slowing down).] The study was undertaken to test this prediction. Also, it was expected that most variables would associate fairly strongly.
Method: The use of speed choice as a predictor of individual traffic accident record was discussed, and four different variants of this variable (maximum, net mean, gross mean, and standard deviation of speed) identified. These variables were then compared to celeration behavior as predictors of accident record of bus drivers in the same set of data.
Results: Celeration behavior was found to be slightly superior, in accordance with the prediction made from the driver celeration behavior theory, although the differences were not significant. Furthermore, the predictor variables were found to associate fairly strongly between themselves, with the exception of gross mean speed, and to have fair stability over time, especially when aggregated.
Conclusions: These results tentatively confirm some of the predictions made from the driver celeration behavior theory. As the results for accidents were in the expected direction, but not significant, and the maximum speed variable may have suffered from a ceiling effect, the conclusion is provisional.
Impact on industry: The correlations found were strong enough to warrant the use of celeration behavior as a predictive variable for transportation companies in their safety work.

Industry Sector: [abc]Transit bus industry in Sweden

Purpose: The purpose of this series of research studies was to determine if driver celeration behavior is related to, and can predict, accident frequency. The author stated that *g*-force is a measure of the force of acceleration, and that variability of driving, or celeration behavior, could be measured as the *g*-forces in a vehicle during a specified time. If greater variation in driving behavior results in more accidents, then celeration behavior, measured as *g*-force, should predict accident frequency. Thus, the primary hypothesis tested by these studies was that drivers with a higher past frequency of accidents will tend to have higher values of *g*-force. Each study expanded upon the previous to develop and test this theory of celeration behavior.

Sample: [a]47 bus drivers with at least 2 years of service.

[b]125 bus drivers.

[c]203 bus drivers.

Methodology:

[a]For the first study, vehicle *g*-force was measured using a *g*-analyst that measures acceleration forces in two dimensions: longitudinal (Gas/Brake) and lateral (Right/Left). These two variables were used to calculate the Resultant *g*-force variable, which was used as the indicator of celeration behavior. The *g*-analyst consisted of a transducer and control unit contained in a case. A researcher, whose identity was unknown to the driver, entered the bus and placed the case on the floor at the rear of the bus, unpacking the control unit. Measurements were made unobtrusively as the drivers worked their normal routes.

Accident data for the participants were collected from accident reports filed during the years 1994–1998 at Gamla Uppsalabuss, the drivers' employer. The accidents for each driver were converted to a frequency by dividing them by the number of years the driver had been in service during this period. Thus, there was one frequency for each of the resulting four time periods (1994-1998, 1995-1998, 1996-1998, and 1997-1998) for each driver.

[b]This study used a larger sample of bus drivers and the same methods for collecting celeration behavior as the 2000 study. Accident data were obtained from accident reports during 1998 through 2001, and an accident rate, or frequency, for each driver was again calculated.

[c]This study measured driver behavior continuously and repeatedly from August 2001 through March 2004, with the exception of the summer of 2003, for technical reasons. In addition, four other variants of speed choice (net mean, gross mean, maximum, and standard deviation) were measured to determine which variable was a superior predictor of accidents. Only incidents where the driver was deemed to be at least partly at fault were included in the dependent variable. Statistical relationships between accidents and speed behavior were determined by Pearson correlations.

Relevant Findings:

[a]No consistent relationships were found between the three acceleration force variables and accidents. The main conclusion that was drawn from this pilot study was that such a small sample of drivers is too unstable for the use of acceleration force and speed variables.

[b]For the drivers who worked the entire period from 1997 to 2001, it was found that, among driver demographic variables, only hours worked had a significant association with crashes. Contrary to previous studies, mean speed had no significant correlation with accidents, when adjusted for hours worked. Two possible explanations for this result were suggested: either the sample was too small to detect this effect, or the urban driving environment did not allow for large enough mean speed differences between drivers for a significant association.

[c]The results revealed that, as predicted, celeration behavior yielded a higher mean correlation with accident frequency than the other speed variables. However, these differences were very small and not statistically significant. The author asserts, however, that doubling the sample size would have yielded significant results at $p < 0.05$. Additionally, findings remain inconclusive regarding the main predictions since the celeration variable was not optimally measured due to equipment malfunctions (i.e., only longitudinal acceleration was used as an approximation of the theoretical parameter).

Although all the speed variables analyzed in this study were very similar as predictors of accidents, celeration behavior was found to be slightly superior. The author was careful to point out that these results do not suggest that speed is not a major cause of accidents; instead, he concludes that the normally used speed variables, such as mean and maximum speed, are not better predictors of accidents on the individual level as compared to celeration behavior.

Limitations:

[abc]Although the celeration behavior theory predicts the type of relationship observed in this study for all types of drivers and vehicles, the data used here may only be valid for the population from which the subjects came, namely city bus drivers. Mean speed is low and maximum speed is limited in urban transit operations, as buses run on city streets and must stop regularly for passengers.

Two additional limitations concern the use of accidents as a dependent variable for predictions from behavior variables. First, accidents are rare events; furthermore, they are often underreported. These features of accidents may result in large error variances and thus low statistical power in the analysis. Secondly, no optimal time period has been identified to use in the calculation of accident frequencies, although reliability tends to increase over longer time periods. Although the use of a longer time period for calculating accident frequency provides a more reliable measure, it also results in a shrinking sample, since, as the author notes, few bus drivers remain at one company for long periods of time (say, more than five years). The statistical power gained by the longer time periods is therefore offset by a smaller sample.

Categorization:

These studies fit within the event timeframe of the driver environment for Haddon Matrix #2: Unsafe Driving Behaviors, as the research focused on establishing a positive relationship between driver acceleration behavior and traffic accident frequency.

Hanowski, R.J., Perez, M.A., & Dingus, T.A. (2005). Driver distraction in long-haul truck drivers. *Transportation Research: Part F Traffic Psychology and Behaviour, 8*, 441–458.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment		Unsafe Driving Behaviors	
Motor Carrier Environment			

Author Abstract: Research on driver distraction has typically been conducted by means of epidemiology or experimental testing. The study presented here uses a naturalistic approach, where real-world driving data were collected from truck drivers as they worked their normal delivery runs. Crash, near-crash, and crash-relevant conflict data from 41 long-haul truck drivers, driving approximately 140,000 miles, were examined. Of the 2,737 crashes, near-crashes, and crash-relevant conflicts (collectively termed "critical incidents") that were recorded, 178 were attributed to "driver distraction." The 178 distraction-related critical incidents were analyzed and 34 unique distraction types were identified. Results showed that a small number of long-haul drivers were involved in a disproportionate number of distraction-related critical incidents. For example, two of the drivers accounted for 43 of the 178 distraction incidents. Important insight was also gained into the relative safety impacts of different distracting agents and behaviors. The frequency and duration of a task, along with the visual demand associated with performing the task, were found to contribute in combination to the prevalence of critical incidents. Finally, it was found that simply because a task does not necessarily require visual attention does not mean that long-haul drivers will not look (sometimes often) away from the roadway. However, it is also clear that visually demanding tasks carry the highest degree of risk, relative to other categories of tasks.

Industry Sector: Long-haul trucking

Purpose: The purpose of this study was to examine the driving of long-haul truckers using a naturalistic approach, with the goal of identifying critical incidents (crashes, near-crashes, and crash-relevant conflicts) related to distraction. These distraction-related incidents were described in terms of the way that they clustered into groups based on frequency and duration (i.e., event duration and eyes-off-road time). Additionally, various tasks were examined for associated risk depending on their time demand, visual demand, and frequency of occurrence.

Sample: 33 long-haul truck drivers who were involved in distraction-related critical incidents.

Methodology:

The sample consisted of data from a subset of long-haul truck drivers used in previous research conducted by Dingus, et al. (*Sleeper Berth* study, 2002). The original sample contained 41 drivers.

Data were gathered naturalistically during driving using two tractors instrumented for data-collection purposes. Due to the length of driver runs (6-10 days in duration), continuous data recording was not possible. Rather, data were selected for retention and analysis based on a high probability of surrounding a critical incident (e.g., pre-determined thresholds for unusually high lateral and longitudinal acceleration, short time-to-collision, and incomplete lane changes).

The flagged video and electronic data were subsequently reviewed by a trained data analyst to determine whether they did, in fact, surround a valid critical incident. Researchers defined three types of incidents as valid for this study: crash, defined as any incident where the truck came in contact with another vehicle, fixed object, pedestrian, or animal; near-crash, defined as any conflict with another vehicle, fixed object, pedestrian, or animal that required a rapid maneuver to avoid it; and crash-relevant conflict, defined as a conflict or driver error that resulted in an unsafe scenario but did not require an evasive maneuver to avoid it.

Incident types were assigned to each clip surrounding an incident, as were primary causes of the incident. Data analysts assigned one of three main cause categories to each. "Judgment error" was defined as any error made by the driver, such as following too closely. "Other vehicle" causes were assigned when the driver of another vehicle was deemed to have initiated the accident. Lastly, "driver distraction" was cited as the cause when the driver had been engaged in an activity not related to his or her primary driving duties, such as talking on a cell phone. This process identified 178 distraction events; subsequently, the cause of the distraction was determined. Additionally, events were classified based on driver demographics and other between-driver factors (e.g., single vs. team driving).

As a second step, researchers analyzed the data to determine exposure criteria for assessing relative risk among the various distraction clips. However, because the events recorded were triggered, traditional exposure estimates were not possible. Without the ability to generate accurate base rates, it was necessary to consider data on the time exposure required by a task instead. Time exposure was estimated using the mean amount of time it took to finish the distraction task (estimate of overall exposure) and the mean amount of time a driver's eyes were off the forward roadway while performing the task (estimate of exposure relative to the risk the task presented).

Finally, eye-glance analyses were conducted using 20-second epochs surrounding the event trigger (10 seconds prior and 10 seconds after an event). Analysts recorded driver glance locations and lengths, which were used to determine mean and maximum glance durations, as well as the proportion of time the driver spent with his or her eyes off the road.

Relevant Findings: The distribution of the types of 178 critical incidents attributed to the driver was highly non-normal: no crashes were recorded; six distraction events did not contain a kinematics trigger because they were part of time-triggered baseline data collection; one event was considered a near crash; and the remaining events were determined to be crash-relevant conflicts. For this reason, no further distinction was made regarding event severity and incidents were considered collectively.

Further investigation of the data determined that two drivers alone accounted for approximately 24% of the recorded distraction incidents. This is consistent with previous findings of a small number of drivers contributing to a large number of incidents (Hanowski, Wierwille, Garness, & Dingus, 2000). While this degree of over-representation is astonishing, the authors did not provide any further analyses pertaining to these two drivers specifically. Further, the distribution of incidents among distraction types for these two drivers appeared similar to the overall distribution of incidents for the rest of the sample. [Reviewer note: findings showing a small number of people as accounting for a large proportion of safety incidents suggests that it may be worthwhile to focus on those who are most responsible (i.e., Pareto's Principle, also known as the 80/20 Rule)]. Similarly, although there was a nearly even split of team and single drivers, single drivers accounted for almost 65% of all incidents. As a possible explanation of this result, it was suggested that having a second person present in the truck cab may help avoid unsafe situations, rather than contribute to distraction. Age and gender differences were not considered, however.

Analysis of the incidents themselves established 34 unique distraction types contained within 7 distinct clusters; these tended to statistically separate based on duration and frequency. Additional analysis of the 20-second epochs surrounding events resulted in significant differences across clusters for the mean duration of a distracter and the proportion of eyes-off-road time. Generally, there was a large degree of variation in distracter duration, and this did not correspond with the relative frequency of events. Overall, Cluster 1 encompassed the majority of all events. The authors described these 121 incidents as those of "average frequency" and "average event duration," such as looking at the CB and lighting a cigarette. The remaining clusters contained incidents of varying degrees of frequency and duration, both event and eyes-off-road duration. High

frequency events, such as looking around or outside the cab to the left or right, were considered a safety risk independent of their duration and visual demand because the driver was frequently being inattentive to the driving task. Visually demanding tasks of short duration and lower frequency were considered a risk because they very much take the driver's eyes off the road, such as when reaching to the floor to pick up an object. Finally, some tasks were moderately high in terms of their duration, visual demands (eyes-off-road), and frequency. These are particularly concerning from a safety perspective and include activities such as talking on/adjusting the CB or talking on a cell phone.

