Medical Exemption Program Study

Preliminary Report of Findings

final

report

prepared for

Federal Motor Carrier Safety Administration

prepared by

Cambridge Systematics, Inc.

October 13, 2006

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1.0 Introduction

1.1 Overview

This Preliminary Report of Findings is the third deliverable in the Medical Exemption Program Study, being performed by Cambridge Systematics on behalf of the Federal Motor Carrier Safety Administration (FMCSA).

The primary mission of the FMCSA is to reduce collisions, injuries, and fatalities involving large trucks and buses. To this end, the FMCSA has established regulations and processes for licensing drivers operating commercial vehicles. Individual states perform the actual licensing. A portion of the licensing process involves a medical examination by a licensed physician. The results of the medical examination must be consistent with standard Federal regulations. The regulations, however, allow for exemptions to be granted on a case-by-case basis. Two of the areas where exemptions may be granted relate to vision impairment (the FMCSA Vision Exemption Program) and insulin-treated diabetes (the Federal Diabetes Exemption Program).

The goal of this project has been to provide process and outcome information regarding these exemption programs that will inform FMCSA policy and guide program improvements. To achieve this goal, Cambridge Systematics used multiple research techniques to review both exemption programs. These techniques included review of relevant literature, interviews of drivers in the Vision Exemption Program, and statistical analysis of reported collision data.

This document presents the project findings. The primary conclusion is that the Vision Exemption Program does not appear to be negatively impacting the safety of the nation's highways. Drivers in the program have lower reported annual collision volumes than a control set of the general commercial driver population and similar reported annual collision volumes compared to a control subset of general commercial vehicle drivers with no reported annual collisions between 2001 and 2003. Potential areas where portions of the program standards could be relaxed and other areas where portions of the program standards may need to be tightened have been identified. The conclusions, however, are not based on a statistically significant sample because of the program's limited size and strict acceptance criteria.

This report presents six recommendations to allow FMCSA to undertake a continuous improvement process for both the Vision and Diabetes Exemption Programs. These recommendations are described in Section 7.2. Implementation of some or all of these recommendations will enable the agency to continue to make informed decisions about the management of these programs.

1.2 ORGANIZATION OF THIS REPORT

This document contains seven sections. These sections include:

- **Section 1.0, Introduction –** Provides an overview of this report.
- **Section 2.0, Analysis Methodology –** Describes the approach used to conduct both the qualitative and quantitative portions of this project.
- **Section 3.0, Information Sources –** Describes the approach for obtaining information to support the analysis methodology.
- **Section 4.0, Literature Review –** Presents the key findings of the scan of over 100 literature items related to vision and diabetes driving issues.
- **Section 5.0, Driver Interviews –** Presents the key findings of the interviews of nine drivers currently enrolled in the Vision Exemption Program.
- **Section 6.0, Quantitative Analysis –** Presents the key findings of the statistical analysis of program and control data, including both descriptive statistics and structured hypothesis testing.
- **Section 7.0, Findings and Recommendations –** Summarizes the most important findings of the study and presents six recommendations for continuous program improvement.

In addition, the report contains two appendices:

- **Appendix A, Literature Sources –** The bibliography of all sources identified by the project team for both the vision and diabetes literature reviews is presented.
- **Appendix B, Driver and Collision Data Schema –** The input schema to the SAS statistical package for both driver information and collision information are presented.

These appendices are provided under separate cover in the Preliminary Report of Findings, but will be incorporated into the same bound version in the Final Report.

2.0 Analysis Methodology

2.1 The Role of Hypotheses

A guiding principle of the project team's approach to analyzing the Vision and Diabetes Exemption Programs was that the analysis approach must be defined in advance of any actual analysis. Specifically, the analysis approach defines the current policy as a series of currently known facts and assumptions, and defines "evaluation" as an approach that challenges relevant components of the policy.

Hypotheses start out as broad statements which over time are refined into more detailed statements. The level of detail at which a hypothesis can be modeled, however, directly depends on the information available. To understand if the current program is the appropriate policy, researchers must be able to model not only the current assumptions, but also the assumptions which are necessary for various alternative policies.

The team's objective is to define hypotheses which model various shifts in both policy and underlying assumptions, and test these hypotheses in as many ways as practical. In the context of this study, "testing" involves four levels of complexity:

- Review of existing literature, to determine how previous research results correspond to the hypotheses;
- Interview of current program drivers, to gain an understanding of how the agency's customers view the hypotheses;
- Descriptive statistical analysis of collision data, to identify general trends in data and how these trends support (or do not support) the hypotheses; and
- Detailed statistical tests of collision data, to explore specific patterns of data and how the data patterns support (or do not support) the hypotheses.

The overall hypothesis used by the project team as a starting point is the following generic statement:

There are parts of the current policy which will appear to be too *lenient*, and other parts of the policy which will appear to be too *severe*.

It is extremely important to establish a neutral hypothesis. Failure to define the project evaluation in neutral terms subjects the project to the risk of introducing bias into the process, and therefore the results. The challenge for the project team was to define the specific analyses in a manner that supports the generic statement. In all cases, the project team attempted to identify elements of current processes where "lenient" and "severe" could be defined.

2.2 Terminology Specific to the Methodology

Part of the assumption documentation process involved the development of specific terms with specific meanings and use of these terms by all members of the project team throughout the project.

Five terms will be used repeatedly throughout this report of findings. The terms and definitions are as follows:

Program Driver

A "program driver" is a licensed Interstate commercial vehicle driver who was accepted at any time in the Vision or Diabetes Exemption Program. The program driver may or may not be active in the program for quantitative analysis, but must be active in the program to qualify for consideration in the driver interview process.

Control Driver

A "control driver" is a licensed interstate commercial vehicle driver who had a driver inspection reported to the Motor Carrier Management Information System (MCMIS), and has never applied for the Vision or Diabetes Exemption Program. Approximately nine control drivers were randomly selected for each program driver, to support qualitative analysis of the form "Program Drivers have different outcomes than Control Drivers in terms of outcome X." Section 3.3 describes the control program in greater detail.

Reported Collision

A "reported collision" is a collision event for which information can be found in MCMIS. Participating state agencies transmit data about collisions to MCMIS via the SAFETYNET program. There is no assumption that all collisions in which a particular driver has been involved will be found in the MCMIS data set, nor any assumption about the driver's fault in the reported collision.

Acceptance Date

The "acceptance date" of a program driver is the date when the driver is first allowed to operate a commercial vehicle using their vision or diabetes exemption.

Control Date

Many of the hypotheses use a qualifier of "for X months before (or after) acceptance date." In order to use these hypotheses to compare program and control drivers, the project team used a single surrogate acceptance date for the control drivers. Without a fixed date, a bias could be introduced as different control drivers could have different dates. After consultation with the FMCSA project manager, December 31, 2003 was chosen as the "control date" for all control drivers.

2.3 Qualitative Analysis Techniques

The analysis approach balanced qualitative and quantitative analyses. Cambridge Systematics' research methodology divided the qualitative analysis into two parts. First, a detailed review of the existing literature concerning vision and diabetes issues for drivers was conducted. Second, drawing on the literature review, an interview guide was developed for use in structured interviews of a sample of current program drivers.

Literature Review

Cambridge Systematics conducted a review of relevant literature using a variety of publications. The results of the review provided direction for developing the interview guide for program drivers as well as for later qualitative review of available data.

The project team divided the literature review into the following tasks:

- **Current Bibliography –** Cambridge Systematics requested the current set of scholarly articles which are used by FMCSA for the Vision and Diabetes Exemption Programs.
- **Development of Approach to Literature Topics –** Cambridge Systematics used the current bibliography to determine an approach for reviewing the literature in this area. The approach involved an intensive search using both general search engines such as Google as well as specific medical literature search engines. The approach constructed a "tree" of key words and phrases from the existing literature.
- **Initial Literature Scan –** Cambridge Systematics reviewed the current literature using the tree-based approach identified above. The results of the initial scan included a bibliography of all relevant articles and, when possible, article abstracts. These results were presented to FMCSA for prioritization, and are included as Appendix A of this report.
- **Detailed Literature Review –** FMCSA staff selected approximately one-fifth of the initial literature for detailed review. Cambridge Systematics obtained full-text versions of each article and developed a summary of the key relevant findings. The results of this analysis can be found in Section 4.0 of this report.

Driver Interviews

Available data is important for establishing a quantitative base for the analysis. Additional qualitative information, however, is appropriate to help shape an evolving view of the true factors surrounding the success of the exemption program. Through the use of surveys of program drivers, it is expected that exemption process issues and concerns will be identified and assessed relative to their impact on the effectiveness of the exemption programs.

Based on the literature review and available data, Cambridge Systematics created a driver interview guide to be used in the structured interview process.

Nine telephone surveys of program drivers currently active in the Vision Exemption Program were performed. The participants were contacted by FMCSA staff by telephone and invited to participate, and only then were they contacted by Cambridge Systematics. The interviews were designed to last approximately 40 minutes. These surveys focused on the individual's assessment of waiver requirements; driving performance; issues or challenges related to their employment by their motor carrier employer; and issues regarding acceptance or resistance of their employment by fellow employees.

2.4 Quantitative Analysis Techniques

To address the quantitative aspects of the analysis, Cambridge Systematics developed an approach to analyze data about characteristics of program and control drivers as well as information about their reported collisions. The main statistical goal was to identify the level of confidence at which the presence or absence of a Vision Exemption Program is believed to have an effect on collision rates. Because of the small number of waivers for the diabetes program, the statistical analysis focused only on the vision program.

The effort was divided into several tasks, as follows:

- **Development of Initial Hypotheses –** At the beginning of the project, Cambridge Systematics developed a technical memorandum outlining a preliminary approach to analyzing hypotheses about the Vision Exemption Program. The purpose of this memorandum was twofold:
  - To stimulate discussion regarding available data and its utility for the project; and
  - To highlight various assumptions which the Cambridge Systematics team had made about the process and the associated data, so that these assumptions could be adjusted as necessary by FMCSA staff.

The initial hypotheses were used as a starting point for acquisition of necessary available data, as described in Section 3.0 of this report.

- **Refinement of Detailed Hypotheses –** After the project team worked with FMCSA staff to determine the available data for the analysis, Cambridge Systematics developed four detailed sets of hypotheses for consideration. These hypotheses are explored in more detail in Section 6.2 of this report.

  The general approach was to define policy choices as confidence in statistical results. Dependent variables were variations of collision events, such as "total number of collisions over X years" (a continuous variable) or "collision occurred within X months of a waiver request" (a discrete variable). Given the limited number of drivers, the hypotheses by necessity were relatively simple and focused on basic safety outcomes such as a fatality, injury, and bad driving record.