Limitations: As acknowledged by the authors, a lack of continuously collected data meant that determining accurate levels of exposure was not possible. Further, it was not possible to establish the proportion of time where a particular task was performed and did *not* result in a critical incident.

Additionally, the data set appeared to be limited by two drivers accounting for nearly one quarter of all incidents. Given Pareto's Principle, the data provided by this small number of drivers contributing disproportionately to a safety risk is important to recognize; however, a larger sample would probably be helpful in establishing a less skewed distribution of incidents.

Categorization: This paper fits within the event timeframe of the driver environment for Haddon Matrix #2: Unsafe Driving Behaviors, as it investigates the manner in which performing tertiary tasks during driving is associated with a risk of being involved in a critical incident.

Sullman, M.J.M., Meadows, M.L., & Pajo, K.B. (2002). Aberrant driving behaviours amongst New Zealand truck drivers. *Transportation Research Part F: Traffic Psychology and Behaviour, 5*, 217–232.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment		Unsafe Driving Behaviors	
Motor Carrier Environment			

Author Abstract: Research using the driver behavior questionnaire (DBQ) has found that aberrant driving behaviors can be categorized into: errors, lapses and violations. There is also extensive evidence that it is only the "violations" score which is significantly correlated with, and predictive of, crash involvement. This consistency has been found both across different samples and different countries. However, recent research conducted on those driving cars in a work-related context has found a different factor structure and a different pattern of correlations with crash involvement. The present study extends this research by investigating the factor structure of the DBQ and the relationship between aberrant driving behavior and crash involvement for a sample of truck drivers. Factor analysis yielded a four factor solution, that broadly replicated the four hypothetical factors (errors, lapses, violations and aggressive violations) found in the general driving population. Only the violations factor was found to be significantly predictive of crash involvement. This research provides evidence of the robust nature of the DBQ findings in populations other than the drivers of private motor vehicles.

Industry Sector: Trucking in New Zealand

Purpose: The DBQ (Reason, Manstead, Stradling, Baxter, & Campbell, 1990) is a measure of aberrant driving behaviors typically used with motor vehicle drivers to assess driving behavior. The purpose of the current study was to administer the DBQ to a sample of truck drivers and investigate the pattern of responses for truck drivers as compared to previous research on motor vehicle drivers. In particular, the authors sought to establish a relationship between reported truck driver behaviors and previous crash involvement.

Sample: 378 truck drivers working for companies transporting logs, milk, and petrol in New Zealand.

Methodology: Fifty five transport companies were contacted to participate in the study. The transport companies were asked to distribute copies of the

questionnaire and a cover letter explaining the project to their drivers. Drivers were then asked to complete the questionnaire and return it to the researchers through the mail. As an incentive to participate, each driver that returned a survey was entered into a drawing to win one of three prizes, valued at $120, $50, or $30.

The questionnaire included demographic information (e.g., age, experience, and crash involvement in the past 3 years) and the 28-item version of the DBQ, asking drivers to indicate, on a 6-point scale from "never" to "all the time," how often they engage in each aberrant behavior. Example behaviors from the DBQ included: speed in a residential area; race away from traffic lights to beat another driver; hit someone when reversing that you had not seen; and brake too quickly on a slippery road or steer the wrong way into a skid.

Relevant Findings: The three most common aberrant driving behaviors reported by truck drivers were: Disregard the speed limit of the open road (mean = 1.45, SD = 1.26); sound your horn to indicate your annoyance with another road user (mean = 1.29, SD = 1.02); and become angered by a particular type of driver and indicate your hostility by whatever means you can (mean = 1.07, SD = 1.00).

The pattern of responses to the DBQ for truck drivers was similar to that of motor vehicle drivers. Analyses revealed four distinct groups of behaviors, similar to those found in previous research. The first group of behaviors was "errors," defined as driving mistakes involving failures of observation and misjudgment. The second group was labeled "lapses," and defined as problems with attention or memory. The third group was "violations," or deliberate deviations from practices believed to be necessary to safely operate a vehicle. The last group was labeled "aggressive violations," and defined as violations that also involved expressing hostility toward another road user or driving in an aggressive manner.

An examination of the correlations between driving behaviors and crash involvement over the previous three years revealed that those who reported being involved in a crash tended to have higher scores on violation behaviors. In addition, they were more likely to be young and have less experience driving trucks. Additional regression analyses suggested that drivers who reported higher levels of violations were 50% more likely to have been involved in a crash over the previous three years.

Limitations: There is some concern about social desirability affecting the responses to the self-report behaviors recorded in this study. Truck drivers may have underestimated their aberrant driving behaviors. However, the underestimation of behaviors would only result in under-estimates of real

associations, rather than over-estimates. Therefore, the relationship between driver violations and accident involvement may be stronger than documented in this study.

Categorization: This study fits within the event timeframe of the driver environment for Haddon Matrix #2: Unsafe Driving Behaviors, as it sought to establish a relationship between self-reported aberrant driving behaviors and crash history.

Motor Carrier Environment: How are motor carrier operations related to event occurrence?

Corsi, T.M., Newhouse, M.L., Shukla, A., & Chandler, P. (2002). Passenger motor carriers: A safety performance profile. In Z.G. Zacharia (Ed.), *International Truck and Bus Safety Research and Policy Symposium* (pp. 523). University of Tennessee, Knoxville: National Safety Council.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment		Motor Carrier Operations	

Author Abstract: No author abstract

Industry Sector: Private and for-hire trucking

Purpose: The purpose of this study was to compare the safety performance of passenger carriers to the safety performance of commodity motor carriers. A stand-alone, more in-depth analysis of passenger carrier safety performance was also conducted in order to evaluate the effect of firm size on performance.

Sample: 2,826 for-hire and 114 private passenger motor-carriers were included in the broad comparison between passenger carriers and other carriers; 444 for-hire passenger carriers were included in a detailed comparative analysis of SafeStat component safety measures; 2,403 for-hire passenger carriers were analyzed for size effects on safety performance.

Methodology: The study used data beginning January 1999 through July 2000 from the SafeStat. SafeStat provides performance indicators based on the results of a carrier's roadside inspections, CRs, enforcement actions taken against the firm, and crashes. SafeStat evaluates performance in four SEAs. SafeStat assigns a score to each firm for each SEA based on underlying safety measures. The scores are used to compare motor carriers to their peers. The four SEAs are the driver SEA, vehicle SEA, accident SEA, and safety management SEA. The study used data from each SEA and its underlying components or safety measures.

The study first compared all passenger carriers in the database to all carriers in other major industry segments, such as building materials, household goods and general freight. All industry segments were broken down into for-hire and private groups. The segments were then compared using the results of the most recent available CR, regardless of when it

occurred. In addition, only 444 for-hire passenger carriers were analyzed using the detailed component measures that are used to calculate the SEA scores. In particular, the recordable crash rate (number of crashes per million vehicle miles), driver safety review measure (driver-related acute and critical violations weighted for severity), safety management review measure (safety management-related acute or critical violations weighted for severity), and enforcement severity measure (number of closed enforcement cases) were compared. These 444 carriers had been given a CR within the 18 months prior to the development of the database. These recent CRs reflect a concerted effort to target at-risk carriers in the CR process.

Second, additional comparisons between passenger and all other industry segments were made based on driver and vehicle safety inspections. Safety measures evaluated include driver and vehicle OOS violation rates, fatal crash rates per vehicle, and total crash rates per vehicle.

Lastly, the passenger carrier group alone was analyzed. It was broken into five sub-groups based on the number of power units owned by each firm to evaluate the relationship between the effect of firm size and a firm's SafeStat safety scores. Carriers were separated into the five groups based on the following categorizations based on number of power units: 1 unit, 2-3 units, 4-8 units, 9-25 units, and 26 or more units.

Relevant Findings: Comparison between passenger carriers and various commodity segments revealed that passenger carriers are among the best performing motor carriers, as measured by results from both CRs and roadside inspections. For example, only 5% of private passenger carriers had overall unsatisfactory reviews. Additionally, 100% of for-hire passenger carriers had satisfactory reviews. Passenger carriers also had some of the lowest numbers of driver OOS violations, fatal crashes, and enforcement cases.

The comparison also revealed a disparity in safety performance between for-hire and private carriers; with more for-hire carriers receiving overall satisfactory CR reviews. Private commodity carriers had recordable crash rates higher than for-hire commodity carriers, private passenger carriers and for-hire passenger carriers. On average, private carriers were more likely to have a severe safety management violation than a for-hire carrier. However, private carriers are less likely, on average, to have a driver safety violation. Also, with the exception of passenger carriers, a higher percentage of for-hire firms than passenger firms had an enforcement case that was initiated and closed within the 30 month period prior to the period of analysis.

Evaluation of roadside inspections produced similar results as the CRs. For example, for-hire carriers had lower driver OOS rates than did private

carriers, although their vehicle OOS rates were comparable. The authors suggest that a greater degree of familiarity with FMCSA regulations among for-hire carriers may explain these differences.

The in-depth analysis of passenger carrier size groups revealed that there were more large carriers receiving overall satisfactory CRs than small carriers. However, results vary with firm size once individual CR components are analyzed. The recordable crash rate first increases with firm size and then decreases with firm size; thus, the largest firms demonstrate the lowest overall recordable crash rate and medium firms exhibit the highest overall recordable crash rate. Larger firms have a higher frequency of involvement in driver violations than smaller firms, but a lower frequency of involvement in safety management violations. The smallest firms also had less enforcement cases than their larger counterparts.

Evaluation of roadside inspections revealed significant differences between for-hire passenger carriers of various sizes. The largest carriers, with more than 26 power units, had lower driver-related and vehicle-related OOS rates. HOS violations were also significantly higher for small passenger carriers; 20.21% inspections of smallest firms found HOS violations in contrast to 2.11% for the largest firms. There was also a significant decline in both the fatal and total crash rate, per power unit, as firm size increased.

Limitations: The sample size of private carriers was small in comparison to the sample size of for-hire carriers. However, the authors were careful not to draw firm conclusions from the firm-size analysis that divided passenger carriers into five subgroups and alert the reader to the small sample size.

In addition, during the period of analysis, only passenger and hazardous materials motor carriers with unsatisfactory safety ratings were prohibited from operating vehicles in interstate commerce. On November 20, 2000, several months past the end of the study period, the FMCSR was changed to prohibit all motor carriers with unsatisfactory safety ratings from operating vehicles in interstate commerce.

Categorization: This paper fits within the event timeframe of the motor carrier environment for Haddon Matrix #2: Motor Carrier Operations. The article analyzed the adherence to safety rules by passenger motor carriers in comparison to motor carriers other industry segments.

[a]Keane, T., Corsi, T., & Braaten, K. (2002). Motor industry profile study: Evaluating safety performance by motor carrier industry segment. In Z.G. Zacharia (Ed.), *International Truck and Bus Safety Research and Policy Symposium* University of Tennessee, Knoxville: National Safety Council.

[b]Horrace, W.C., & Keane, T.P. (2004). Ranking and selection of motor carrier safety performance by commodity. *Accident Analysis & Prevention, 36*, 953–960.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment		Motor Carrier Operations	

Author Abstract: [a]No author abstract

[b]We use recent safety performance data to rank US motor carrier commodity segments (e.g., Tank segment or Produce segment) in terms of several driver-related, vehicle-related, and crash-related safety measures. Ranking and selection inference techniques are used to determine the best and worst performing commodity segments at the 95% confidence level. The results are mixed, however the Passenger segment is generally best, while the Produce, Intermodal, and Refrigerated segments tend to be worst.

Industry Sector: [ab]For-hire and private trucking

Purpose: [ab]The purpose of this study was to explore potential differences in safety performance across industry segments. The 2002 conference proceedings and 2004 journal article both outline the same study.

Sample: [ab]Approximately 94,000 for-hire carriers in 11 commodity segments, and 55,000 private carriers in 10 commodity segments.

Methodology: [ab]Researchers used the MCMIS and the SafeStat to rank commodity segments by safety through the evaluation of various safety performance measures. Only carriers having an inspection within the past 30 months were included. Eleven for-hire carrier commodity segments and ten private carrier commodity segments were identified in the MCMIS system. The 10 private segments examined were: Building Materials, Bulk Freight, Refrigerated (non-produce), General Freight Truckload, Household Goods, Intermodal, Large Machinery, Passenger, Produce and Tank. The 11 for-hire segments examined included the same 10 commodity segments, plus the General Freight, LTL segment.

The SafeStat data provided nine safety performance measures for ranking the commodity segments. These included two driver-related measures, two vehicle-related measures, three crash-related measures and two safety management performance measures. Examples of the measures are the total crash rate and the driver OOS rate. An average safety performance measure was developed for each segment from carrier level data. Ranking and Selection Theory was then used to identify and rank the best, and worst, performing commodity segments. This theory is a probabilistic technique that divides observations into three groups: a best group, a worst group, and a group containing all other observations that can not be classified at a statistically significant level. In this study, the individual commodity segments were divided into these three groups.

Relevant Findings: [ab]Overall, the Passenger and General Freight LTL segments performed the best, being in the best subset for six measures. The Intermodal and Produce segments performed the worst among the for-hire segments, being in the worst subset for four measures. However, many segments, especially private-carrier segments, received both best and worst rankings, depending on the safety measure being used or were not able to be classified at all. The authors attributed this lack of clarity in ranking for private-carrier segments to the small sample size for some of the private-carrier segments. For example, the Passenger, Intermodal, and Household private segments had only 7, 12, and 29 observations in one of the safety management performance measures.

The authors recommend that different safety measures be applied to evaluate the performance of different segments. The research shows that if identifying the best and worst performing segments is important, then it is even more important to recognize that there may be more than one best or worst segment along any safety metric. In addition, a segment may be best according to one measure and worst according to another. Since SafeStat contains data on crashes, and crashes are clearly important safety measures, the authors recommend that the database be expanded to include commodity segment as a variable.

Limitations: [ab]The nine safety performance measures used in this study were selected from a larger list of 23 measures for which data were collected. Many of the 23 measures are closely correlated, and several serve as direct inputs to others. Consequently, there was some concern that relatively poor performance on one measure would automatically result in poor performance on another related one. The researchers addressed this limitation by balancing the types of measures used in the analysis, including two driver-related measures, three crash-related measures, two vehicle-related measures, and two safety management-related measures.

Thus, there was a fairly even representation among the types of measures examined.

A second limitation of the data involved the inability of the researchers to assign motor carriers to a single segment if they had indicated that they carried two or more commodities. The potential difficulty is that the mean scores for some of the more common, generalized segments (e.g., General Freight) will presumably track close to the industry means since many carriers assigned to different segments will also be assigned to General Freight. This also led to small sample sizes for many private-carrier segments.

Additionally, results of the study are valid only for motor carriers that have had an inspection within the past 30 months (the criteria used for inclusion of MCMIS data in SafeStat).

Categorization: These papers fit within the event timeframe of the motor carrier environment for Haddon Matrix #2: Motor Carrier Operations, because they provided overall safety ratings for firms by industry segment.

Post-event

Driver Environment: How can feedback provided to the driver benefit safety?

Hickman, J.S., & Geller, E.S. (2003). Self-management to increase safe driving among short-haul truck drivers. *Journal of Organizational Behavior Management, 23*, 1.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Driver Self-management
Motor Carrier Environment			

Author Abstract: The relative impact of a self-management for safety (SMS) process was evaluated at two short-haul trucking terminals. Participation in the Pre-Behavior group (n = 21) recorded their intentions to engage in specific safe versus at-risk driving behaviors before leaving the terminal (i.e., before making any of their deliveries for the day), whereas participants in the Post-Behavior group (n = 12) recorded their actual safe versus at-risk driving behaviors after returning to the terminal (i.e., after making all their deliveries for the day). Each participant drove a truck equipped with an on-board computer-monitoring device that recorded two driving behaviors, traveling > 63 mph (overspeed) and stopping or braking > 7 mph/sec (extreme braking) [Reviewer note: 7mph/sec equals 0.319 *g*]. During the SMS intervention, participants in the Pre-Behavior group reduced their mean percentage of time overspeeding by 30.4%, and their mean frequency of extreme braking incidents by 63.9%. Similarly, during the SMS intervention, the Post-Behavior group reduced their mean percentage of overspeed and their mean frequency of extreme braking incidents by 19.3% and 49.4%, respectively.

Industry Sector: Short-haul trucking

Purpose: The purpose of the current study was to examine the potential benefits of using SMS techniques in combination with on-board monitoring devices to improve safety in the trucking industry. SMS is a behavior-focused improvement process whereby individuals change their own behavior in a goal-directed fashion, thereby precluding the need for interpersonal observation and feedback.

Sample: 33 short-haul truck drivers from 2 trucking terminals in the northeastern U.S.: 21 in the Pre-Behavior experimental condition and 12 in the Post-Behavior experimental condition.

Methodology: The two short-haul trucking terminals were randomly assigned to a Pre-Behavior or Post-Behavior experimental condition. Drivers in the Pre-Behavior condition were asked to record their *intentions* to engage in specific safe versus at-risk driving behaviors before leaving the terminal at the beginning of their shift. The drivers who participated in the Post-Behavior condition were asked to record their *actual* safe versus at-risk driving behaviors after returning to the terminal at the end of their shift. All participants had trucks equipped with on-board monitoring devices that recorded overspeeding (defined as traveling greater than 63 mph) and extreme braking (defined as braking the vehicle at a decrease in speed greater than 7mph/second). Drivers were aware that the monitoring devices were installed on their trucks. Each driver entered an individual ID number into the on-board computer before the start of each trip, linking their ID to the data obtained from the trip.

Both experimental groups were given a two-hour training session explaining the rationale and importance of SMS techniques, as well as how to identify the antecedents and consequences of safe and at-risk behaviors, how to record behavioral self-intentions (Pre-Behavior group) or self-observations (Post-Behavior group), and how to set goals and administer self-rewards. All participants were then asked to complete the self-monitoring forms on a daily basis for four consecutive weeks. The Pre-Behavior group was asked to estimate the percentage of time they *would drive* without overspeeding and the number of times they *would have* an extreme braking incident while driving on a particular day. The Post-Behavior group was asked to estimate the actual percentage of time they *drove* without overspeeding and the number of times they *had* an extreme braking incident on each day.

Baseline data were recorded by the in-vehicle technology for 11 weeks preceding the 4-week intervention period. In addition, information was collected during a four week withdrawal phase, following the completion of the intervention phase, where the in-vehicle monitoring equipment continued to record data on overspeeding and extreme braking.

Relevant Findings: Results for the Pre-Behavior group demonstrate that the mean percentage of time overspeeding (2.3% during baseline) and the mean frequency of extreme braking incidents (1.22 during baseline) was reduced by 30.4% and 63.9%, respectively, during the intervention period. Drivers in the Post-Behavior group decreased their mean percentage of time overspeeding (5.7% during baseline) and mean frequency of extreme braking incidents (7.3 during baseline) by 19.3% and 49.4%, respectively. Over the four-week intervention period, the Pre-Behavior group had 16 fewer extreme braking incidents and 9.7 fewer hours overspeeding than during the baseline period. Taken cumulatively, these results suggest that, if SMS monitoring were to continue for an entire year, a total of 192 fewer

extreme braking incidents and 116.4 fewer hours overspeeding would occur for the Pre-Behavior group. In addition, the Post-Behavior group could expect 516 fewer extreme braking incidents and 352.8 fewer hours overspeeding over the course of a year.

Both the Pre- and Post-Behavior groups returned to near baseline levels of performance after the intervention was discontinued, suggesting that the behavioral change that occurred during the intervention was due to the actual SMS techniques, and not an artifact of training or simply an increased awareness of safety conscious behaviors. Overall, the SMS techniques significantly reduced the occurrence of at-risk behaviors for both Pre- and Post-Behaviors groups. However, these techniques must be used continuously to maintain their effectiveness, suggesting the need for an ongoing SMS program.

Limitations: Although one of the original goals of this study may have been to compare the results of the Pre- and Post-Behavior groups to determine whether SMS was more effective when self-monitoring intentions or actual behaviors, systematic differences in the Pre- and Post-Behavior groups preclude the authors from drawing conclusions about the observed differences in results. For example, the results suggested that the Post-Behavior group had superior decreases in the targeted at-risk behaviors. However, the Pre-Behavior group drove more safely during the baseline than did the Post-Behavior group, and thus did not have the potential to improve behaviors at the same rate as the Post-Behavior group. In addition, the Post-Behavior group had fewer drivers, but each driver drove significantly more minutes during the study than the drivers in the Pre-Behavior group. This may be because the Pre-Behavior trucking terminal lost a major business account prior to the study, resulting in a significant decline in business. Additional data analysis would be necessary, examining rate-based assessments and outcomes, before valid comparisons could be made between the two groups. Nevertheless, the small sample sizes of the Pre- and Post-Behavior groups suggest a need for replication of the aforementioned findings with more participants and randomization of experimental groups.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #2: Driver Self-management, as it discusses the potential benefits of implementing SMS programs in the trucking industry.

Olson, R., & Austin, J. (2001). Behavior-based safety and working alone: The effects of a self-monitoring package on the safe performance of bus operators. *Journal of Organizational Behavior Management, 21*, 5–43.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Driver Self-management
Motor Carrier Environment			

Author Abstract: Experimental evaluations of Behavior-Based Safety (BBS) processes applied with lone workers are scarce. Clinical and organizational researchers alike have studied the effectiveness of self-monitoring as a performance improvement strategy, but further work is needed to determine the power of such interventions for improving safe behavior and to explore the best practices for using such processes with lone workers. In this study, 4 male bus operators (20.5 yrs average experience) self-monitored their safe performance and received feedback based on self-monitoring data. Dispatch supervisors used radio communication to prompt Ss [subjects] to complete self-monitoring forms and also conducted special observations of Ss to measure target performances. Both operators and supervisors were unaware of experimental Os [observers] who measured the performance of each S by riding on busses as passengers. A multiple baseline design across performances was used to assess the effects of the intervention on 4 performance targets. The intervention resulted in a 12.3% increase in safe performance for the group, with individual increases in performance ranging from 2 to 41% for specific target performances. The results are discussed in terms of the value of BBS processes for employees who work alone and the research needed to determine the components of self-monitoring processes that are most critical for generating improvements in safe performance.

Industry Sector: Transit bus industry

Purpose: The goal of the current study was to evaluate the effectiveness of self-monitoring procedures for improving the safe performance of bus operators.

Sample: 4 male bus drivers employed by a Midwestern public transportation system with 19–23 years of experience who worked a regular 10-hour shift (6:30am–4:30pm) driving a route on a university campus.

Methodology: Bus drivers were observed at least once a day for approximately 30 days. The experimenters rode a complete one-way cycle of the bus route (lasting 30 minutes) for each session and monitored safety-critical behaviors. Experimenters recorded performance for (1) complete stopping, defined as the complete termination of forward movement at stop signals; (2) remaining stopped during passenger loading and unloading, defined as remaining motionless for at least two seconds after the last loading/unloading passenger either steps behind the yellow line on the bus, steps off the bus to the right, or clears the front left corner of the bus; (3) mirror checking, defined as visually checking both side mirrors after loading/unloading passengers as the bus pulls out of a loading zone; and (4) stopping position, defined as keeping bus doors shut until the bus is completely stopped and positioning the bus so that no cars can pass on the right.

After an initial baseline observation period of 13 days, the participating bus drivers attended an informational meeting where they were introduced to the behavior-based self-monitoring program. Drivers were given information on the purpose and rationale behind the use of BBS techniques, and instructions for completing self-monitoring forms. The first stage of the intervention lasted 8 days and asked drivers to complete self-monitoring on stopping performance forms twice per day. Phase two added self-monitoring of remaining motionless after loading/unloading and continued for five days. Phase three added self-monitoring of bus stopping position and checking mirrors and was also five days in duration.

Bus drivers received regular feedback on their self-monitoring data from the previous day in the form of individual and group graphs posted in the drivers' lounge. As a validity check, drivers were asked to initial the feedback graphs each day to indicate that the feedback had been viewed. In addition, supervisors were asked to prompt drivers via radio twice each day to complete their self-monitoring forms.

Supervisors also conducted special ride-along sessions with drivers to observe the behaviors being self-monitored by the drivers. On such occasions, experimental observers were also present on the bus during the duration of the supervisor assessment to record driver performance. The drivers were not informed of the presence of the experimental observers until the debriefing following conclusion of the study.