- **Analysis of Descriptive Statistics –** Due to the small sample size, several aspects of the analysis could not be properly analyzed using only formal hypothesis tests. A battery of descriptive statistics was substituted to identify potential trends in the data. In these situations, a formal confidence interval could not be identified.

- **Formal Hypothesis Testing –** A variety of techniques was used to analyze the variance in data while considering the four key hypotheses. The SAS statistical analysis package was used to execute the formal testing. Only the most relevant analysis results are presented in this report.

  The result of these analyses is an estimate of the confidence based on the data that the Vision Exemption Program is impacting the rate of collisions. The greater the variance attributed by the statistical techniques to the participation in the exemption program, the greater the confidence in asserting that the exemption program is statistically significant.

  Hypotheses are reported against a 95 percent confidence interval, following convention. Hypotheses for which a formal statistical test was available, but a 95^{th} percentile confidence interval could not be obtained, are classified as rejected.

3.0 Information Sources

3.1 Overview and Challenges

Obtaining the information needed to support the project was the subject of early analysis. The questions involved in this analysis were:

- What would be the appropriate information for a detailed analysis of the Vision and Diabetes Exemption Programs?
- What information could be obtained from existing data sources (as resources were not available for a new data collection effort)?
- Given available information, how should the information be obtained and structured to maximize the effectiveness of the project?

This section discusses the project team's decisions about gathering information for the project. While no issue threatened the success of the project, several issues did pose challenges. The key issues were as follows:

- **The Lack of a "Before" Analysis –** Ideally, the program analysis would be a "before/after" analysis, where the characteristics of the system before the Vision and Diabetes Exemption Programs are compared to the current characteristics of the system. Unfortunately, no "before" analysis existed at a sufficient level of detail. The impact on the project was the establishment of the control data set as a method of comparing the program impacts versus the general population. *One key attribute of the methodology was the documentation of the program data as of the end of 2005 to enable before/after analyses of any future policy changes*.
- **The Need for Transcription and Compilation –** The majority of data about characteristics of program drivers was not found in an electronic format due to resource constraints. The data is found in handwritten documents stored in each driver's physical program file. A major task for the project team was the transcription of over 50,000 data items into an electronic format, with the appropriate quality control measures. Data for each driver accepted in the program before December 1, 2005 has been transcribed into an Excel spreadsheet and provided to FMCSA to support future analyses.
- **Challenge of Imperfect Data –** In several situations, the data available, while not missing, was inconsistent. This was especially true of information on drivers accepted in the first years of the program.

  One of the major areas where data was not useful was in the mileage information for accepted drivers. The information provided by drivers in their applications and transcribed into electronic format was inconsistent across applications, and there were concerns about the accuracy of the information provided by the drivers. Inability to validate this data precluded the project team from using "reported collisions per 100,000 driving miles" as a dependent variable. This is a critical issue, and it is reflected in our overall program recommendations in Section 7.2 of this report.

- **Challenge of Small Data Set Size –** With only 1,155 drivers accepted in the Vision Exemption Program to date, stratification of drivers became extremely problematic. In several situations, representations of hypotheses had to be discarded from formal testing because the number of drivers in one or more categories would be much less than 100. In these situations, use of descriptive statistics was expanded to help understand relevant trends.

3.2 Characteristics of Exemption Program Drivers

The analysis only considers drivers who have been accepted in the Vision Exemption Program. This defines a data set of 1,155 drivers. The initial methodology was to consider drivers who were rejected in order to compare reported collision volumes prior to the application date of approved versus rejected drivers. However, the vision characteristics data for rejected drivers was of inconsistent quality and could not be utilized.

General Characteristics of Program Drivers

Three general categories were used to classify program drivers in preparation for the development of a control set:

- **Age –** The driver's age as of December 1, 2005 was classified into a series of five-year bands. The median age of drivers accepted in the program was 52 years.
- **Gender –** Male drivers composed an overwhelming percentage (over 98 percent) of drivers accepted in the program.
- **State of Residence –** To account for potential issues introduced by the highway network on which a driver may be more likely to be driving, drivers' residence was captured. For categorization purposes, residence was assigned to the corresponding FMCSA region.

Vision Characteristics of Program Drivers

The vision characteristics of program drivers were transcribed from the paper exemption application summary forms into an Excel spreadsheet. These forms are originally generated by staff at MANILA, a contractor of FMCSA responsible for processing program applications. Vision deficiency information was checked for quality control purposes against the Federal Register entry for that driver.

Three sets of information were transcribed for each driver:

- **Deficiency and Cause –** One attribute of the handwritten exemption application summary forms is that "deficiency" and "cause" are often mixed. The project team transcribed any information in the relevant summary form fields. The information was then cross-referenced against the Federal Register entries for each driver.

  At that point, the data was returned to FMCSA for review. The process for identifying deficiency and cause produced a number of individual "issues" which, if not categorized, would hamper any statistical analysis. Cambridge Systematics worked with FMCSA staff to peruse the data and categorize drivers based on input from FMCSA staff.

  As a result, the drivers were placed in the following categories:

  – Amblyopia (amblyopic drivers were by far the largest group, and it was decided that these drivers deserved their own category for analysis);

  – Accident/Injury/Trauma;

  – Congenital;

  – Disease; and

  – Unknown.

Table 3.1 provides the distribution of drivers across these categories.

Table 3.1 Distribution of Program Drivers by Deficiency Category

Deficiency Category	Number of Drivers
Amblyopia	506
Accident/Injury/Trauma	365
Congenital	57
Disease	116
Unknown	63

- **Onset –** Onset was originally transcribed as the year in which the deficiency first occurred, in accordance with how it is captured on the paper summary forms. Once transcribed, onset was transformed into a more useful analysis variable: the number of years before acceptance that the deficiency occurred.

  For some drivers, especially amblyopic drivers, values such as "birth" and "childhood" were transcribed. The project team worked with FMCSA staff to identify the appropriate onset date to use for these drivers.

- **Vision at Acceptance –** Vision information was captured in terms of rating (e.g., "20/80") for each eye and overall field of vision. Drivers who were legally blind (20/200 or worse) in one eye were identified as "blind" regardless of the actual rating provided.

Driving Characteristics

This is an area where most information currently is not available. The information about miles/year on the written applications is not verifiable, and there is no detail which could estimate exposure to potential incidents (e.g., an Interstate rural commute versus nationwide driving versus heavy urban driving), day versus night, etc.

Type of vehicle driven is transcribed by MANILA. There are, however, a substantial amount of drivers (just under 10 percent) without information for this field. Furthermore, this information is not available for control drivers. Therefore, no reasonable hypotheses could be created with sufficient data for testing.

3.3 CONTROL DRIVERS

The Role of a Control Set

A control driver is a licensed Interstate commercial vehicle driver who had a driver inspection reported to the MCMIS, and has never applied for the Vision or Diabetes Exemption Program. The control driver is needed to explore hypotheses such as "program drivers might be involved in more collisions than other drivers." To explore such a hypothesis, the methodology must properly identify what is meant by "other drivers."

Identification of a Control Sample

In an ideal situation, a control sample would be a set of drivers who had almost the same characteristics as the program drivers, with the exception of the driver's vision quality. The drivers would live in the same neighborhood, work for the same carrier, be of the same age, and drive the same routes at the same times of day.

Given the limitations of the available data, far less information could be used to identify a control set. The control set was built from the general characteristics of the program drivers.

The drivers used in the control set were sampled by FMCSA staff (and their on-site contractor staff) from available MCMIS driver inspection records. While not all licensed Interstate drivers will have a corresponding MCMIS inspection, for the purposes of our analysis this difference between the control set and the real world was deemed by FMCSA staff to be minimal.

The control drivers were sampled to provide a distribution equal to the program drivers in the following categories:

- **Age –** The percentage of drivers in each five-year age band should be as close to identical as possible; and
- **Residence –** The percentage of drivers residing in each FMCSA district should be as close to identical as possible.

Given the overwhelming percentage of male program drivers, only male drivers were considered for the control set.

To mitigate the lack of other information, the control set size was set at a multiple of the program driver set. The target was a control set of 10,000 drivers; with category rounding the actual number used was 9,829, or a ratio of 8.5 control drivers per program driver.

Table 3.2 illustrates the balance of the set of control drivers versus the set of program drivers ("exempt" drivers in the table).

Table 3.2 Relative Frequency of Exempt and Control Drivers by Age and Residence

Age Group	Licensing Region 1		3		4		5		6	
	Exempt	Control	Exempt	Control	Exempt	Control	Exempt	Control	Exempt	Control
25 to 30	1.1%	1.0%	0.0%	0.0%	2.6%	2.3%	1.3%	1.2%	2.5%	1.7%
31 to 35	3.2%	3.0%	5.0%	4.0%	4.7%	4.5%	3.3%	3.1%	2.5%	3.2%
36 to 40	12.9%	12.2%	8.6%	9.4%	7.3%	6.7%	7.5%	7.5%	8.3%	7.4%
41 to 45	16.1%	15.5%	9.3%	9.7%	15.0%	14.7%	15.9%	15.3%	10.0%	10.7%
46 to 50	17.2%	18.2%	20.7%	20.8%	18.2%	17.4%	15.1%	15.5%	18.3%	16.5%
51 to 55	17.2%	17.0%	21.4%	21.0%	11.7%	12.8%	19.2%	18.4%	15.8%	16.8%
56 to 60	11.8%	12.2%	15.7%	18.4%	19.0%	18.4%	16.7%	16.9%	20.8%	20.0%
61 to 65	15.1%	14.1%	7.9%	8.5%	11.7%	12.3%	14.2%	14.6%	15.8%	16.2%
66 to 70	3.2%	4.5%	7.1%	5.4%	7.7%	8.1%	3.8%	4.6%	3.3%	4.9%
71 or older	2.2%	2.0%	4.3%	2.6%	2.2%	2.9%	2.9%	2.9%	2.5%	2.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Age Group	Licensing Region 7		8		9		10		All	
	Exempt	Control	Exempt	Control	Exempt	Control	Exempt	Control	Exempt	Control
25 to 30	2.4%	2.1%	5.2%	3.9%	1.7%	1.7%	2.9%	2.2%	2.0%	1.7%
31 to 35	1.2%	1.3%	6.5%	7.4%	1.7%	1.9%	1.4%	2.2%	3.6%	3.6%
36 to 40	8.3%	8.2%	5.2%	6.1%	5.1%	3.1%	8.7%	7.9%	8.0%	7.7%
41 to 45	8.3%	6.8%	2.6%	3.8%	15.3%	15.1%	11.6%	10.9%	12.6%	12.4%
46 to 50	17.9%	17.9%	13.0%	11.9%	18.6%	18.6%	15.9%	15.9%	17.3%	17.0%
51 to 55	14.3%	15.1%	23.4%	21.8%	16.9%	18.8%	27.5%	26.1%	17.5%	17.5%
56 to 60	9.5%	10.3%	15.6%	18.5%	18.6%	21.3%	13.0%	13.7%	16.5%	17.0%
61 to 65	20.2%	19.7%	11.7%	12.5%	3.4%	5.9%	13.0%	14.4%	12.7%	13.3%
66 to 70	11.9%	12.3%	13.0%	9.9%	6.8%	7.3%	4.3%	4.9%	6.4%	6.6%
71 or older	6.0%	6.5%	3.9%	4.4%	11.9%	6.3%	1.4%	1.8%	3.5%	3.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

3.4 REPORTED COLLISIONS

One of the decisions faced early in the project was the source of information about reported collisions. There were three key issues involved in this analysis:

- The ability to request specific collision records for a particular driver, without violating policy constraints regarding privacy of identifiable data about an individual;
- The ability to obtain specific collision records in a timely fashion with minimal impact on FMCSA resources; and
- The ability to obtain the most information possible about each collision.

One option evaluated was to obtain reported crash information for each driver from the Commercial Driver License Information System (CDLIS). CDLIS would contain the most information about each collision. The distributed nature of the CDLIS data, however, would necessitate either a manual query for each driver or a request to each state for information. In either case, the resource requirements would be excessive. The combination of potential privacy issues for each jurisdiction and resource requirements made CDLIS an untenable source.

For project purposes, the project team was not attempting to evaluate collision cause or fault, simply participation. The working assumption, approved by FMCSA project staff, was that program drivers are no more or no less likely than control drivers to be involved in collisions fully caused by third parties. Therefore, adding collisions that were not the driver's fault to the volume totals would be uniform in nature for statistical purposes, and would be canceled out in any comparative analyses.

As a result of this assumption, the project team concluded that the data on reported collisions in MCMIS would be sufficient for the research needs. FMCSA staff, assisted by their on-site contractors, used the set of driver license identifiers obtained from both the program driver and control driver data sets, and returned information from MCMIS for each reported collision involving the driver. Due to the nature of the MCMIS data, several rounds of queries were needed to account for data quality issues. FMCSA was notified of any data records where the MCMIS collision data was inconsistent with the data transcribed from the Vision Exemption Program application summary forms, and each such record was evaluated on an individual basis. In the majority of situations, changes were made to the data set used for the project team's evaluation.

Because of the privacy issues surrounding use of this data, Cambridge Systematics' contract was amended to include the appropriate provisions of the Privacy Act of 1974. The FMCSA project manager was briefed on Cambridge Systematics' internal policies for maintenance of the security of the data. Upon conclusion of the project, all data will be removed from Cambridge Systematics' internal systems and returned to FMCSA for its use.

3.5 Driver Interview Subjects

As part of the methodology, telephone interviews were conducted with nine commercial vehicle drivers currently enrolled in the Vision Exemption Program. FMCSA staff selected potential interview subjects at random from the roster of current active drivers in the Vision Exemption Program.

The project team requested that interview selections be made to maximize their diversity. To that extent, the selections reflected the following criteria:

- At least one driver from each of five decades of birth (1930s through 1970s);
- At least two drivers from each of the four time zones found in the Continental United States (excluding Alaska and Hawaii); and
- At least one driver from each of the deficiency categories that are not "unknown" in Table 3-1.

Drivers were selected at random, subject to the above constraints. To minimize potential driver concerns about the purpose of the interview, Cambridge Systematics requested that FMCSA staff contact each driver by telephone to obtain their permission to be interviewed.

3.6 Available Literature

The final information source used for the project was the body of available literature. Literature known to FMCSA was obtained first. This included 42 items, most published before December 2000.

The project team developed search terms from an analysis of these articles. Search terms include key phrases, author names, journal names, deficiency and cause phrases, and outcome issues (example: "compensation").

The team used the search terms to find a broad set of potential articles. FMCSA staff reviewed the initial bibliography and directed the project team to review specific articles.

4.0 Literature Review

4.1 Overview

As part of the qualitative analysis of issues regarding the Vision and Diabetes Exemption Programs, a detailed review of the current published scholarly literature was conducted. The literature review generated a bibliography of 160 articles. The full bibliography is found in Appendix A.

This section summarizes the literature review process, provides insight into over thirty-five of the most relevant articles, and summarizes the key findings found during the review process.

4.2 Literature Selection

Cambridge Systematics conducted a review of relevant literature, including both trade and scholarly publications. The results of the review provided direction for developing the interview guide for program drivers as well as for later qualitative review of available data.

The project team divided the literature review into the following tasks:

- **Current Bibliography –** Cambridge Systematics requested the current set of scholarly articles which are used by FMCSA for the Vision and Diabetes Exemption Programs.
- **Development of Approach to Literature Topics –** Cambridge Systematics used the current bibliography to determine an approach for reviewing the literature in this area. The approach involved an intensive search using both general search engines such as Google as well as specific medical literature search engines. The approach constructed a "tree" of key words and phrases from the existing literature.
- **Initial Literature Scan –** Cambridge Systematics reviewed the current literature using the tree-based approach identified above. The results of the initial scan included a bibliography of all relevant articles and, when possible, article abstracts. These results were presented to FMCSA for prioritization.
- **Detailed Literature Review –** FMCSA staff selected approximately one-fifth of the initial literature for detailed review. Cambridge Systematics obtained full-text versions of each article and developed a summary of the key relevant findings. The results of this analysis can be found in Section 4.4 of this report.

4.3 LITERATURE COMPOSITION

The literature review for the Vision Exemption Program produced 96 additional pieces of references covering the period between 1991 and 2006. Including the references provided by FMCSA, the total number of references is 112, excluding the Waiver Program Status reports. The list contains 96 peer-reviewed journal articles, 6 research reports, 4 conference/symposium papers, 5 editorial and professional communications, and 1 book. The distribution of publication dates for these references is given below as Table 4.1.

Table 4.1 Distribution of Vision Literature Publication Dates
All References

Year of Publication	Number of References
1986 to 1990	2 (2%)
1991 to 1995	15 (13%)
1996 to 1999	23 (21%)
2000 to 2002	36 (32%)
2003 or later	36 (32%)
Total	112

From the set of 96 new articles, the project team asked FMCSA staff to provide the bibliography and select articles of interest for further review. FMCSA staff provided a list of 21 references on which to focus the vision literature task. The list consisted of 18 peer-reviewed journal articles and three editorial comment letters. Table 4.2 provides the distribution of publication dates for the selected references.

Table 4.2 Distribution of Vision Literature Publication Dates
Key References

Year of Publication	Number of References
1986 to 1990	2 (10%)
1991 to 1995	2 (10%)
1996 to 1999	2 (10%)
2000 to 2002	7 (33%)
2003 or later	8 (38%)
Total	21

The Diabetes Exemption Program literature review used the identical selection process. Using keywords that relate to driving and diabetic symptoms or conditions associated with diabetes, and limiting the time horizon to the last 10 years, medical and engineering indexes were searched. The effort resulted in 48 pieces of references covering the years 1994 to 2006. The list comprised 39 peer-reviewed journal articles, 8 editorial comment letters, and 1 research report. Seven of these items were published in either French or German; the references are included in Appendix A but the articles were not examined. The refined article set requested by FMCSA consisted of 11 references, 8 peer-reviewed journal articles and 3 editorial comment letters. Tables 4.3 and 4.4 summarize the distribution of diabetes articles by publication date.

Table 4.3 Distribution of Diabetes Literature Publication Dates
All References

Year of Publication	Number of References
1986 to 1990	0 (0%)
1991 to 1995	5 (10%)
1996 to 1999	17 (35.5%)
2000 to 2002	17 (35.5%)
2003 or later	9 (19%)
Total	48

Table 4.4 Distribution of Diabetes Literature Publication Dates
Key References

Year of Publication	Number of References
1986 to 1990	0 (0%)
1991 to 1995	0 (0%)
1996 to 1999	2 (18%)
2000 to 2002	2 (18%)
2003 or later	7 (64%)
Total	11

4.4 Literature Analysis – Vision

The references requested by the FMCSA can be grouped into four categories:

- General reviews;
- Studies of the impacts on driving of limited visual field;
- Studies of the impacts on driving of limited visual field due to certain diagnosis; and
- Studies of the impacts on driving of visual impairments due to diabetes.

The literature review for the vision program began with general studies such as reviews of literature and standards, and proceeded to studies that investigated relationships between driving and specific visual impairments. This section summarizes the key articles reviewed during the task.

Effects of Vision for General Driving

The fitness to drive and physical and sensory impairments has been a subject of numerous studies. One such study was conducted by **Galski et al. (1998)** who performed a multifactor ANOVA study to investigate whether certain driving conditions require different levels of driving skills and abilities and identify the relative demands of specific skill and ability. The analysis of ratings of professional driver evaluators and trainers revealed that certain scenarios required higher levels of skills and abilities. These included highway and city driving, heavy traffic, but not weather alone. Their findings indicated that inclement weather had significant interaction effects with traffic condition and road type. Moreover, the study suggested that higher levels of certain skills were required under these conditions, including scanning, attention and concentration, and information processing speed. Although the study did not offer specific findings on the needs of visual ability, consideration of the adverse effects of road, traffic, and weather conditions can be beneficial in assessing fitness to drive for commercial drivers who are unlikely to have the luxury of avoiding such adverse conditions.

In order to ensure that all drivers possess a certain level of physical and sensory fitness for meeting the demands of safe driving, all countries have established standards and medical review procedures to assess the degree of fitness to drive of driver license applicants and current drivers of passenger vehicles. Those standards and review procedures also are scrutinized in the literature. In their review of vision requirements for driving, **Casson and Racette (2000)** surveyed transportation authorities in Canada and the United States to identify and contrast the current standards and medical review procedures. Their results suggested that the standards in Canada were more consistent than those in the United States, and few of the standards in either country were evidence-based.