Relevant Findings: Overall, the drivers improved their safe driving by an average of 12.3% over baseline conditions. Complete stopping improved by an average of 21.2% (range: 14%–41%), motionless after loading/unloading improved by an average of 11.8% (range: 3%–19%), mirror checking improved by an average of 10% (range: 3%–15%), and bus stopping position improved by an average of 6.2% (range: 2%–12%). Individual levels of

improvement varied greatly across different behaviors, suggesting individual differences in the effectiveness of the self-monitoring procedures. Interestingly, participant 1 demonstrated the greatest average improvement (14%), the most consistent improvements across phases, and also provided the most accurate estimations of his own safe performance levels. An in-depth examination of participant 4 demonstrated the smallest average improvement over baseline (10%), and the least accurate self-ratings. This may suggest that the greatest improvements in performance occur when participants are most accurate in their self-estimations of performance. However, accuracy levels were not directly related to performance levels at all points in the study for all participants. The accuracy of self-observations appears to be related to performance, but a clear pattern is not apparent given the current data.

Although only small improvements in behavior were observed in this study, the cumulative benefits of small effects should not be ignored. A 12.3% improvement in overall performance of safety-critical behaviors may have a large impact on an organization if those effects are observed across all employees. Given similar levels of improvement as observed from the four drivers that participated in the study, the transit system could experience 31,200 fewer at-risk behaviors across all (68) employed drivers each month, and 374,400 fewer at-risk behaviors each year.

Limitations: The sample used in the current study was extremely small, thus making it difficult to draw conclusions about observed trends in the data. In addition, a longer time period of observation would be beneficial to assess whether performance improvements remain stable after the completion of the intervention.

In addition, the study may not have succeeded in adequately motivating employees to participate in the self-monitoring process because employees were not involved in the design of the BBS procedures. Past research on BBS suggests that employee participation is key to the success of the process because it encourages employee buy-in.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #2: Driver Self-management, as it evaluates the effectiveness of driver self-monitoring in the busing industry.

Reinach, S.J., & Everson, J.H. (2005). Transit bus operator performance and attitudes toward a collision warning system: Results of a simulator experiment. *Traffic Injury Prevention, 6*, 248–57.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Driver Attitudes Towards Technology
Motor Carrier Environment			

Author Abstract: *Objective*: This article discusses the results of a simulator experiment to examine the efficacy of a collision warning system for transit bus operators.
Methods: Bus operators from a major metropolitan transit agency were assigned to one of three conditions: a collision warning system with a visual-only driver-vehicle interface, a collision warning system with a visual and auditory driver-vehicle interface, or no collision warning system (baseline). Operators were exposed to a critical event at the end of the simulation, in which a vehicle suddenly stopped in front of the bus while the operator was distracted by an in-vehicle task. Upon completing the experiment, operators who used the collision warning system were asked about their experience using the system, as well as whether or not they would like such a system in real life.
Results: Experimental results revealed new information about transit bus operator performance, but indicated no statistically significant differences among the three conditions. Subjective data indicated that operators had a positive attitude toward collision warning system usage. Operators generally liked the collision warning system and felt that a system such as the one used in the experiment would help them in avoiding crashes in the real world.
Conclusions: These findings suggest that a collision warning system for transit bus operators is feasible from the perspective of user acceptance. However, several technical areas still need to be resolved.

Industry Sector: Transit bus industry

Purpose: The purpose of this research was to further the Federal Transit Administration's (FTA) understanding of the potential efficacy of a transit bus CWS and how such a system may be designed to be most effective and accepted by transit bus operators.

Sample: 24 bus operators from New York City Transit (NYCT).

Methodology: The simulator used in the experiment consisted of a mock bus driver's workstation, similar to that used by many NYCT operators. The CWS driver-vehicle interface (DVI) consisted of two columns of seven vertically-stacked light segments mounted in the simulator cab, as well as an auditory warning alert. It was designed to present the operator with information regarding the imminence of the collision as well as the location of the threat. As a hazardous situation became more imminent, progressively more light segments illuminated; in addition, the visual display illuminated amber to indicate the presence of a less severe threat and changed to red to indicate a more imminent hazard. At the seventh, and most imminent, level, the audible warning alert also sounded.

Participants received an incentive for on-time performance and successful responses to master alarms. The drivers encountered two very minor hazardous situations involving a threat vehicle during a practice route, and encountered one additional minor hazard part-way through the experimental route. The critical event at the end of the experimental route consisted of a lead vehicle braking to a stop in front of the bus, just as operators were distracted by the need to respond to the master alarm. The goal was to create a simulated distraction that required the operator to look away from the forward roadway just as the scenario became hazardous.

The 24 participants were equally divided into one of three conditions: A visual-only DVI, visual and auditory DVI, or baseline (no DVI and, consequently, no CWS). The dependent variables included whether or not drivers crashed, operator response time to the lead vehicle braking, and various vehicle velocity, response time, and time-to-collision values at various points in the critical event sequence. The operators who were exposed to the CWS were asked to complete a brief survey regarding subjective workload and preference ratings with respect to the CWS and DVI. It was expected that operators with the visual and auditory DVI would perform better than those with the visual-only DVI, and both sets of operators exposed to the DVI would outperform those with no CWS.

Relevant Findings: Five of the 24 bus operators crashed in response to the experimental critical event (two in the baseline condition, two in the visual-only DVI condition, and one in the visual and auditory DVI condition). In addition to crash outcome, a number of other safety measures were examined for the 17 participants who did not crash and who braked as their primary evasive maneuver. Operators in all three conditions averaged the same maximum deceleration of −0.433 g in response to the critical event. Although not statistically significant, those in the baseline group stopped closer to the lead vehicle than those in the two DVI conditions. Operators in the visual and auditory DVI condition were also slightly faster to brake in response to the critical event compared to operators in the visual-only DVI and baseline groups.

Responses to the survey questions, completed by the 16 operators exposed to the CWS, revealed that the visual and auditory DVI was rated as slightly more useful than the visual-only DVI. However, operators also found the visual and auditory DVI slightly more annoying and distracting than the visual-only DVI. Overall, operators gave a positive assessment of CWS usefulness, and did not find the CWS to be overly annoying or distracting. Seven operators reported that the CWS improved their workload, while another seven reported no difference. One operator felt that the CWS negatively affected his or her workload. In general, operators felt that a CWS like the one they experienced in the simulator would be useful to them in the real world.

Overall, experimental results indicated that the CWS appeared to neither improve nor worsen operator performance during the critical lead vehicle event. As a possible explanation for these inconclusive findings, the authors posited that a CWS may not improve operator performance, given that operators are already highly trained, defensive drivers. It is also possible that the design of the critical event did not allow for differences in operator performance to be exhibited; in other words, the critical event may have been too easy to avoid. Another possibility is that the CWS was not optimized for use in the low-speed, high-obstacle-laden urban transit bus driving environment.

Limitations: The authors suggested that the sample used in this experiment may have been too small to allow a difference between CWS usage and no CWS to be detected. A post-hoc power analysis indicated that adding a few more participants in each condition (from about 6 to 8) would increase the power to detect a difference from 67% in the current study to 85%. Another shortcoming of the study was that false alarms (providing a warning when no hazard exists) and nuisance alarms (providing a warning to the operator when the operator is already aware of the hazard) were not evaluated as a measure of effectiveness of the CWS performance. The researchers stated that the impact of false and nuisance alarms on operator performance, acceptance, and trust of the CWS is a major issue that must be studied further and resolved prior to CWS deployment.

Categorization: This paper fits within the post-event timeframe of the driver environment for Haddon Matrix #2: Driver Attitudes Toward Technology, as the project assessed the usefulness of a vehicle-based CWS and DVI in terms of driver performance and operator acceptance.

[a]Roetting, M., Huang, Y.-H., McDevitt, J.R., & Melton, D. (2003). When technology tells you how you drive—truck drivers' attitudes towards feedback by technology. *Transportation Research Part F: Traffic Psychology and Behaviour, 6*, 275–287.

[b]Huang, Y.-H. , Roetting, M., McDevitt, J.R., Melton, D., & Smith, G.S. (2005). Feedback by technology: Attitudes and opinions of truck drivers. *Transportation Research: Part F Traffic Psychology and Behaviour, 8*, 277–297.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			Driver Attitudes Towards Technology
Motor Carrier Environment			

Author Abstract: [a]Behavior based safety approaches have proven effective in reducing accidents in industrial settings, but cannot easily be extended to commercial driving. For considerable periods of working time, truck drivers are alone, and do not interact with peers. It might be possible to use data gathered by new in-vehicle technology to provide real-time and post-shift feedback to drivers about their driving behavior. This paper reports the results of focus group interviews conducted with SMEs from the trucking industry (truck drivers, supervisors, managers, and other involved persons, such as insurance industry safety professionals). The focus groups discussed safety critical behaviors in commercial driving, the best way to provide feedback to truck drivers, and benefits of feedback by technology as well as concerns drivers and operators may have regarding monitoring and feedback systems. The focus group discussions showed that, in general, drivers would like to receive more feedback and that feedback by technology is acceptable, if designed and implemented properly. In addition, the participants had many suggestions on how to properly design and implement such systems.

[b]This study explored the potential uses of feedback systems in the trucking industry as a means of improving safety. Since truck drivers spend a majority of their working time alone and do not interact with peers, it may be possible to use data gathered by in-vehicle technology to provide feedback to drivers about their driving behavior. The purpose of this study was to examine truck drivers' attitudes toward using in-vehicle technology to provide feedback for enhancing driving safety and to understand the best ways of providing feedback to truck drivers. Nine focus groups were conducted, with a total of 66 participants, to collect qualitative data on attitudes toward technology and feedback. The focus group results were used to develop a questionnaire. Survey data were then collected from 198 long-haul truck drivers to provide quantitative information. Truck drivers

reported that they would like to receive more feedback and that positive feedback was preferred over negative feedback. Feedback from truck drivers' supervisors or managers was more desired than feedback from technology. However, most drivers were willing to accept feedback by technology if the program was designed properly. The truck drivers expressed no strong preference regarding the best form of feedback by technology on driving performance (i.e., modality, frequency and timing). Therefore it is important for a program which uses technology for providing feedback to be adaptable to different drivers' preferences.

Industry Sector: [ab]Trucking

Purpose: [ab]The purpose of the Roetting (2003) and Huang (2005) studies were to explore truck driver opinions of the use of technology as a means of providing feedback to drivers concerning safety-related behaviors. BBS methods focus on using feedback as a teaching mechanism to encourage improvements in safety. However, most commercial drivers work alone in the truck, leaving little opportunity for immediate driving feedback. In-vehicle technology may function as a feedback tool that drivers can use to improve their safe driving behaviors.

Sample: [ab]The initial focus group sample included a total of 66 participants: 35 long-haul drivers, 5 short-haul drivers, 12 managers, and 6 insurance professionals, all recruited from the northeast.

[b]The follow-up survey sample included 198 North American, long-haul truck drivers.

Methodology: [ab]Nine focus groups were conducted with truck drivers, managers, and insurance professionals. Each of the focus groups incorporated open-ended questions concerning characteristics that make a safe driver, past experiences receiving feedback, awareness of in-cab technology, benefits and drawbacks of receiving feedback from in-cab technology, and how one would prefer to receive safety feedback. All focus groups used a discussion format to obtain the answers to these questions. Data from audio recordings, detailed notes taken by a member of the research team, and flip charts created in each session were consolidated into a single transcript. The written information was then coded and sorted to identify major themes from the focus group discussions.

[b]Using the results from the focus groups, a survey was developed to collect additional data from long-haul truck drivers concerning the use of in-vehicle technology for safety feedback. Truck drivers were recruited from a truck stop in New England to participate in the survey. Participants were asked to provide demographic information, rank the most important critical safety behaviors of truck drivers, and respond to a number of

questions concerning in-vehicle technology using a 1 to 5 response scale where 1 equaled "strongly disagree" and 5 equaled "strongly agree." The major topic areas of the survey questions paralleled those covered in the focus groups.

Relevant Findings: [ab]Drivers in both studies reported that using mirrors and turn signals, looking well ahead of the vehicle to adjust to what is happening, having patience, and being ready to expect the unexpected from other drivers on the road are all characteristics that make for a good, safe truck driver. Drivers in the focus groups also reported that they believe other truck and automobile drivers were often equally, or more, responsible for the unsafe behaviors of truck drivers. In addition, there was concern that safety can be negatively affected by demanding dispatchers who are unaware of the challenges of driving, inconsistent application and enforcement of federal regulations, and a lack of secure rest areas to stop at when fatigued.

The group discussions also suggest that drivers want feedback that is specific, constructive, respectful, and individualized. However, responses varied when participants were asked about the feedback given and received at their particular company. Feedback appears to be dependent upon the safety climate of the company. Some drivers reported receiving very little feedback and having very little interaction with their company's management, whereas others reported more positive and frequent interactions, including regular feedback from supervisors.