The study also contained of a review of the literature on visual function and driving. The study concluded that adequate contrast sensitivity was as important as, if not more important than, good visual acuity for driving and that there was little evidence to support a monocular standard for acuity, contrast sensitivity, or visual field. Although the study found evidence that the extent of a visual field defect is related to the ability to perform driving tasks, a relationship between the location of the visual field defect and fitness to drive was not clear. Compensating driving behavior of visually impaired or older drivers in order to avoid challenging driving conditions and developing adaptive strategies are suggested as possible reasons for such outcomes.

The relationship between visual acuity and driving performance has been evaluated by a number of authors. Some of the most influential work was performed by **Burg (1967, 1968)** and reanalyzed by **Hills and Burg (1977)**. The Burg studies analyzed data from 17,500 California drivers. These analyses indicated that for young and middle-aged drivers, there was no relationship between poor visual performance and crash rates. With respect to older drivers, visual acuity demonstrated significant relationships with crash rates. The authors noted, however, that despite statistical significance the magnitude of the correlation was low, and they cautioned that the relationships found should not be taken to conclude that poor vision must be a causal factor in automobile crashes.

The lack of evidence identifying a significant relationship between changes in visual functions and automobile crashes was emphasized by **Wilkinson (1998)** who provided examples from the literature to highlight the absence of a cut-off criterion for visual acuity, peripheral visual field, and contrast sensitivity to be adopted for categorizing drivers into risk groups based on visual test scores. Based on the literature review, the study concluded that since visual acuity alone was a poor predictor of driving performance individuals with visual acuities less than 20/40 but better than 20/200 or those with a visual field less than 140 degrees should be judged individually, including an on-road test under the supervision of a qualified driving instructor or driving evaluator. Building on his work above, **Wilkinson (2003)** set forth criteria for possible adoption by each state's Department of Motor Vehicles or equivalent agency concerning visual functioning and driving with a non-commercial license.

The criteria suggested that acuity of 20/40 in one or both eyes, an uninterrupted visual field of 120 degrees, and absence of other conditions that may limit driving ability would qualify for an unrestricted non-commercial license. Restrictions would be imposed on individuals who have less acuity than 20/40 but not less than 20/70 with an uninterrupted visual field of 120 degrees and absence of other conditions that may limit driving ability. The criteria call for individual assessment, through both visual tests by an eye care professional and actual driving performance under the supervision of a qualified driving instructor or driving evaluator, for those having visual acuity of minimum of 20/200 and/or a visual field of minimum 20 degrees, and for those who were issued restricted driving license but wish to drive under no restriction.

Jolly (2002) provides results of on-road assessments of Australian drivers with different visual impairments and those who do not meet Austroads guidelines. The outcome of the study provided some evidence about the relationship between clinical standards and on-road performance. According to the current Austroads guidelines, visual fitness to drive is determined by the criteria in these four vision areas: visual fields, loss of vision in one eye, diplopia, and visual acuity.

Individuals are required to have a visual field of 120 degrees across the horizontal meridian of a Goldmann field test using an IV4e target. Those with quadrantanopia (loss of vision in the minimum of 25 percent of the visual field in one eye) are not allowed to drive. However, the study reported individuals with

120-degree horizontal visual field and a considerable loss of peripheral vision who do not fall into the definition of quadrantanopia. On-road tests showed that driving performance was adversely affected by the peripheral loss of vision. Two patients with hemianopia who were driving for more than five years were tested and the results indicated that they could drive at a reasonable standard and more interestingly, errors that were observed were made in opposite relation to the side of intact field (e.g., in the presence of a left hemianopia, the errors of judgment occurred at the right side of the vehicle). This suggested over-compensation to the detriment of the intact side. In both cases, driver performance showed a decrease in safe driving. However, it was concluded that individuals with sufficient intellectual capacity can be trained to adapt to the deficiencies and to learn to compensate for peripheral vision loss.

Individuals with a loss of vision in one eye tend to face and turn their body to position the operational eye to check the blind spot. The extra time taken to do this decreases the amount of time that information in front of the vehicle can be seen. It has been observed that use of convex mirrors in the rear view mirrors as well as mirrors to cover the blind spots of the vehicles eliminated the need to turn the head. It has been suggested that additional driving time and driver training are necessary to adapt to driving with monocular vision.

Individuals with diplopia are not permitted to drive and occlusion is suggested. Diplopic individuals have difficulty in judging distance especially when positioning the vehicle at intersections and when changing lanes, and problems with blind spots and seeing signs. Use of prisms is suggested as the most useful remedy to establish a single vision. The corrected visual acuity of 6/12 (20/40) was accepted as the threshold for minimum level of acuity for driving. The tests with 6/18 and 6/36 were conducted and unsafe driving behavior was observed. Based on the findings, the study pointed out the need to assess on-road performance of the dysfunctions set forth in the guidelines based on clinical criteria.

Furthermore, **Hodson (2002)** reported substantial differences in practical applications of the guidelines across Australia, suggested an alternative vision field test, and stressed the need for clearer and more consistent guidelines.

In order to assess the effectiveness and efficiency of the guidelines and medical standards, several studies with certain levels of statistical designs were conducted to evaluate the performance of drivers with visual dysfunction through on-road assessments and/or driving simulators. In such a study, **Racette and Casson (2005)** conducted an on-road driving assessment of 131 Canadian drivers having different levels of visual field loss; 13 hemianopics; 7 quadrantanopics; 25 monocular patients; 10 patients with moderate peripheral loss (less than 135 degrees of horizontal visual field measured at the midline); and 76 patients with mild peripheral losses (between 135 and 186 degrees of horizontal visual field). Subjects were tested in a test area composed of a mix of different road and traffic conditions and evaluated during a time period of approximately 50 minutes. The subjects were subsequently classified into different categories: Safe, Unsafe, and Unknown. Contrary to the general expectations, the findings suggested that the extent of visual field loss did not have a significant impact on driving performance. Hemianopia tended to have more negative impact on driving performance than quadrantanopia with a marginally significant result. Overall, the location of the visual loss (localized, diffuse, and monocular) was not significantly related to driving fitness. However, localized defects in the left hemifield and diffuse visual loss in the right hemifield seemed to be associated with driving impairments. A large percentage of monocular drivers proved to be safe drivers and the location of their deficit had no significant impact.

Another on-road driving assessment was conducted by **Bowers et al. (2005)** in which 28 current drivers who have limited peripheral vision were tested. The drivers with limited vertical and horizontal vision showed significantly poorer skills in speed matching when changing lanes and in maintaining lane position and keeping to the path of the curve when driving around curves, and they received significantly poorer ratings for anticipatory skills. Deficits in useful field of view (UFOV) performance and poorer contrast sensitivity scores were significantly correlated with overall driving performance as well as specific maneuver/skill combinations.

In Finland, **Lamble et al. (2002)** conducted a smaller scale on-road assessment study in which they tested five experienced and "safe" (more than 250,000 kilometers driven without a crash) drivers with central visual field restrictions but normal peripheral vision. The subjects were matched with drivers of equivalent experience, age, gender, and safety record, but having normal vision. The tests focused on car following under different road and traffic conditions. The results showed that there were no apparent differences between the drivers with central visual field restrictions and those with normal vision. The drivers with impaired vision were significantly slower, by 0.2 seconds, in detecting the onset of brake lights than the normal vision drivers. Their headway closure detection was 0.7 second slower than normal vision drivers, but this difference was not statistically significant in this small data.

Although the extent of visual field defects appears to be related to driving performance, particularly for maneuvers for which a wide field of vision is likely to be important, large individual differences were not uncommon in the on-road driving assessments. In spite of some impairment in car following (a central vision task), the results from such studies together with the clean record of drivers with central vision restrictions indicate that these drivers can be considered fit to drive. The results of the studies also demonstrated the lack of evidence to support the clinical criteria and test methods. Similar assessment methods with drivers with more restricted fields can determine the extent of the minimum field for safe driving. Moreover, individualized on-road assessments for patients with visual field defects are recommended in order to assess driving capabilities effectively.

The evidence on the positive effects of compensatory viewing behavior of drivers with visual impairments attracted the attention of several researchers who focused on the development of such behavior and its potential. **Coeckelbergh et al. (2001)** investigated the impacts of training for compensatory viewing behavior and practical fitness to drive. Fifty-one subjects with visual field defects due to ocular pathology were trained to use compensatory viewing. Practical fitness was assessed on the road as well as on the driver simulator. It was observed that compensatory viewing behavior and practical fitness to drive could be improved by training. The effect of visual field defect on viewing behavior and practical fitness to drive was analyzed separately for subjects with central or peripheral visual field defects. The results showed that none of the outcome measures differed between the central and peripheral visual field defect groups.

In another effort to demonstrate the effects of compensatory viewing behavior, the study by **Coeckelbergh et al. (2004)** of 100 participants with central and/or peripheral visual field defects caused by ocular pathology modeled the outcome of the driving test conducted by the Dutch driving license authority using the protocol for investigating practical fitness to drive. The predictive power of a model based on the current vision requirements for driving, including visual acuity and visual field, was significantly increased when taking compensatory viewing efficiency into account. The model was compared with another model which used traditional predictors such as visual attention, contrast sensitivity, and age, and produced identical prediction outcomes. One outcome of this study was, in contrast to general suggestions in the literature, that a smaller percentage of participants with central visual field defects (25 percent) or both central and peripheral visual field loss (29 percent) passed the driving test compared to 42 percent in the peripheral group and 64 percent in the mild visual defect group. The effect of diagnosis was not significant. Vision parameters varied within a category and showed large overlaps between categories. The predictive power of both models was low, indicating that solely relying on test results may produce misleading outcomes; as a result, one may deem legally unfit drivers as safe drivers or vice versa. The study recommends inclusion of more complex measurements and case-by-case assessments.

There are a considerable number of research papers and reports on the impacts of visual dysfunctions caused by certain medical conditions such as glaucoma, cataract, macular degeneration, monocular vision, diplopia, retinitis pigmentosa, and diabetes. Although there is some evidence that cause of the dysfunction is irrelevant to the driving performance, these studies offer important insight.

Szlyk et al. (2005) present the findings of a study in which 40 glaucoma patients were matched with 17 control subjects with equivalent driving experience, gender, and age. Their driving performance was assessed by an interactive driving simulator and their self-reported accident involvement is compared. Clinical vision data such as visual acuity, letter contrast sensitivity, and visual field also were collected. The study found that the number of accidents as measured on the driving simulator in the glaucoma group was significantly correlated with three Goldmann visual field measures: combined horizontal extent, total horizontal extent, and total peripheral extent. There were no statistically significant correlations between the driving performance of the glaucoma group and the visual acuity or contrast sensitivity measures. When compared with the control group, a significantly greater proportion of the glaucoma group reported having at least one real-world accident within the past five years.

Another study of glaucoma patients' involvement in accidents and driving avoidance is provided by **McGwin et al. (2004).** Two groups of subjects older than 50 (glaucoma, n=576 and control, n=117) were created by using data from university affiliated eye care practice centers, patient surveys, and police records of motor vehicle collision involvement. The findings suggested that patients with glaucoma were less likely to be involved in collisions than patients without glaucoma. There was no difference between the at-fault crash rates of the patients with glaucoma and those not having glaucoma. Patients with glaucoma had significantly higher levels of avoidance for driving at night, driving in fog, driving in the rain, driving during rush hour, driving on the highway, and high density driving. Although drivers with glaucoma were observed to avoid challenging driving conditions, the statistical analysis to predict crash involvement did not produce significant coefficients for a driving avoidance variable.

Szlyk et al. (1992) compared the driving performances of 21 subjects who were diagnosed with retinitis pigmentosa (RP) with 31 normally sighted control subjects who did not differ statistically from the RP subjects in age, gender, and driving experience. Driving performance was assessed by self-reported accident frequency and by an evaluation of performance on an interactive driving simulator. A significantly greater proportion of individuals had self-reported accidents in the RP group than in the normal group. Likewise, a significantly greater proportion of subjects with RP than normal subjects had accidents on the driving simulator. Logistic regression analyses indicated that binocular horizontal field extent and binocular field area significantly differentiated between those having no self-reported accidents and those subjects with RP having one or more self-reported accidents.

The effects of age related macular degeneration (ARMD) on driving were studied by **Szlyk et al. (1995)**. The study investigated the effects of age and central vision loss on driving skills of 10 subjects with age related macular degeneration compared to 11 healthy older and 29 young control subjects. The analysis included a battery of cognitive and visual tests, an interactive driving simulator, and an on-road driving test. Data were collected on the frequency of real-world accidents and convictions for traffic violations. The ARMD group demonstrated poorer performance on the driving simulator, including delayed braking response times to stop signs, slower speeds, and more of both lane boundary crossings and simulator accidents. The ARMD group also demonstrated poorer overall on-road test performance, including having significantly more points deducted for driving too slowly and for not maintaining proper lane position. However, these effects on the simulator and the on-road test did not translate into an increased risk of real-world accidents for the age related macular degeneration group.

There was evidence of compensation in the ARMD group in four major areas: 1) not driving in unfamiliar areas; 2) traveling at slow speeds; 3) self-restricting their nighttime driving; and 4) taking fewer risks while driving (e.g., not changing lanes). There also was evidence of compensation in the older control group. Vision, simulator, and on-road test variables combined with subjective risk taking predicted self-reported real-world accidents in a logistic regression analysis. However, risk taking, rather than simulator or road-test performance, was the most significant predictor for both patients with ARMD and the control group.

Another medical condition that adversely affects driving performance is diabetes. Diabetic drivers' driving performance is affected not only by visual problems but other complications with which diabetes is associated. For years, the question of whether diabetic drivers have an increased accident risk has been considered. While some studies from the 1960s and 1970s reported a statistically significant increased crash risk for diabetic drivers, more recent studies found no difference or only a slight increase in the accident rate of diabetic drivers. These studies, however, examined the general diabetic population, not just individuals with diabetic retinopathy.

Szlyk et al. (2004) conducted a study which analyzed the effects of severity of retinopathy of diabetic patients and the laser scar grades on the simulated driving performance. Twenty-five licensed drivers with diabetic retinopathy (median age, 53 years; range, 34 to 72 years) completed clinical tests (visual acuity, letter contrast sensitivity, and Humphrey 30-2 visual fields) and structural examinations (retinal thickness analysis and fundus photograph grading of retinopathy and laser scarring). Driving performance was assessed with an interactive driving simulator and a driving history questionnaire. Objective retinal thickness measurements and the presence of laser scars were more often related to driving simulator performance than were traditional clinical vision measures and subjective retinopathy grades. Increased retinal thickness was significantly correlated with a higher frequency of simulator accidents and near accidents. Laser scar grades significantly correlated with steeper brake-response slopes, increased brake-pressure standard deviation (SD), and longer response times. Subjects with focal laser scars had significantly higher average brake-pedal pressure and brake-pressure SD than subjects without focal laser scars. Retinal thickness and laser scarring correlated with driving simulator performance in subjects with diabetic retinopathy.

It also was reported that subjects having one or more real-world accidents within the past five years had greater brake-pressure SD and steeper brake-response slopes than did subjects not reporting accidents. Logistic regression analyses in the literature have found both brake-pressure SD and brake-response slope can be used to predict real-world accident involvement. However, preliminary data comparisons between diabetic subjects and age-matched controls indicated that the diabetic subjects drove more cautiously and at slower speeds, suggesting that they used compensation techniques. Compensatory behavior was reported numerously in the literature. Therefore, future research must examine the extent of compensation that drivers with varying retinopathy and laser scarring levels can achieve.

The final paper reviewed in this section analyzed the traffic safety benefits of cataract surgery for older adults. In a cohort study of 277 patients with cataract, aged 55 to 84 years at enrollment, **Owsley et al. (2002)** analyzed the impact of cataract surgery on the crash risk for older adults in the years following surgery, compared with that of older adults who have cataract but who elect to not have surgery. Police-reported motor vehicle crashes involving patients who elected to have surgery were compared with crashes of those who did not have surgery. Comparing the cataract surgery group (n=174) with the no surgery group (n= 103), the relative risk for crash involvement was 0.47, after adjusting for race and baseline visual acuity and contrast sensitivity. It was estimated that cataract surgery may reduce crashes an average rate of 4.74 crashes per million miles of travel for older adults with cataract.

Effects of Vision for Commercial Driving

The majority of the studies investigated the associations between visual impairment and automobile driving rather than operation of heavy commercial vehicles.

Studies such as **McKnight, Shinar, and Hilbum (1985)** have reported a difference between the operation of heavy vehicles and the operation of personal vehicles in the amount of reliance placed on scanning the visual field. The observation of the total visual surroundings is considerably more difficult when driving a heavy commercial vehicle than when driving a personal vehicle. The inability of an operator to see vehicles immediately behind the heavy commercial vehicle makes the operator much more dependent on mirrors than is the operator of a car. Additionally, the heavy vehicle operator must be more aware of the gauges on the instrument panel. This combination of visual demands requires continual scanning of the near and distant fields of view. To successfully compensate for a reduced visual field, it is likely that the visually impaired driver, particularly the monocular driver, would necessarily make more head or eye movements, because the side-mounted mirrors of most heavy vehicles demand a turn of the head when looking toward the blind side.

The higher levels of visual and physical demands for safe operation of heavy vehicles, coupled with the severity of accidents involving heavy commercial vehicles, lead to more stringent requirements for commercial driver license applicants and drivers. The Federal regulation states that a person is physically qualified to drive a commercial motor vehicle if that person has distant visual acuity of at least 20/40 in each eye without corrective lenses or visual acuity separately corrected to 20/40 or better with corrective lenses; distant binocular acuity of at least 20/40 in both eyes with or without corrective lenses; field of vision of at least 70 degrees (horizontal) in each eye; and the ability to recognize the colors of traffic signals and devices showing standard red, green, and amber. Monocular individuals as well as those with different medical conditions such as diabetes requiring insulin also are prohibited from operating a commercial vehicle in the United States **(Owsley and McGwin, 1999)**.

In their review, **Owsley and McGwin (1999)** discussed the findings in the literature with a focus on visual impairment and driving performance of commercial drivers. They referred to the work by **McKnight et al. (1991),** one of the most frequently cited studies in the field. The authors measured the visual and driving performances of 40 monocular and 40 binocular commercial drivers and found no differences with respect to visual search, lane placement, clearance judgment, gap judgment, hazard detection, and information recognition. Static acuity in the sighted eye among monocular subjects did not differ significantly from static acuity scores obtained binocularly from the binocular driver group, and the two groups were comparable with respect to age, total years of driving experience, and mileage during the preceding year. Monocular drivers showed deficiencies in a number of clinical visual measures, but in general no differences were found between monocular and binocular drivers in tasks involving actual driving performance. The single exception was the finding that binocular drivers are first able to read road signs at significantly greater distances. The authors concluded that monocular drivers have some significant reductions in selected visual capabilities and in certain driving functions compared with binocular drivers. However, differences in the safety for most day-to-day driving functions were not apparent.

The question of whether monocular drivers should be granted commercial licenses is controversial. The term “monocular” is typically used quite broadly in the research literature on this topic and denotes drivers who have a total absence of function in one eye and additionally those who have visual function in one eye below the minimum level for commercial licensing.

Sheedy et al. (1986) conducted a small scale study in which they analyzed the functional advantages of binocularity in a group of occupational-type tasks under binocular ad monocular conditions. Thirteen subjects with normal (20/20) visual acuities and normal binocular vision were selected for the study. The tasks that were tested included: pointing the ends of straws protruding from a wooden object at random angles using a pointer with the preferred hand; needle threading by threading randomly placed beads at a given order; file card alphabetizing; grooved peg board test; reading task by using Bailey-Lovie reading charts; VDT letter counting where subjects were expected to count the number of letter Rs in a paragraph of randomly distributed nonsense words; and bean bag toss where subjects were expected to hit the targets marked by concentric scoring circles at given distances and positions. The study showed that the first four tasks of the seven total tasks exhibited higher scores for binocular conditions. These tests were closely related with hand-eye coordination. The authors also tested whether monocular training has a positive impact on the performances. It was found that training improves both binocular and monocular performance. However, the length of the training period (five days) and the utilization of subjects with perfect visual health prevent distinct conclusions from being drawn. Possibly the test most closely related to driving, bean bag toss, did not have significantly different performance scores under binocular and monocular conditions.

Keeney and Garvey (1981) argued that monocular drivers should not be licensed to drive commercial vehicles, but at the time of their review, little empirical work had been conducted. Since that time, only a few studies have provided data to examine the question. **Laberge-Nadeau et al. (1996)** and **Dionne et al. (1995)** reported that commercial motor vehicle drivers with binocular vision problems (operationalized as no or poor stereoacuity) had more severe crashes (as measured by the total number of crash-related victims) than did those with normal stereoacuity, but their crash rate was not higher. **Maag et al. (1997)** reported that problems with binocular vision (assessed by stereoacuity) were associated with higher crashes per year among taxi drivers; however, severity of crashes, in terms of the number of victims, was not significant for the drivers with vision problems. Moreover, their models indicated that the driver's past record (number of crashes and demerit points in the previous year) was a significant predictor of the number of crashes. Age is associated significantly with the number and the severity of crashes with older drivers having a better record than the youngest group (30 years old or less).