The focus group participants indicated that they expected in-cab technology to be beneficial for driving performance and efficiency. It was also perceived as having the potential to reduce driver stress. Feedback from technology was viewed positively because it is objective, and therefore may aid in vindicating drivers in the event of an incident or crash. However, participants reported some concern about privacy issues when using in-cab technology. Many reported that they would not be comfortable being "watched" by technology. Other concerns included the initial costs and reliability of the technology, and the potential to rely too heavily on technology and less on routine safe driving habits.

Participants agreed that even when feedback is given by a machine, additional human feedback is still wanted. There was less agreement concerning the form and timing of the feedback received from the in-cab technology. Some drivers preferred an audible or visual alarm immediately, whereas others suggested composing an electronic report or printout that would be available on a daily, weekly, or monthly basis. Still, others wanted to be able to access feedback information using multiple formats at driver-specified times.

[b]Results from the truck driver survey support the findings of the focus groups. In general, truck drivers expressed a desire to receive more feedback, and preferred feedback that was positive in nature. When asked about the perceived benefits of receiving feedback by technology, 56% of drivers believed that the data from the technology may aid in defending a driver if involved in an accident, 46% of the drivers agreed that in-vehicle technology would make them a safer driver, and 31% thought that the technology might reduce their stress levels. Privacy issues were again cited as a drawback to in-vehicle technology in the survey sample, with 65% of drivers reporting concern about the data from in-vehicle technology getting into the wrong hands. The majority of drivers were not concerned about the complexity of the technology. However, 52% of the drivers agreed that relying too heavily on in-cab technology may lead to a loss in safe driving skills. Additionally, 49% of the drivers thought that receiving feedback from technology could be a distraction for drivers.

When asked about the preferred mode of feedback, results were mixed. Forty seven percent reported that they would like to receive feedback from a display on the dashboard, 37% responded favorably to receiving a computer printout at the end of their shift, and 20% indicated that they would like a computerized voice. Results were also split regarding the timing of feedback, 51% of respondents preferred having feedback delivered when they requested it, whereas 43% agreed that they would like to receive feedback at regularly scheduled intervals. Fifty six percent of drivers reported that they would like to receive feedback immediately after driving. However, there was no clear preference for how frequently feedback should be received. It ranged from once a day to once a year.

Results were split when asked about feedback from technology in comparison to feedback from a real person. Equal numbers of truck drivers (37%) agreed and disagreed with the statement, “Receiving feedback about how I drive from technology is as helpful as feedback from a real person,” with the rest indicating that they were neutral. As in the focus groups, the survey results suggested that, even though drivers may find feedback from technology helpful, they would still like feedback from a real person in addition to the technology. The majority of drivers reported that when it comes to receiving feedback from a person, they would most like feedback from a safety director or their direct supervisor, followed by a dispatcher, driving partner, or another truck driver. Drivers most often disagreed with wanting to receive feedback from a “1-800 how’s my driving” service or “4-wheelers” (truck driver slang for automobile drivers).

[ab]Overall, participants from both studies seemed to be receptive to additional feedback concerning their safe driving behaviors, especially positive feedback. Participants were receptive to feedback from in-vehicle

technology, yet there were lingering concerns about how data from monitoring systems might be used. Using feedback from technology may only be beneficial when there exists a strong climate for safety within the company and buy-in at all levels. Drivers should also be included in the development and implementation of the technology and given some choice about how, when, and how frequently they will receive feedback from the technology.

Limitations:

[ab]These studies are preliminary in nature as they are part of an initial needs assessment examining feedback by technology as a viable tool to assist in implementing BBS initiatives in the trucking industry. All data were self-report in nature, and participants may not have responded with complete candor. In addition, responses from various participants may heavily depend on their knowledge and past experience with in-vehicle technology and how such a hypothetical system might work. Participants in the focus groups and the survey were all recruited from the New England region of the United States. In addition, drivers that participated in the survey were recruited from a single truck stop. Although participants resided in 40 different states, caution should be used when generalizing to the entire U.S. trucking industry.

Categorization:

These papers fit within the post-event timeframe of the driver environment for Haddon Matrix #2: Driver Attitudes Towards Technology, because they explored driver opinions about receiving feedback from in-cab technologies regarding their safety-related behaviors.

Motor Carrier Environment: How can feedback provided to the motor carrier benefit safety?

Lantz, B.M. & Blevins, M.W. (2002). An analysis of commercial vehicle driver traffic conviction data to identify high safety risk motor carriers. In Z.G. Zacharia (Ed.), *International Truck and Bus Safety Research and Policy Symposium* (pp. 549–556). University of Tennessee, Knoxville: National Safety Council.

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Safety Oversight

Author Abstract: This project explores the idea of using commercial motor vehicle driver traffic conviction data from the Commercial Drivers License Information System (CDLIS) to help identify high safety risk motor carriers. Prior research and intuitive knowledge suggest that certain types of motor carriers may employ drivers with higher than average traffic conviction rates. This study should help to provide new knowledge of high-risk carriers, and allow better focusing of enforcement efforts to reduce crashes and fatalities on the highways.

Because there is not a national traffic citation database, and there are substantial problems with state or local police officers accurately identifying the employing motor carrier when issuing a traffic citation, a direct approach of using citation data for analysis is not feasible nationwide. Therefore, the present project studies whether a correlation exists between traffic conviction data (a subset of citations), accessible through CDLIS, and high risk motor carriers linked to drivers through inspection and crash reports contained in the Motor Carrier Management Information System.

This study concludes that linking driver conviction data to the employing motor carrier provides a method to identify those motor carrier companies with safety problems. A carrier driver history measure created based on the average number of convictions of drivers associated with the carriers is significantly correlated with carriers' out-of-service (OOS) rates, accident rates, and SafeStat Safety Evaluation Area (SEA) scores. Carriers with higher (worse) driver history measures are also more likely to have higher OOS rates, accident rates, and SEA scores.

Industry Sector: Trucking

Purpose: The purpose of this study was to explore the idea of using CMV driver traffic conviction data from the CDLIS to help identify high safety risk

motor carriers. The intended goal of the project was to provide new knowledge of high-risk carriers and to allow better focusing of enforcement efforts to reduce highway crashes and fatalities.

Sample: 64,711 truck drivers representing 13,829 carriers.

Methodology: Carriers were selected using census data from the MCMIS. A stratified random sampling scheme was used to include carriers across various size categories and geographic regions, with a maximum of 50 drivers per carrier being sampled. Drivers were matched to CDLIS driving history records for the time period of 1997–2000. Individual driver history measures were subsequently created as a weighted sum of each driver's convictions/offenses, where higher scores indicated more and/or more serious offenses. Carrier driver history measures were then created by calculating the mean value of all individual driver history measures associated with that carrier. For each carrier, critical safety data were also obtained. This included the number and type of crashes, number and type of OOS roadside inspections and violations, and scores in each of the four SEAs (Accident, Driver, Vehicle, and Safety Management) of the SafeStat.

Relevant Findings: Results of correlation analyses indicated significant positive linear relationships, where, generally, higher carrier driver history scores were associated with higher OOS rates, crash rates, and SEA scores. A detailed examination of carriers by size group also revealed significant positive correlations between the carrier driver history measure and carrier safety data. In addition, significant positive correlations were found between the carrier driver history measure and driver OOS rates and driver SEA scores for carriers in each region of the country; and the carrier driver history measure was significantly correlated with crash rates per power unit in every region except the Deep South and Great Lakes regions. Thus, carriers employing drivers with more severe driving history records were also more likely to have greater numbers of recorded crashes, OOS violations, and poorer performance on the SafeStat SEAs. Based on these results, the authors reached the overall conclusion that linking driver conviction data to the employing motor carrier appeared to serve as an indicator of those motor carrier companies that have safety problems.

Limitations: This study is very exploratory in nature as only correlational analyses were performed to test for a relationship between driver history and carrier safety status. The authors also point out the need for further research to determine exactly how this information can be used.

Categorization: This study fits within the post-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Oversight, as driver conviction data was used to link drivers with their carriers as a means to identify high safety risk motor carriers.

Smith, M., Owens, N., Stock, D., Lantz, B., & Murray, D.S.G. (2005). *Driver violation notification service feasibility study*. Washington, D.C.: Federal Motor Carrier Safety Administration. (NTIS No. PB2005-110645)

Haddon Matrix for Review #2: Improving Driver Safety			
	Pre-Event	**Event**	**Post-Event**
Driver Environment			
Motor Carrier Environment			Safety Oversight

Author Abstract: The Driver Violation Notification Service Feasibility Study assessed the safety benefits of driver violation notification programs (also known as Employee Pull Notice or Driver Pull Notice programs). In these programs, states automatically notify motor carriers of changes in their drivers' CDL records due to violations and convictions. The project team analyzed programs in ten States, and surveyed several motor carriers, in order to both determine how well these programs work and establish requirements for an expanded nationwide program.

Industry Sector: Trucking

Purpose: This study evaluated the design of commercial DVN systems, also known as an Employee/Employer Pull Notice (EPN), and their relationship to highway safety. One of the major goals was to shorten the time between a driver receiving a conviction for a driving violation and the employer being notified. It was surmised that more prompt notification of convictions will allow more carriers to take immediate and appropriate corrective action to mitigate the potential negative consequences of high-risk driving behaviors.

Sample: 10 states already using a DVN-type program and 4 states that did not have DVN programs in place.

Methodology: The DVN Study Team conducted a five-stage research program. The approach used for each stage or study task is described below.

Task 1: State Visits to Government Agencies—Interviews were conducted with representatives responsible for implementing each state's DVN program, as well as representatives from FMCSA, in order to understand existing DVN-type programs and obtain information on costs and effectiveness. For states without an existing DVN program, potential implementation issues were identified that, if not addressed, would impact the success of a national program.

Task 2: Document User Requirements for DVN Programs—The Study Team conducted focus groups, interviews, and a motor carrier survey to obtain information on the effectiveness and user requirements of existing DVN-type programs, as well as to identify lessons learned and best practices.

Task 3: Cost/Benefit Analysis—Two analyses were conducted to determine the economic feasibility of expanding DVN programs on a nationwide basis. The first analysis used data from national commercial vehicle and CDL databases to assess the relationship between previous serious convictions or crash involvement for drivers who were involved in fatal crashes. The second analysis focused on identifying the difference in crash risk between drivers with no convictions in the prior 12 months and those having had a crash within 12 months of the most recent conviction.

Task 4: Develop Alternate Approaches for the Deployment of DVN Programs—The functional requirements of an Employer Notification Service (ENS) were defined. In DVN states, state DMVs and law enforcement agencies offered suggestions based on their own state's experience with a DVN program. In non-DVN states, suggestions were based on what they believed would be needed for an effective ENS.

Task 5: Recommend Deployment Approach and Work Plan for the Development of DVN Programs—The recommended deployment approach was developed using findings from the preceding four tasks, in particular, the preferences stated by government and industry stakeholders identified in Tasks 1 and 2.

Relevant Findings: Results of the focus groups, interviews, and surveys indicated support from both DVN and non-DVN participants for a national DVN program. Motor carriers expressed a preference for an internet-based, national program with a centralized registration and notification system. Additionally, a considerable number of participants indicated that the national program should be mandatory in order to create a level playing field for all carriers, and should provide some type of incentive for enrollment.

Results of the cost/benefit and crash risk analyses confirmed the hypothesis that poor driving behavior, as demonstrated by prior convictions and involvement in crashes, increases the risk of involvement in future crashes. A greater percentage of drivers had one or more crashes within the 12-month period following a conviction than those with no convictions in the previous 12 months (2.98% as compared to 2.17%) This difference, multiplied by the number of convictions nationally, represents the maximum potential DVN benefits, in terms of reducing the number of drivers involved in crashes. Costs of a DVN program were estimated

based on information obtained from three states with existing DVN-type programs. Thus, the overall outcome from this analysis was a Benefit/Cost Ratio of $121 million/$7.8 million per year. In other words, the benefits of a DVN program are estimated to outweigh the costs by a magnitude of 15.6.