A study in California by **Rogers and Janke (1992)** examined the two-year crash and conviction rates of 16,465 heavy vehicle operators, including a subgroup of 1,202 drivers who were visually impaired. Visually impaired drivers (those with 20/40 visual acuity or worse in the worse eye) had significantly more total crashes and convictions than did non-impaired drivers. Driving exposure did not differ in the two groups. However, the authors also reported that due to observed inconsistencies in reported mileage and accident involvement and absence of out-of-state accident reports for the control group who had considerable out-of-state mileage compared to visually impaired drivers who were not allowed to operate outside the State of California, the results were biased in favor of the control group. Therefore, their findings could not substantiate the Federal standard.

The report by the **Federal Highway Administration (FHWA) (1996)** analyzed crash rates of the 2,234 drivers in the previous Federal vision waiver program as of 1995, adjusted for self-reported miles traveled, compared to the crash rates of heavy trucks provided by the 1994 General Estimates System of the National Highway Traffic Safety Administration. The waiver group's crash rate was not higher than the national reference group, nor was the set of crashes considered more severe.

4.5 LITERATURE ANALYSIS – DIABETES

Laberge-Nadeau et al. (1996) studied the association between commercial motor vehicle drivers' medical conditions and crash severity. The severity of a crash was measured by the total number of victims (injured and dead). Non-linear regression models were estimated using Poisson and negative binomial distributions which incorporated information on drivers' characteristics, crash circumstances, and health status, in order to isolate the association between health status and crash severity. The medical conditions studied in this paper were diabetes mellitus (type 2, with no distinction between different treatments), coronary heart disease, hypertension (a diastolic pressure between 110 and 130 which is controlled by medication to be below 110), and binocular vision problems (non-stereoscopic vision: > 160 seconds or an acuity of at least 20/40 in the better eye and zero in the other). Drivers with multiple conditions were excluded.

The primary observations were the crashes of these drivers while driving a truck or a bus. The period considered in the study covered January 1985 through December 1990. A total of 542 truck crashes and 579 bus crashes were analyzed. The results show that crashes of truck drivers with binocular vision problems and bus drivers with hypertension are more severe than those of healthy drivers. No other medical condition considered in this study was significantly associated with crash severity. Other variables that also were found to be insignificant included age, time of day, permit class, the year, and trimester. Although the study found truck drivers with binocular vision problems and bus drivers with hypertension to be contributing factors to crash severity, the distinction of the party at fault was not made. Therefore, the findings of the study are not sufficient enough to generalize for purposes of deriving public policy decisions.

Sagberg (2006) investigated the relative crash involvement risk associated with diagnosed medical conditions, subjective symptoms, and the use of some medicines based on self-report questionnaires from 4,448 crash-involved Norwegian drivers. Relative risk for each health condition was estimated by comparing drivers with and without the condition, regarding the odds of being at fault for the crash. Odds ratios (OR) were adjusted for age and annual driving distance. The analyses identified the following significant risk factors: non-medicated diabetes (OR=3.08); a history of myocardial infarction (OR=1.77); using glasses when driving (OR=1.26); myopia (OR=1.22); sleep onset insomnia (OR=1.87); frequent tiredness (OR=1.36); anxiety (OR=3.15); feeling depressed (OR=2.43); and taking antidepressants (OR=1.70). The finding for non-medicated diabetes patients is somewhat contradictory to the results of the previous studies which usually find type 1 diabetes riskier and report lower odds ratios in the range of 1.3 to 2.6 (Vaa, 2003; Charlton et al. 2004). The study did not differentiate type 1 and 2 explicitly, rather it considered whether patients are under medication. Diabetes patients who were under medication did not have significant odds ratios. This was explained by the presumption that insulin treated patients were better able to control their condition.

Diabetes is recognized by most of the world's driving license issuing agencies as a prospective disability with respect to medical fitness to drive. Hypoglycemia (lower blood glucose levels than normal), a side effect of diabetes treatment, and the potential risk of imposing visual complications are behind this perception. Most countries impose restrictions on the commercial driver licenses of drivers who have diabetes. While there are no studies that clearly demonstrate that diabetic individuals using insulin have higher incidences of motor vehicle crashes, it is well documented that hypoglycemia leads to impairments in cognition and motor abilities at blood glucose levels around 3.6 mmol/l. A substantial amount of evidence exists that documents adverse impacts of hypoglycemia on skills that are crucial for driving. However, the analysis of national crash databases does not necessarily indicate higher crash involvement rates by drivers who have been diagnosed as diabetic. This result is widely associated with the compensatory behavior of the diabetic patients, including limiting their driving and tracking their condition closely. Furthermore, conducting well-designed studies is not free of challenges, which include underreporting of blood glucose levels for fear of losing driving privileges, reluctance to participate in surveys seeking detailed medical information, and underreporting of medical conditions in the crash reports.

MacLeod (1999) reports the findings of a study commissioned by the British Diabetic Association that examined and interpreted the available evidence of accident risk in insulin-treated diabetic patients after the introduction of new restrictions on driver licensing of people with insulin-treated diabetes. The report features an extensive search and assessment of the existing literature on diabetes and driving. The study concludes that increasing the driving restrictions on all insulin-treated diabetic drivers is unlikely to result in a significant improvement in road safety. Hypoglycemia is implicated in the etiology of a small number of road traffic accidents among insulin-treated patients but the total accident rate in this group does not consistently exceed the figure for non-diabetic drivers. Currently available scientific evidence at the time of the study could not support a blanket restriction of driving for insulin-treated diabetic patients. The study suggested that such restrictions should be undertaken under the light of more robust and definitive evidence.

Cox et al. (2000) evaluated the blood glucose (BG) levels at which driving was impaired, impairment was detected, and corrective action was taken by subjects, along with the mechanisms underlying these three issues. There were 37 adults with type 1 diabetes who drove a simulator during continuous euglycemia and progressive hypoglycemia. During testing, driving performance, electroencephalogram (EEG) for brain activity, and corrective behaviors (drinking a soda or discontinuing driving) were continually monitored, and BG, symptom perception, and judgment concerning impairment were assessed every five minutes. Mean ± standard deviation euglycemia performance was used to quantify Z scores for performance in three hypoglycemic ranges (4.0–3.4, 3.3–2.8, and 2.8 mmol/l). During all three hypoglycemic BG ranges, driving was significantly impaired, and subjects were aware of their impaired driving. However, corrective actions did not occur until BG was 2.8 mmol/l.

Driving impairment was related to increased neurogenic symptoms and increased theta-wave activity. Awareness of impaired driving was associated with neuroglycopenic symptoms, increased beta-wave activity, and awareness of hypoglycemia. Driving performance is significantly disrupted at relatively mild hypoglycemia, yet subjects demonstrated a hesitation to take corrective action. The longer treatment is delayed, the greater the neuroglycopenia (increased theta), which precludes corrective behaviors. The study suggested that patients should treat themselves while driving as soon as low BG and/or impaired driving is suspected and should not begin driving when their BG is in the 5.0–4.0 mmol/l range without prophylactic treatment.

The study's findings on the behavior of drivers during hypoglycemia indicate that treatment occurs at later stages and 45 percent of the time subjects reported that they resumed driving when their BG levels were between 2.8 to 2.0 mmol/l. These findings suggest the need for better awareness and training programs for diabetic drivers regarding hypoglycemia and driving; a program called BGAT (blood glucose awareness training) was cited as a example program in the study. The authors concluded that due to the method used (simulator) and sample size the direct relevance of these findings to actual driving risk was unclear, therefore relevance to driving privileges cannot be implied.

Barry-Bianchi (2000), in response to Cox et al. (2000), features her own experience on hypoglycemia and driving and presents a case of a conscientious diabetic patient. The author posed a number of methodological questions about the instructions given to the subjects and argued that since individual responses to hypoglycemia are idiosyncratic, assertion of general rules of practice (4-5 mmol/l) as suggested by Cox et al. 2000 should be avoided. Furthermore, the author suggested further research on habitual behavior formation during driving and recognition of hypoglycemia (for example, does familiarity with road and traffic conditions increase the propensity of ignoring hypoglycemia), determining the BG levels that severely impair driving, and driving experience recollection.

Cox et al. (2003) investigated whether diabetes is associated with increased risk of driving. Data was collected by anonymous questionnaires concerning diabetes and driving collected from patients on routine visits to diabetes specialty clinics in seven U.S. and four European cities. Consecutive adults with type 1 diabetes, type 2 diabetes, and non-diabetic spouse control subjects (n=341, 332, and 363, respectively) participated in the study. According to the study, type 1 diabetic drivers reported significantly more crashes, moving violations, episodes of hypoglycemic stupor, required assistance, and mild hypoglycemia while driving as compared with type 2 diabetic drivers or spouse control subjects ($P < 0.01$– 0.001). Type 2 diabetic drivers had driving mishap rates similar to non-diabetic spouses, and the use of insulin or oral agents for treatment had no effect on the occurrence of driving mishaps. Crashes among type 1 diabetic drivers were associated with more frequent episodes of hypoglycemic stupor while driving, less frequent blood glucose monitoring before driving, and the use of insulin injection therapy as compared with pump therapy. One-half of the type 1 diabetic drivers and three-quarters of the type 2 diabetic drivers had never discussed hypoglycemia and driving with their physicians.

The findings of the study highlight the importance of awareness of risks associated with driving with hypoglycemia, frequent self-monitoring blood glucose levels, and method of insulin delivery. The study also draws attention to possible positive impacts of a training program on blood glucose awareness training (BGAT) designed to assist patients in anticipating, preventing, detecting, and treating hypoglycemia. The authors also state that the findings of the study are not adequate to support a decision to restrict driving of individuals with type 1 diabetes since they were able to find other contributing medical factors for some subjects in the type 1 group such as attention deficit/hyperactivity, sleep apnea, or alcohol abuse.

In response to Cox et al. (2003), **Adams (2003)** stresses the methodological issues that can create biases towards distinct differences between type 1 and type 2 and spouse groups. These include age difference in type 1 and type 2 groups although Cox et al. co-varied age in their study. Adams suggests that age differences should not be dismissed. The self-reported nature of the study and absence of any form of follow-up also were cited as possible sources of weakness in the data collection. The author, while pointing out possible flaws in any single mode of inquiry (questionnaire, performance testing, simulation, and epidemiological investigation), calls for the need to develop a framework of fairness to competently set reasonable standards for traffic safety across disease conditions.