Several alternative approaches to the design and operation of an ENS were evaluated. Currently, a jurisdiction-based approach is used, in which each jurisdiction determines whether or not to offer an ENS, which employers to include, and how best to provide it. After considering many alternatives, the DVN Study Team recommended a decentralized nationwide system that would include: the ability to post a notice of change in a driver's history record, which would in turn direct the notice to the driver's employer; the capability for motor carriers to receive DVNs from all states; web-based processing to enable all motor carriers to access program services, irrespective of size or technical capability; and public domain ownership of the system, with system operation done through either the Federal government (e.g., FMCSA) or through an association representing public agencies involved in motor carrier regulation and credentialing (e.g., American Association of Motor Vehicle Administrators [AAMVA]).

Limitations: The DVN Study Team identified several issues that will need to be addressed prior to implementation of the national system; these issues will be evaluated in an upcoming national pilot program.

Categorization: This study fits within the post-event timeframe of the motor carrier environment for Haddon Matrix #2: Safety Oversight, because the program is aimed at providing CDL driver conviction information to motor carriers in a timely manner to enable the carriers to take quick corrective action to potentially reduce crash risks caused by at-risk drivers.

Secondary Sources

Brock, J.F., Jacobs, C., Van Cott, H., McCauley, M., & Norstrom, D.M. (2001). *Simulators and bus safety: Guidelines for acquiring and using transit bus operator driving simulators* (TCRP Publication No. 72). Transportation Research Board; Milestone Group, L.L.C. (NTIS No. PB2002-102252)
Foreword: TCRP REPORT 72, "Simulators and Bus Safety: Guidelines for Acquiring and Using Transit Bus Operator Simulators," provides guidance to transit agency managers on whether to purchase a driving simulator and, if so, what kind. Also, this document provides guidance on how to use simulation effectively to improve bus operator training and safety. Information was obtained from a literature search, surveys, and site visits. The guidelines are designed to be used by transit-operations management, human resource management, training instructors, operations, and safety personnel.

Dodsworth, R.W. (2004). Accident reduction and absenteeism. *Bus and Paratransit & Bus Rapid Transit Conference*. Washington, D.C.: American Public Transportation Association.
TRIS Abstract: The first step toward realizing significant savings in the area of accident prevention may seem fundamental, but it is absolutely essential that we be able to identify the right issues and quantify those issues before developing, negotiating and implementing any strategy that requires changes to the existing programs and/or union contracts. Listed below are the four (4) steps to accident reduction identified by the Denver RTD: (1) Identify and quantify the right issues; (2) Negotiate any necessary changes in union contracts; (3) Implement strategy or changes needed to reduce accidents; and (4) Measure effectiveness. These steps lead to a 54% reduction in accidents which in turn lead to savings that preserved significant amounts of service. This is service that would have most certainly faced elimination in response to severe budget challenges.

Drew, T. (2002). Carrier safety management systems... A collaborative approach to carrier safety. In Z.G. Zacharia (Ed.), *International Truck and Bus Safety Research and Policy Symposium* (pp. 371-385). University of Tennessee, Knoxville: National Safety Council.
Abstract: Roadway fatalities represent the single greatest cause of death for young adults in North America, ages 15 to 29. The societal cost of roadway fatalities and injuries in the United States alone exceeds Canada's national revenue budget. Between the United States and Canada, the cost of roadway fatalities and injuries is in the order of $160 billion annually. Although motor vehicle injuries and fatalities can be attributed to a wide variety of drivers and vehicles, the carrier industry including regulators and legislators, public safety advocates, shippers, and insurers are facing significant pressure to improve on-road safety in both the trucking and busing sectors. Historically, these pressures have been satisfied through the creation of more legislation and regulations, followed by enhanced enforcement and increased punitive action. The purpose of this paper is to highlight, for the benefit of transportation safety stakeholders, the value and contribution consensus based, national or international standards can bring to achieving these initiatives and road safety goals, and the support than can be derived through third party certification/qualification programs. This paper also addresses the application of a consensus based standard by CSA International in the delivery of its road safety initiative Carrier Safety Management Systems, to the private and "for-hire" trucking sectors.

Effective practices to reduce bus accidents. (2001). (TCRP Publication No. 66). Transportation Research Board; Technology and Management Systems, Inc. (NTIS No. PB2002-102253)
TRIS Abstract: This report presents a directory of effective practices used to prevent bus accidents at small, medium, and large transit systems. Most of the information was obtained from 182 transit systems in the United States and in Canada and from statewide transit insurance pools in six states. The directory is designed to be used by transit management, operations, and safety personnel.

Farber, F.S. & Miskulin, J.C. (2004). Performance management - Is it time? *Bus and Paratransit & Bus Rapid Transit Conference*. Washington, D.C.: American Public Transportation Association.
Author Abstract: How do transit agencies know when they are meeting strategic objectives? Are they driving the right behaviors in their organizations? Do they identify the warning factors of negative change?

Those familiar with performance management design, implementation, and analysis understand the challenges of establishing a system of effective performance measures. However difficult it may be, successful organizations attest to the rewards. Measuring results allow a transit agency to determine what is successful and what is not.

Establishing a successful performance management program requires a focus in several key areas. The first requires the creation of a framework that links organizational objectives to the business unit (departments) and individual levels by ensuring that everyone understands not only how roles align with organizational objectives, but also how each unit and individual contributes to the outcome.

The next area is the design of measures. Transit agencies need to produce measures that align with strategic objectives, demonstrate results, and focus on the results, while avoiding potential challenges (and/or pitfalls) during the development process.

The third topic area centers on the determination of how to use measures and get more leverage; and finally, converting theory into practice. This is often regarded as the most difficult aspect of successfully implementing a performance management system. For any transit agency, of a successful performance management program by sharing ownership, increasing data integrity, building communications and ensuring a firm commitment to the transit agency and its performance management program.

Grace, R. & Suski, V. (2001). Improving safety for drivers and fleets: Historical and innovative approaches. Driving Assessment 2001: The First International Driving Symposium on Human Factors in Driver Aassessment, Training and Vehicle Design (pp. 345–350).University of Iowa Public Policy Center.
Author Summary: A two-day conference that addressed “improving safety for drivers and fleets” was held at Carnegie Mellon University and sponsored by the 21st century driver and truck alliance and the Federal Motor Carrier Safety Administration (FMCSA). The conference brought together stakeholders within the trucking industry and safety experts

from other industries to explore approaches to improve driver and fleet safety. The goal of the conference was to facilitate discussions among industry stakeholders as a first step in identifying and implementing effective safety processes that may advance the FMCSA's ambitious goal of 50% reduction in truck-related fatalities by 2010. On day one there were three sessions related to trucking and industrial safety. The first session offered two views of historical safety initiatives as a foundation for understanding current industry safety practices. The second session focused on current efforts by government, fleets and truck manufacturers. The third session provided an opportunity for presenters to describe successful safety programs not currently being widely applied to the trucking industry.

On day two a morning-long panel discussion considered the approaches presented the previous day. A subsequent brainstorming session involving all attendees generated other independent or related approaches. The goals of the discussions on day two were 1) to identify practical safety steps that can be applied by fleets and drivers now and in the near future and 2) to identify potential partnerships for implementing and testing new safety initiatives. Ultimately, the panelists and participants developed 26 action items that will be ranked and used as a springboard for future truck safety efforts.

Hartman, K., Jennings, K., Johnsom, J., Knipling, R., Macgowan, J., Oliphant, L., Onder, M., Pritchard, B., & Sanft, C. (2000). *Commercial vehicle safety: Technology and practice in Europe* (FHWA Publication No. PL-00-010). Federal Highway Administration (U.S. Department of Transportation). (NTIS No. PB2001-101244)
Author Abstract: The United States and countries of the European Union share many of the same concerns and face similar challenges about commercial vehicle safety issues. This summary report describes the September 1998 technology transfer scan tour to four European countries to learn how these countries are addressing their own safety issues, even as they comply with the increasing centralization of rules and regulations enacted by the European Commission. The nine-member scan tour team that visited France, Germany, Sweden, and the Netherlands represented the Federal Highway Administration, the Virginia and Minnesota State Departments of Transportation, the Owner/Operators and Independent Drivers Association, and independent transportation consultants. The key areas examined by the team were human resources, vehicle safety systems, and regulations. The report also includes recommendations and implementation strategies.

As this report demonstrates, team members were particularly interested in the European's integrated approach to driver training and preparation, the role of truck manufacturers in assessing crash causes and statistics to improve safety design, and the public/private partnerships that enhance training and safety, and augment regulatory policies and practices. The team believes that these practices provide valuable models for fresh opportunities for public/private cooperation in the areas of safety enhancement, regulatory policies, and standards enforcement for the U.S. motor carrier industry.

Hickman, J.S. (2006). *High-risk commercial motor vehicle drivers and differential crash risk: Future directions.* In N. Kassabian (Ed.), Future Truck and Bus Safety Research Opportunities (pp. 16-23). Washington, D.C.: Transportation Research Board.
TRIS Abstract: A variety of factors influence commercial motor vehicle (CMV) driver risk.

Few studies have attempted to integrate all the interacting factors that may contribute to an increased risk of a crash and most studies fail to account for exposure. Most studies use self-reports of prior crashes or retrospective Department of Motor Vehicle records. These approaches have limited utility because they are likely to be inaccurate, crashes are not always reported, and near crashes are not considered. Current knowledge suggests there are certain factors associated with high-risk driving, but a comprehensive model on how these factors interact with each other does not exist. Further, all of these factors have not been included in one study, nor have they been studied under naturalistic driving conditions. The finding of differential crash risk among CMV drivers along many safety-related personal dimensions presents an opportunity for the trucking industry and government safety officials. Suggested research and development opportunities for addressing the problem of high-risk drivers include the following: validating prior research findings indicating differential driver risk; determining how enduring these differences are across time; profiling individual differences within a group of drivers and relating these differences to safety outcomes; assessing the efficacy of various driver selection instruments; verifying that differences in fatigue susceptibility are long-term personal traits, identifying ways to assess the level of fatigue susceptibility, and determining the physiological basis of differential fatigue susceptibility; documenting and disseminating the best driver management practices for use by carrier safety managers; developing onboard safety monitoring (OBSM) devices that can record a variety of safety-related driving behaviors and management protocols for the successful use of OBSM data for reducing at-risk driving behaviors and crash rates; improving driver training programs; and industry pilot testing of behavioral safety management techniques to reduce the risky driving behaviors of high-risk drivers.

Iavicoli, S., Rondinone, B., Marinaccio, A., & Fingerhut, M. (2006). Research priorities in occupational safety and health: A review. *Industrial Health, 44,* 169-178.
Author Abstract: Changes in the world of work in the last few decades have markedly affected questions regarding OSH. Jobs in our economy continue to shift from manufacturing to services. Longer hours, shift work, reduced job security, temporary work are realities in the modern workplace, new chemicals, materials, processes are developed at an ever accelerating pace. The workforce is also changing. It will become older and more racially diverse and women are increasing. These changes present new challenges to protect worker safety and health and it was been indispensable to redefine priorities, by consulting all those involved in OSH. The present study therefore made a critical comparative analysis of the main published projects to identify research priorities in the OSH field, comparing methods, approaches and results. Comparison of the priority areas established in each of these studies is inherently difficult due to differences in socio-cultural backgrounds, in the methods employed to identify priority topics, and the many factors involved. However, it is clear that the Delphi technique is widely used as a reliable method, in that it covers a broad range of qualified witnesses, from a variety of backgrounds-such as trade union representatives and researchers-providing different viewpoints. It also takes account of the intrinsic features of OSH which-compared to other disciplines-involves multidisciplinary factors calling into play a range of scientific settings, such as toxicologists, molecular biologists, epidemiologists, occupational hygienists and occupational physicians. This analysis showed how important it is to reach consensus among all those operating in the OSH sector, in order to establish standard methods that can be applied in different contexts, and give results that can be validly

compared.

King, R. D. (1996). Bus occupant safety. *TCRP Synthesis of Transit Practice, 18.*
Author Abstract: This synthesis will be of interest to transit agency general managers, bus operations, safety, and risk management staffs, as well as agency human resources, personnel, and training staffs. It offers information on the current practices of transit agencies to reduce injuries to bus occupants during collisions and injuries to passengers while boarding, riding, and leaving the bus. This synthesis covers characteristics of bus occupant safety and transit agency programs for reductions of accidents/incidents such as those addressing driver and customer safety, vehicle improvement needs and safety inspections, bus stops and stations, safety management, and state transit agencies and transit operating companies.