Grvaeling et al. (2004) present the findings of the survey study that queried 202 drivers with insulin-treated diabetes in Edinburgh, UK. Participants were asked about their employment, driving habits, awareness of hypoglycemia, experience of hypoglycemia in general, experience of hypoglycemia while driving and any associated accidents, blood glucose testing in relation to driving, and self-treatment of hypoglycemia while driving. Participants rated their hypoglycemia awareness using a validated scale from 1 (always aware) to 7 (never aware); ratings of 3 or higher were considered to indicate impaired awareness.

The results of the study suggested that the licensing authority (commonly referred to as the "DVLA") and motor insurance company had been informed by almost all participants. Sixty-four participants (31.7 percent) had experienced hypoglycemia while driving. A minimum blood glucose level of 4.0 mmol/l or higher was considered necessary for driving by 151 drivers (74.8 percent), and 176 (87.1 percent) reported always keeping a carbohydrate in their vehicle. However, 77 (38.1 percent) reported never carrying a glucose meter when driving, and 121 (59.9 percent) reported that they never test blood glucose before driving or test only if symptomatic of hypoglycemia. Most participants (89 percent) would stop driving to treat hypoglycemia and would not resume driving immediately, although only 28 (13.9 percent) would wait longer than 30 minutes. The study found perfect compliance with statutory requirements to inform the licensing authority and motor vehicle insurer and adequate knowledge of the minimum safe blood glucose level for driving. However, experience of hypoglycemia while driving was reported by nearly a third of drivers, and most drivers rely on symptoms to detect hypoglycemia while driving and seldom test blood glucose before driving. These findings suggest the importance of patient education which should emphasize the role of blood glucose monitoring in relation to driving and highlight the potential deterioration in driving performance when blood glucose falls below 4.0 mmol/l.

Gilbey (2004), in response to an inquiry for a case-scenario, provides detailed descriptions of legislation for different groups of vehicles in the UK where using the vehicle classification scheme consistent across Europe. Group 1 vehicles include motor cars and motorcycles. Group 2 vehicles include large lorries (trucks, category c) and buses (category D). Diabetic patients on diet may drive Group 2 vehicles unless other problems prevent them (e.g., retinopathy). Patients on oral treatment must notify the DVLA but may continue driving subject to the same proviso and provided there are no significant problems with hypoglycemia. Patients on insulin may not hold a Group 2 license, except a small number of drivers having "grandfather rights." Diabetic patients on insulin must notify the DVLA when insulin is started. They may continue to drive Group 1 vehicles subject to a medical report each time their license is renewed (every one to three years). The medical report includes a self-assessment of their management and the stability of their diabetes, their vulnerability to hypoglycemic episodes during waking hours, their vision, and their ability to manage the controls of a car (e.g., neuropathy, peripheral vascular disease). This report is commissioned by the DVLA from the patients' medical team.

A recent European Directive re-classified vehicles in C1 and D1 as Group 2, thus making these drivers subject to the more stringent medical regulations applying to Group 2 and, initially, denying all insulin-treated diabetic patients the right to drive these vehicles. Interestingly, "volunteer" drivers of D1 vehicles (e.g., for charities, church groups) were exempted from this restriction and allowed to continue driving these vehicles for this purpose only. Following extensive consultations, the rules were revised to allow some insulin-treated diabetic patients to apply for or retain their C1 (not D1) licenses under "exceptional circumstances" if they could demonstrate:

- Good care of their diabetes, including regular glucose monitoring;
- A good understanding of the risks of hypoglycemia at the wheel and the strategies necessary to avoid it; and
- No significant ongoing problem with hypoglycemia, and in particular no loss of warning of hypoglycemia (which would in fact preclude their driving any vehicle, if permanent).

This approach requires an annual review by a Consultant Diabetologist specifically for this purpose and implies a responsibility for the whole diabetic team to impart the education necessary to achieve this "exceptional" state. Insulin-treated patients are still not allowed to drive D1 vehicles, except under the "volunteer" driver exemptions noted above.

Diamond et al. (2005) present results of analysis of five type 1 diabetes patients who were involved in motor vehicle crashes due to severe hypoglycemia (plasma glucose values less than 2.5 mmol/l.). None of the patients suffered from poor acuity. The motor vehicle accident involving patient 1 may have been related to fat hypertrophy at injection sites. Failure to rotate insulin injection sites may result in a localized anabolic effect of insulin on subcutaneous fat cells leading to a potential "depot" for insulin storage. Erratic insulin release may have led to the hypoglycemic event. Patient 2 was known to suffer from longstanding, poorly compliant coeliac disease with malabsorption. Patient 3 drove a 17-ton truck. On the day of his accident, he was unexpectedly called out to work an unrostered shift and failed to consume sufficient carbohydrate. Patient 4 missed his lunch on the day of the accident, despite having administered his long acting insulin that morning. Patient 5 suffered from suboptimal, glycaemia control with infrequent self-monitoring of blood glucose and poor clinic attendance. The accident occurred mid-morning before his usual snacking.

These results imply that adequate self-monitoring of BG levels is extremely critical in prevention of hypoglycemia during driving. Hypoglycemic events are common in type 1 diabetes; occurrence of asymptomatic hypoglycemia twice a week and severe disabling hypoglycemia once a year are common in patients with type 1 diabetes. The author refers to data from the Diabetes Control and Complications Trial that suggest that individuals treated with intensive insulin regimens experienced a three-fold increased risk of severe hypoglycemia than those treated with standard therapy (Diabetes Control and Complications Trial Research Group, 1993) to emphasize the significance of the risks associated with hypoglycemia and driving. The following list features factors contributing to hypoglycemia in type 1 diabetes patients:

- Increased insulin due to over dosage, ill timing, wrong type, or erratic absorption (injection sites with fat hypertrophy);
- Decreased glucose delivery due to missed meals or snacks, malabsorption (e.g., coeliac disease);
- Decreased endogenous glucose production due to alcohol ingestion, acute liver disease;
- Increased glucose utilization during exercise;
- Increased insulin sensitivity following prolonged exercise, significant weight loss, improved glycemia control, use of insulin sensitizers (metformin, angiotensin converting enzyme inhibitors);
- Decreased insulin clearance due to progressive renal disease;

- Defective glucose counter regulation due to autonomic neuropathy, glucocorticoid deficiency (adrenal failure or hypopituitarism), aggressive glycemic therapy; and
- Infrequent self monitoring, psychological disorders (e.g., malingering and anorexia).

The study emphasizes the lack of well controlled studies or consensus that confirm or dispute more frequent driving mishaps of individuals treated with insulin compared to non-diabetic drivers. The authors point to Australian Driver Licensing Authorities guidelines for general practitioners in managing diabetic drivers. Practitioners are entrusted with a responsibility to alert and educate individuals with diabetes to the potential hazards of hypoglycemia that may occur during driving. The guidelines also emphasize the importance of preventive action and adherence to the law.

Tauveron et al. (2006) present an insightful case study in which the dog of a type 1 patient with hypoglycemia unawareness was able to detect its owner's hypoglycemic episodes especially during driving. The authors also refer to other two studies that confirm the ability of dogs to detect hypoglycemia and present two hypotheses on the mechanism of detection that currently are under study. Pets specifically trained to detect hypoglycemia could be of substantial help to diabetic patients, especially those with hypoglycemia unawareness.

4.6 Key Identified Findings – Vision

The studies in the current scientific literature for vision deficiencies vary considerably in the design and techniques of measuring visual deficiency and driving performance. Collectively these studies provide direction for further research in developing procedures and policies to assess visual deficiencies, driving performance, and licensing of the visually impaired.

The list below summarizes the detailed findings presented in this section into a set of *Key Points* that may have significant implications for interpreting statistical results as well as for guiding general FMCSA research and policy.

- Visual field loss (deficits in the Useful Field of Vision) is a significant factor in safe driving (Szlyk et al.,1992; Bowers et al., 2005; Szlyk et al., 2005);
- Peripheral vision loss is more critical than central vision loss (Jolly, 2002; Lamble et al., 2002); however, Coeckelbergh et al. (2001) had not found any differences;
- Crash rates for visually impaired drivers were not found to be higher than for the non-impaired drivers (Dionne et al., 1995; FHWA, 1996);
- It is likely that age can confound the observed associations between visual impairment and driving (Burg, 1967 and 1968; Hills and Burg, 1977; Maag et al., 1997; Owsley and McGwin, 1999);

- Compensatory viewing behavior is developed in order to mitigate the visual loss (Szlyk et al., 1995; Jolly, 2002; Szlyk et al., 2004);
- Compensatory viewing however, may confound the observed associations between visual impairment and driving (Jolly, 2002; Lamble et al., 2002; Coeckelbergh et al., 2004);
- Compensatory viewing is a significant predictor of on-road driving test outcome in the existence of other clinical measures such as visual acuity and visual field (Coeckelbergh et al., 2004);
- Poor driving simulator performance does not necessarily imply poor on-road performance due to avoidance and compensatory viewing behavior (Szlyk et al., 1995);
- Compensatory viewing and practical fitness to drive can be improved by training (Coeckelbergh et al., 2001);
- Drivers with visual defects tend to avoid challenging driving conditions; however, driving avoidance variable was not found to be significant in an accident prediction model (McGwin et al., 2004);
- Diagnosis category of visual field loss is not significant (Coeckelbergh et al., 2004);
- Monocular performance can be improved by experience and training (Sheedy et al., 1986);
- Monocular commercial drivers did not have significant differences in the performance of tasks involving safe driving (McKnight et al.,1991);
- Location of visual loss is not significant (Jolly, 2002; Racette and Casson, 2005);
- More errors were observed at intact-vision side of the vehicle due to compensation effort for hemianopic drivers. Intact side was more neglected than the deficient side (Jolly, 2002);
- Hemianopia in the left eye is critical (Racette and Casson, 2005);
- Diffused loss of visual field in the right eye is critical (Racette and Casson, 2005);
- Case-by-case assessment is highly recommended (Jolly, 2002; Wilkinson, 1998 and 2003; Coeckelbergh et al., 2004); and
- Retinal thickness and focal laser scars are correlated with poorer driving simulator performance indicators that are associated with self-reported accident involvement (Szlyk et al., 2004).

Issues and Challenges

Almost all of the studies examined in the area of vision deficiencies illustrate similar challenges in the design, implementation, and patterns of their findings. The challenges can be summarized in three categories.