Knipling, R.R. (2005). Evidence and dimensions of commercial driver differential crash risk. Driving Assessment 2005: 3rd International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design (pp. 2-8). Iowa City: University of Iowa.
Summary: This paper highlights evidence from several instrumented vehicle studies that crash risk varies significantly among commercial truck drivers, and also cites findings from surveys of fleet safety managers and other experts on the topic of individual differences in commercial driver crash risk. Within various subject groups, 10-15% of the drivers typically account for 30-50% of the crash risk. This pattern is seen in measures of driver errors associated with crashes and also in measures of driver drowsiness. The evidence also suggests, but does not yet prove, that these individual differences are long-term. To the extent that these individual differences are long-term, they may be considered personal traits. This paper conceptualizes driver risk factors, provides illustrative examples of differential individual risk within groups of drivers, identifies driver factors thought to be most associated with crash risk, and considers the opportunities for improved commercial driving safety presented by differential crash risk.

Knipling, R.R., Alvarez, A., Carroll, R.J., Robin, J.L., & Roke, P.J. (2002). Commercial driver human factors R&T. In Z.G. Zacharia (Ed.), *International Truck and Bus Safety Research and Policy Symposium* (pp. 3-14). University of Tennessee, Knoxville: National Safety Council.
Author Abstract: The human element is dominant in commercial motor vehicle (CMV) crashes, as in all types of traffic crashes. Driver human factors research and technology (R&T) at the Federal Motor Carrier Safety Administration (FMCSA) is directed toward improving CMV driver safety performance as a means of CMV crash reduction. This includes R&T to better assess the problem; improvement of driver physical qualifications and health; R&T on CMV driver training, licensing, and safety performance; and R&T on CMV driver alertness and fatigue. In addition, studies of carrier safety management include human factors-related approaches to increasing the safety knowledge and motivation of drivers and other carrier personnel. This paper reviews the principal safety issues and agency activities associated with these human factors R&T areas, which are coordinated and managed primarily by the Research Division of the FMCSA Office of Research and Technology. It highlights recent findings, current activities, and future plans relating to these human factors issues.

Knipling, R.R., Boyle, L.N., Hickman, J.S., York, J.S., Daecher, C., Olsen, E.C.B., & Prailey, T.D. (2004). *Individual differences and the high-risk commercial driver.* Transportation Research Board Commercial Truck and Bus Safety Synthesis Program (CTBSSP) Synthesis 4. (NTIS No. PB2005-100981). http://www.trb.org/news/blurb_detail.asp?id=4295
Foreword: This synthesis will be of use to state agencies, commercial truck and bus carriers, and others interested in improving commercial vehicle safety. It explores individual differences among commercial drivers, particularly as these differences relate to the "high-risk" commercial driver. The synthesis identifies factors relating to commercial vehicle crash risk and assesses ways that the high-risk driver can be targeted by various safety programs and practices, at both fleet- and industry-wide levels. It summarizes available information on individual differences in commercial driver safety performance and alertness, examines various metrics and tests that might be used to hire safer drivers and avoid hiring high-risk drivers, and identifies safety management techniques that are currently used by commercial vehicle carriers to target problem drivers and their specific risky behaviors. Information for this synthesis was obtained through surveys of current commercial motor vehicle safety managers and other experts in commercial motor vehicle safety; a focus group conducted with staff members of the U.S. Department of Transportation Federal Motor Carrier Safety Administration; and a review of relevant literature.

Knipling, R.R., Hickman, J.S., & Bergoffen, G. (2003). *Effective commercial truck and bus safety management techniques.* Transportation Research Board Commercial Truck and Bus Safety Synthesis Program (CTBSSP) Synthesis 1. (NTIS No. PB2003-107644) http://www.trb.org/news/blurb_detail.asp?id=1619
Foreword: This synthesis, the first in the CTBSSP series, will be of use to commercial truck and bus carriers and others interested in improving commercial vehicle safety. It provides a useful summary of practice in the area of commercial truck and bus safety management techniques. The synthesis focuses on the problems fleet managers confront and the methods that are available to address these problems. Twenty discrete safety problems and 28 safety management methods are identified. Problems addressed encompass driver-safety knowledge, skills, alertness, physical/medical condition, attitudes, and driving behaviors. In addition, several vehicle-related problem areas, including vehicle maintenance and inspection, are discussed. Major safety management approaches addressed include driver recruiting and selection, carrier-based training, management-driver communications, driver safety-performance evaluation, safety incentives, behavior-based safety, on-board safety monitoring, event-data recorders, accident investigation, improved driver scheduling and dispatching, fatigue management, carrier-based medical programs, preventive maintenance and vehicle inspection, advanced safety technologies, and industry-based safety standards and certification. The synthesis is based on a review of relevant literature, as well as a survey of commercial motor vehicle safety managers (139 respondents) and other experts in motor carrier safety (57 respondents).

Kompier, M. A. J., Aust, B., van den Berg, A.-M., & Siegrist, J. (2000). Stress prevention in bus drivers: Evaluation of 13 natural experiments. *Journal of Occupational Health Psychology, 5,* 11–31.
Author Abstract: The research aim was to select, compare, and analyze interventions and

preventive actions from international bus companies to decrease bus drivers' occupational stress and sickness absenteeism. Through networking, international surveys, and literature study, 13 "natural experiments" were identified with an acceptable research design rating. Interventions were both work and person directed. Principles of worker participation were often followed. The variety in intervention programs, outcome measures, case evaluations, and methodological flaws makes it difficult to present a general picture of program effectiveness. However, analyses on more objective and more subjective outcomes do point at positive effects. This study suggests that stress prevention that combines adequate interventions and proper implementation may be beneficial to both the employee and the company.

Krause, T.R., Robin, J.L., & Knipling, R.R. (1999). *Potential application of behavior-based safety in the trucking industry - Final rept. Aug 98-May 99* (FHWA Publication No. MC-99/071). Federal Motor Carrier Safety Administration.
TRIS Abstract: Behavior-based safety (BBS) is a set of methods to improve safety performance in the workplace by engaging workers in the improvement process, identifying critical safety behaviors, performing observations to gather data, providing feedback to encourage improvement, and using gathered data to target system factors for positive change. In August, the Federal Motor Carrier Safety Administration (FMCSA) sponsored a group of seminars on BBS as part of its human factors research program on driver performance enhancement. In particular, FMCSA is interested in ensuring the safe, effective use of current and advanced in-vehicle driver performance monitoring devices (e.g., speed monitoring, headway monitoring, alertness monitoring). Performance monitoring offers an opportunity to improve driver safety and productivity by measuring and providing feedback to drivers on critical performance variables.

Mullen, M. (1996). *Truck safety: The search for excellence.* F. Saccomanno & J. Shortreed (Eds.), Truck safety: Perceptions and reality (pp. 23-28). University of Waterloo: Institute for Risk Research.
TRIS Abstract: The author of this paper acknowledges problems with public perceptions of truckers and the trucking industry. He offers ways in which the trucking industry can improve its image and its performance. Some of these are: management commitment and leadership; setting performance standards; safety accountability; recruitment standards; training and skills upgrading; performance measurement; excellence rewards; and correction of non-conformance.

Murray, D.C., Dick, V.R., & Houser, A. (2006). Synthesis of commercial motor vehicle safety technology surveys: What have we learned? *Transportation Research Board 85th Annual Meeting.*
TRIS Abstract: This paper documents and synthesizes the major qualitative survey efforts within the U.S. relating to stakeholder design, use and perspectives of onboard truck safety technologies. The Federal Motor Carrier Safety Administration (FMCSA) and the American Transportation Research Institute (ATRI) have conducted a survey synthesis and meta-analysis to consolidate, analyze, and identify gaps in the existing survey research on safety technologies. Over the last several years, there has been an increasing interest in onboard truck safety technologies. At different times, entities such as the FMCSA, Federal Highway

Administration (FHWA), ATA and ATRI have undertaken different survey projects to document and understand onboard safety technology applications. While a wide variety of data has been collected by these projects, there has been little effort to aggregate data across projects. The current synthesis includes the analysis of over 11 survey, interview and focus group instruments; representing 558 respondents and 56 unique questions. Preliminary results indicate that while the existing research addresses many issues related to carrier purchase and use of technologies, there is a considerable gap in research addressing driver attitudes, experiences, and preferences. At the technology level, satellite or cellular communication between terminal and vehicle and GPS are the technologies most commonly used by carriers. Most carriers who have a safety technology installed on their fleet have already realized the desired safety benefits, often an intangible one from a quantitative perspective. Cost and lack of clear data about benefits are the two biggest factors preventing wider installation of safety technologies.

Murray, W., & Whiteing, T. (1995). Reducing commercial vehicle accidents through accident databases. *Logistics Information Management, 8,* 22.
Author Abstract: Commercial vehicle accidents impose very significant costs on industry and society but for a variety of reasons the full costs are often poorly understood. It is advocated that vehicle operators should undertake a full and systematic analysis of accident levels, causes and costs. The CCSM model of vehicle accident reduction is introduced. By undertaking analysis based on this approach, most vehicle operators should be able to identify measures to reduce accidents substantially. Typical measures include the implementation of vehicle accident monitoring systems, driver age and experience policies, reviews of vehicle speed policy, driver training schemes, more systematic driver recruitment and better vehicle specification.

National Private Truck Council (2006). *National Safety Conference: Solving the Safety Puzzle*. Program Agenda, Retrieved from https://www.nptc.org/pdf/nscwebprog06.pdf on February 15, 2007.

Porter, R.C. (2002). Training and supervision safety regulations used to support company negligence claims. In Z.G. Zacharia (Ed.), *International Truck and Bus Safety Research and Policy Symposium* (pp. 323-325). University of Tennessee, Knoxville: National Safety Council.
TRIS Abstract: Is it proper to hire or retain a driver who received two speeding tickets within the past year? What about a driver who was convicted of check fraud? Can you hire or retain a driver who takes Prozac by prescription? Suppose the driver has been involved in a previous major accident? What about four minor accidents, three of which were preventable? What if the driver has driven only a box van and you want him to pull a flat bed? If the driver has worked as a truck driver for less than a year can you put him to work without any training? Should you accept a driver whose eye tests are right at the outer limit of 20/40? The answer is "yes," you can hire these drivers in full compliance with the regulations. Of course, if the question is being asked in the aftermath of a serious accident involving that driver, the company will be portrayed as acting in reckless disregard of its safety obligations. In any driver work force there are many drivers with blemishes such as these which may make them less than perfect, but not necessarily ineligible for hiring. How can it be that these drivers

may appear entirely proper in any sort of Department of Transportation audit or safety review and yet become an abomination merely because they had the misfortune of being involved in a serious accident? The problem lies in the subjective nature of certain regulations.

Proceedings of the first international driving symposium on human factors in driver assessment, training and vehicle design. (2001). In D.V. Mcgehee, J.D. Lee, M. Rizzo, K. Holeton, and T. Lopes (Eds.), *International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.* University of Iowa, Iowa City.
TRIS Abstract: Driving Assessment 2001 was originally conceived to fill a multidisciplinary gap in driver safety research. The symposium brought together experts in human factors, medicine, engineering design, operations and policy from all over the world. Participants from 16 countries contributed to the scientific program. The friendships and partnerships forged at this meeting have created new opportunities for collaboration. The papers contained in these proceedings represent a significant contribution to the human factors and driver safety research literature. The proceedings include 81 papers, a panel discussion, and an author index. The papers are organized into the following technical sessions: Attention and Distraction; Driver Training and Licensing Issues; Fatigue and Impairment; Driver Performance Assessment; Information Display Issues in Driver-Vehicle Interface Design; Medical Factors; Commercial Vehicle Operations; Infrastructure and in-Vehicle Systems.

Roberts, S. & York, J. (2000). *Design, Development, and Evaluation of Driver Wellness Programs*, Final Report, FMCSA Report No. MC-00-193.
Introduction: The initial step in designing a successful wellness program for commercial vehicle drivers is to review the current literature and practice with regards to the health status of the population and wellness programs in operation.

As the literature and practice review are presented it must be noted, that even though there are almost three million commercial motor vehicle drivers in the United States, little research has been done specifically to examine the health status of these workers. Likewise they are not a population that has had frequent opportunity to participate in company sponsored wellness programs. This is quite ironic and of significant importance considering the results of this review.

The following sections provide an overview of the driver health literature and a review of existing wellness programs and practices—both within and outside of the trucking industry. The results of the first two driver focus groups are also included in this document to provide a summary of research progress to date. A summary of this effort's research implications and next steps are also provided.

Schneider, N.R. & Cottrell, D.P. (2002). Using performance measures to effect safety improvements: A case study from the New York State comprehensive bus safety inspection program. In Z.G. Zacharia (Ed.), *International Truck and Bus Safety Research and Policy Symposium.* University of Tennessee Knoxville: National Safety Council.
Author Abstract: This paper describes how the New York State Department of Transportation, through a cooperative relationship with the bus industry, undertook an action

plan to clarify and strengthen its Bus and Passenger Vehicle Safety Regulations and to establish industry performance goals to reduce Bus Safety Out-of-Service (OOS) rates statewide. Over the course of 5 years, the State's regulations were updated with extensive industry input and the average OOS rate for key operators has been reduced from 24.5% in 1995 to 9.6% in 2002—a 60% reduction in vehicles being placed Out-of-Service and requiring a safety re-inspection before being operated on a public highway in the State. The paper is intended to assist others involved in performance based safety programs better understand how to build outcome driven performance programs that can achieve significant results.

Stock, D. (2001). *I-95 Corridor Coalition Field Operational Test 10: Coordinated Safety Management*. Volume I: Best Practices in Motor Carrier Safety Management, Final Report.
NTIS Abstract: Coordinated Safety Management is an I-95 Corridor Coalition-sponsored project which was designed to identify the factors that contribute to exemplary motor carrier safety performance and develop outreach materials and tools to help carriers operate more safely. One of the goals of the I-95 Corridor Coalition Field Operational Test No. 10 (FOT 10)-Coordinated Safety Management-is to develop recommendations for educational and outreach programs and materials to improve motor carrier safety and compliance with regulations. Maximizing the value of these efforts requires an understanding of what the common safety deficiencies are and what safe carriers do to avoid these deficiencies. To this end, the study team analyzed the results of roadside safety inspections for motor carriers based in the I-95 Corridor Coalition states; performed an extensive review of motor carrier safety educational materials and programs; and, conducted a survey of nearly 600 commercial motor carriers who are, arguably, among the safest operators. This report provides an overview of: Motor carrier safety/compliance deficiencies; The safety management practices of safer fleets; The topic and delivery media the safer carriers feel would be of most value to their safety programs; and, Motor carrier views on enforcement and regulations.

Truck safety: Perceptions and reality. (1996). F. Saccomanno & J. Shortreed (Eds.) University of Waterloo: Institute for Risk Research.
TRIS Abstract: This book is the result of a North American conference of industry stakeholders, government regulators, and highway safety researchers held to review factors affecting safety in the trucking industry and to develop a collective view of critical truck safety issues. Published with support from Transportation Development Centre and Ontario Ministry of Transportation, the book features current issues, trends, and future directions on the following topics:
- Carrier management practices to improve safety and profitability
- Driver fatigue and accident risk
- Causes and consequences of truck accidents
- New technologies in vehicle and roadway design
- Regulation and policy in Canada, U.S. and Mexico
- Load security issues
- Industry stakeholder consensus on critical truck safety issues and proposed initiatives

Tse, J.L.M., Flin, R., & Mearns, K. (2006). Bus driver well-being review: 50 years of research. *Transportation Research Part F: Traffic Psychology and Behaviour, 9,* 89-114.
Author Abstract: This review paper consolidates the key research on the occupational health of urban bus drivers since the 1950s. Several electronic databases were searched and 27 key studies were identified, which form the basis of this paper. Early findings that bus drivers are liable to suffer ill health as a result of the job remain true today. The research has, however, demonstrated a greater understanding that specific stressors result in certain physical (cardiovascular disease, gastrointestinal disorders, musculoskeletal problems, fatigue), psychological (depression, anxiety, post-traumatic stress disorder) and behavioural outcomes (substance abuse). Bus driver ill health will have consequences for organisational performance in terms of employee absence, labour turnover and accidents. Stressors for bus drivers include poor cabin ergonomics, rotating shift patterns and inflexible running times. Over the last few decades, the heightening of other work stressors such as traffic, and violence from passengers have compounded the situation for bus drivers. Greater attention to salient moderating and mediating variables in the stressor-strain relationship is featuring in more recent research. Despite such theoretical advances, the research needs to also concentrate on practical interventions that are systematically implemented and evaluated, to improve the well-being of bus drivers. By improving this 'human side' of the role, it is expected that the efficiency of this transport will be enhanced for bus drivers, operators and passengers alike.

Wachtel, J., Sizov, K., Fisher, D.L., Mourant, R., & Crean, C.M. (2006). *Safety challenges facing tomorrow's commercial drivers and the role of new simulation technology to meet them.* In N. Kassabian (Ed.), Future Truck and Bus Safety Research Opportunities Washington, D.C.: Transportation Research Board.
Preface: On March 23 and 24, 2005, a group of industry, government, university, and consultant experts gathered in Arlington, Virginia, to participate in a conference on future truck and bus research opportunities. The purpose was to ponder the future of the commercial vehicle industry and to identify research requirements in preparation for the proposed future. The conference was jointly sponsored by the Transportation Research Board and the Federal Motor Carrier Safety Administration.

The conference was planned and conducted under the auspices of a specially appointed committee convened by the National Research Council. The purpose of the project was to examine future scenarios and consider the following questions: What will the future be like in terms of truck and bus travel? What will be the impact of the anticipated conditions on safety? What research should be accomplished to prepare for the future? Some related issues, such as potential barriers to implementation of research findings, were briefly raised during the conference and their importance noted. Because such issues go beyond the scope of this project, however, they were not a focus of conference or committee discussions, and they are not addressed in this report.

Wilde, G. (1996). *Improving trucking safety and profitability through safety incentive schemes.* F. Saccomano & J. Shortreed (Eds.), Truck safety: Perceptions and reality (pp. 21-252). University of Waterloo: Institute for Risk Research.
Author Abstract: The current state of knowledge concerning the effects of incentives for

safety in industrial settings and in road traffic is applied to the specific purpose of enhancing the safety of long-haul trucking in Canada. Mobility and accident statistics pertaining to recent years in the U.S. and Canada are reviewed. Attention is drawn to the important distinction between incentives for specific behaviors (such as using safety equipment, sobriety, or obeying the speed limit) and incentives for successful avoidance of accidents of their own fault. The disadvantages of the use of disincentives (punishments) as compared to positive incentives (rewards) are also pointed out. The report includes a checklist of the requirements for maximally effective incentive programs for accident-free operation according to the present state-of-the-art. The issues of benefit-cost ratios of incentive programs and of the possible desirable and undesirable side-effects of their implementation are also discussed.

CONCLUSIONS

This review demonstrates the utility of using tailored versions of Haddon's matrix as a framework for addressing some of the prime safety concerns in the trucking industry and FMCSA alike. These include the recruitment, selection and retention of a safe workforce in Review #1, and the factors related to improving safety as associated with existing drivers and motor carrier operations in Review #2. As a caveat that should be noted regarding the current effort, this document is not intended as a comprehensive review of the many antecedents of safety outcomes, and it intentionally did not duplicate the focus or content of any recent FMCSA-sponsored work.

With regard to the findings presented in this document, although it was not possible to annotate the hundreds of trade sources that were amassed in the same way as was done for the resultant scientific literature, exploring both academic and industry viewpoints was beneficial and allowed for a more complete understanding of the complex nature of the trucking industry. Precisely because new and updated industry information is constantly being generated, in particular online, only the most recent published trade material was relied upon when citing sources.

Also, as previously mentioned, the scientific literature pertaining to the two Haddon matrices used to structure the reviews did not produce a uniform distribution of studies across pre-event, event, and post-event stages. There are a number of plausible explanations for this outcome. For example, it may be the case that trends in research areas (i.e., current, popular topics) drive individual academic pursuits more so than do industry needs; or alternately, that studies indeed exist, but have not been published in the open literature for reasons of perceived competitive advantage or even potential liability. Further, although research often could have been framed by reviewers to fit within more than one area of the matrix, the literature was categorized with the perceived purpose of the author(s) in mind regarding whether results were geared towards the individual (driver) or organizational (motor carrier) level, and additionally by which focus question and stage of the event cycle was best addressed.

This process resulted in 80% of studies falling within the post-event stage for Review #1, where the bulk of the research concentrated on issues related to voluntary and involuntary driver turnover. It bears restating here that a company's singular focus on minimizing turnover, while indeed a means of stabilizing workforce size, may have the unintended consequence of retaining unsuited or undesirable drivers. If not carefully considered and implemented, such practices have the potential to negatively impact both safety and motor carrier performance. For this reason, a more complete consideration of the pre-event and event stages as pertaining to selecting safe drivers is recommended. This implies the need for additional, systematic investigation of methods for improving motor carrier strategies and procedures for recruitment and selection, so that larger pools of qualified applicants may be hired, and ultimately retained as CMV drivers. In contrast to Review #1, the second review of literature, which explored improving driver safety, resulted in over twice as many annotations, with 50% of the studies falling within the pre-event stage of the Haddon matrix. This focus on the driver factors and existing motor carrier practices that impact various safety outcomes is logical in the sense that it concentrates on issues that may be preemptively used to help ensure safe driving, including attending to individual driver differences pertaining to age and abilities, considering past behavior as a predictor of future behavior, and organizational factors, such as safety climate and incentives. However, in an effort

to more fully consider the entire event-stage continuum, additional research in the areas of improving safety outcomes through real-time monitoring of driver-generated data and including successful strategies for providing feedback to drivers and motor carriers is recommended.

Research gaps in the annotated literature aside, certain related themes span the two reviews or are common across the scientific and trade publications. As stated within the goal of this effort, study outcomes that focused on safety were of primary importance to the project. Objective measures of safety, including crash rates, driving performance, and motor carrier safety records, were directly assessed within the second review; whereas indirect impacts to safety, such as the organizational effects of and individual reasons for driver turnover, as well as costs associated with company efforts to recruit, select, train, and retain the best/safest drivers, were more common within the first review. As an example, findings in Review #2 referenced a favorable performance record for passenger over commodities carriers, and that private carriers tended to be statistically safer than for-hire carriers. This is noteworthy in conjunction with results from the first review indicating that quit rates are lower for drivers who are home more times per month, as is the case with passenger over commodities carriers and is also true for smaller, private firms. Additionally, information provided in trade publications suggests that insurance policies are less expensive for private carriers due to generally superior safety records and a more stable workforce than their for-hire counterparts. Indeed, drivers with longer job tenure, as often found in private fleets, are likely to be a reflection of a successful organizational model that serves to promote a culture of longevity and should be considered across trucking sectors. This model encompasses direct communication with drivers and maintaining one-on-one contact to the extent possible, so that dispatchers are not perceived as the sole "face" of the company. Moreover, offering competitive wages, fair treatment of employees, appreciation of effort, and favorable and safe working conditions is prescribed in the first review as a means of bolstering job satisfaction. The organizational benefit to satisfied drivers is a workforce that is less likely to turnover, or "churn," thus reducing the need for and cost of additional recruitment, selection, hiring, and training.

Overall, outcomes from the two reviews suggest that the safety of CMV drivers may be improved through a multifaceted approach that strives to consider all stages of the Haddon matrix event-cycle as tailored for this project. To start, the systematic and selective use of inexpensive technology (e.g., the internet and available methods for obtaining current driver history data) in the applicant recruitment and selection process will both reach the greatest number of potential employees and most effectively eliminate those who are not well-suited for the job. Given the projected, continued growth of the trucking industry, this demand for drivers will remain unmet to the extent that non-traditional applicant source pools are left untapped. These include younger people, who may not have otherwise considered truck driving as a job and can be initially trained in apprentice programs; the older generation now looking for a career change; women, who have not, historically, been a focus of recruiting; and minorities, who may require additional training to help develop necessary English-language skills, but are otherwise well-equipped for such a career.

Once a company has successfully hired the most qualified and motivated workers, it is imperative that compensation is adequate, and also essential that employees are satisfied with their jobs and quality of life outside of work. This is especially important for truck driving, as it does not typically provide the same type of career path as other occupations (beyond the benefits

associated with seniority). In this manner, over time and in conjunction with continued organizational investment, it should be possible to build a workforce that is stable and well-trained. Ultimately, these conditions are optimal for engendering employee trust, commitment, and buy-in. With employee trust, effective communication, and a positive safety climate, promising technologies such as on-board monitoring and programs utilizing behavior-based safety are likely to be more favorably received and more effective due to a universal understanding of organizational goals pertaining to safety. All things considered, the outcome for trucking organizations that commit more time and additional resources up-front should include a larger, more qualified workforce, improved job satisfaction, increased safety performance, and ultimately, a significant cost savings.

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