Confounding Factors

Confounding effect is observed when a factor that is not controlled statistically or by the study design obscures the effect of treatment. Examples of such factors impacting the field of vision and driving are age, driving exposure, and compensating behavior. Vision impairment is more prevalent in older drivers who also are more likely to have deficiencies in their motor abilities and less likely to resist fatigue. Moreover, crash rates increase with age. Driving exposure and driving environment also are important factors since experienced drivers are less likely to be involved in crashes and more likely to avert and/or avoid challenging driving conditions.

It is well recognized that visually impaired drivers develop effective compensatory strategies to accommodate their impairments. Therefore, relying on medical test scores and ignoring actual driving performance can easily obscure the treatment effect under study. A well-designed study should incorporate, but not be limited to, driver age, driver exposure (miles driven per year), driver experience (number of years of driving), and existence of compensatory behavior (onset of the impairment) in the design phase.

Outcome Definitions

Traffic safety factor has numerous indicators, including crashes, violations, crash and/or violation rates per miles driven, performance in on-road tests and driving simulations, and self-reported incidence involvement rates and other habits. Since the relationship between these outcomes is not clearly established, making comparisons across different studies becomes tenuous. Therefore, caution is needed when reporting similarities or dissimilarities among different studies measuring different outcomes or even similar outcomes from different sources, such as self-reported crashes and state records.

Impairment Definitions

Another source of possible inconsistencies when comparing studies is how visual defect is measured. Incorrect reports of the presence or absence of an eye condition can alter the crash involvement rates. Visual function is generally categorized using certain thresholds in order to designate subjects as impaired or unimpaired. Inconsistencies in these thresholds, which are not uncommon, may introduce difficulties in comparing studies. Researchers should provide clear reasons for defining impairment levels and preferably select thresholds that have been commonly accepted in previous studies.

4.7 Key Identified Findings – Diabetes

Type 1 diabetic drivers are at increased risk for driving mishaps, but type 2 diabetic drivers, even on insulin, appear not to be at a higher risk than non-diabetic individuals. Clinical and treatment factors appear to increase risk, e.g., more frequent hypoglycemia while driving, method of insulin delivery, and infrequent self-testing before driving. Physicians should be encouraged to talk to their type 1 diabetic patients about hypoglycemia and driving.

It also is implied that licensing rules might affect driving risks in a positive way: European drivers on insulin who are required to renew their license at regular intervals reported fewer episodes of significant hypoglycemia while driving than U.S. drivers who do not renew their license at similar intervals. More studies are needed to answer questions about the fairness of including insulin-treated type 2 diabetic patients in the same risk category as type 1 patients for licensing purposes.

5.0 Driver Interviews

5.1 OVERVIEW

Interviews with current drivers about their experiences with the Vision Exemption Program were a key component of the research methodology. The interviews focused on driving issues, but also addressed the drivers' views of the overall FMCSA exemption process.

Nine drivers were interviewed by telephone. To reduce the potential bias of any particular interview, two actions were proactively taken:

- A detailed interview questionnaire was jointly developed by Cambridge Systematics and FMCSA staff; and
- Each telephone interview was conducted by the same member of Cambridge Systematics' staff.

This section describes the interview process, summarizes the responses of each interviewee, and identifies key findings.

5.2 INTERVIEW GUIDE

The interview process used a structured interview guide, developed jointly by Cambridge Systematics and FMCSA staff. At the start of each interview, the interviewer provided an overview of the study and the reason for the interview. In the interview, the driver was asked general background questions, questions about their medical condition, questions about the overall FMCSA exemption process, and questions about potential process improvements.

The full set of questions follows.

Background

1. What type of company do you represent (e.g., for-hire motor carrier, private motor carrier, owner/operator)?
2. Are you a member of any special interest groups within the motor carrier community (e.g., motor coach, intermodal, hazardous materials hauler)?
3. What type of vehicle do you typically operate?
4. Do you operate interstate or intrastate?
5. How many years of driving experience do you have (both overall and commercial)?

6. What are the hours during which you typically operate your commercial vehicle?
7. Do you normally operate during adverse weather conditions?

Medical Condition

8. Please identify the medical condition that causes your visual deficiency.
9. Please indicate the eye in which you have a vision deficiency.
10. How long have you had this deficiency?
11. Have you undergone any medical procedures to attempt to correct the deficiency?
12. Are you required to wear any corrective lenses?
13. How does the deficiency affect your driving?
14. Are there any apparent differences when operating a commercial vehicle versus operating a non-commercial vehicle?

Exemption Application Process

15. How were you made aware that a Federal vision exemption exists?
16. Once you were aware, what means did you use to obtain an application package?
17. Did you find this means to be satisfactory?
18. Did the application package outline the required information to be submitted in a format that was easy to understand?
19. Once you submitted your application, did you receive timely responses to your submissions? If no, what timeframe do you feel is acceptable?
20. Did you submit questions to the Federal vision program related to your application? If so, did you receive timely responses? Were the responses provided adequate in providing you the information that you needed?
21. As a participant in the Federal vision program, do you believe that this affects how safely you operate a commercial motor vehicle? If yes, in what way?
22. During your visual exam required by FMCSA for the exemption application, did your ophthalmologist/optometrist discuss with you what impact your visual deficiency has on your ability to drive a CMV safely?

Potential Process Improvements

23. What would you consider to be the biggest challenge that you face as an operator with a vision deficiency? (If appropriate) How could FMCSA play a role in helping to solve this issue?
24. Do you feel that means of getting information related to medical exemptions is well distributed in the trucking industry? If not, what improvements could be made?
25. What aspects of the current Federal vision program do you like?
26. What aspects of the current Federal vision program do you dislike?
27. What steps could FMCSA take to improve the overall process?
28. If FMCSA made it possible to apply, obtain application status, and submit questions electronically at our web site, would you use this service?

5.3 ABSTRACTION OF INTERVIEW SUBJECTS

To protect the privacy of the drivers who volunteered for this project, we will refer to them as "Driver 1" through "Driver 9." The summary characteristics of the drivers who volunteered for the interview process are shown in Table 5.1.

Table 5.1 Characteristics of Interviewed Drivers

Driver Identifier	Year of Birth	State of Residence	Vision Deficiency
Driver 1	Early 1950s	CT	Macular Degeneration
Driver 2	Early 1970s	GA	Scar
Driver 3	Late 1960s	ID	Blindness
Driver 4	Early 1940s	KS	Prosthesis
Driver 5	Late 1940s	OR	Amblyopia
Driver 6	Late 1930s	UT	Macular Degeneration
Driver 7	Early 1960s	WA	Scar
Driver 8	Early 1940s	TX	Strabismus
Driver 9	Late 1950s	FL	Blindness

5.4 INTERVIEW COMMENTARY

Driver 1

Driver 1 is a male driver born in the early 1950s, currently residing in Connecticut. He is a for-hire driver who currently is laid off; is in school to obtain a CDL Class A license; and is not a member of any special interest groups.

Driver 1 primarily operates fuel oil and box trucks in the Northeast United States, near his Connecticut residence. Driver 1 has been operating a vehicle since 1968, and started operating a commercial vehicle in 1970 as a member of the military. Driver 1's operating times vary widely based on the needs of his employer. Given his driving patterns, Driver 1 routinely operates during snow and sleet.

Driver 1 entered the Vision Exemption Program due to a diagnosis of macular degeneration in his right eye. He claims to have "good vision"; however, he cannot read fine print with his right eye. Driver 1 has had the deficiency since 1990, and the deficiency currently cannot be corrected. Driver 1 indicated that he can drive a car without lenses, but the law requires him to drive a truck with lenses.

Driver 1 stated that he believe that the deficiency does not affect his driving.

Driver 1 indicated that after he reported for his DOT physical to obtain his medical certification from the State of Connecticut, he was told he could not drive a truck. The Connecticut DMV informed him that he could apply for the waiver. Driver 1 called FMCSA which sent the application through the mail. During his required physical examination, Driver 1's physician did not discuss the impact of his deficiency on his driving.

Driver 1 indicated that he repeatedly mailed the requested information to FMCSA, but received multiple requests for supplemental information. Driver 1 stated that he "had to re-take the tests and there was a lot of paperwork" and indicated that he found the process to be cumbersome.

During the interview, Driver 1 commented that the process is cumbersome because "these people just want to keep themselves employed."

Driver 1 indicated that he "called a couple of times and didn't get anyone" and left a message. He "couldn't wait around all day" for a response, so a message was left for him to return the call. The cycle repeated itself until he was able to connect with someone. He indicated that he would like to see a two hour window for return calls.

Driver 1 stated that being a participant in the Federal vision program does not affect how safely he operates a commercial motor vehicle, and that being a member of the program may result in negative reaction from potential employers.

Driver 1 stated that the amount of paperwork involved "is a big challenge." He considered the program to be too complicated and said that as long as a driver has 20/40 vision in the best eye, there should be no need to participate in the program.

Driver 1 had the most negative feelings about the Vision Exemption Program of any participant. He stated that he was told he needed to see an eye doctor to obtain a report, he saw an optometrist, and he did everything he was instructed to do, yet FMCSA requested more information indicating what he provided was insufficient and additional information was required. Driver 1 indicated that some of the information requested by FMCSA is too vague and that "they don't specify until it is too late."

Driver 1 stated that the tests involved to fulfill the application requirements were costly, especially for someone without medical insurance.

Driver 2

Driver 2 is a male driver born in the early 1970s, residing in Georgia. Driver 2 works for a small number of private carriers operating electric line and bucket trucks, and does not belong to any special interest groups. Driver 2 currently operates only in the State of Georgia, within approximately a 40 mile radius from his place of employment.

Driver 2 has been driving for 15 years and driving a commercial vehicle for over nine years. The majority of his driving is during the daytime. He often drives in rain or in solar glare conditions.

Driver 2 has been legally blind in his right eye since childhood. He indicated that as a child the eye "turned in" and that while growing up it "turned up"; he later developed double vision. He underwent muscle surgery to correct the double vision; however, vision in the eye is still poor.

Driver 2 is not required to wear any corrective lenses, and stated that the deficiency does not affect his driving of either a commercial or a non-commercial vehicle.

Driver 2 had a restriction on his CDL. When he renewed his CDL, as a result of a clerical error, the restriction was left off his license. Driver 2 returned to the facility in an attempt to correct the error and was told that once the restriction is removed it cannot be reinstituted. At this point he was informed that in order to drive a commercial vehicle he would need to participate in the Vision Exemption Program.

Driver 2 requested his application by telephone. He indicated that the process took eight months; he needed to call "all over the place" before the package was sent. One setback was the expiration of his CDL before he received his waiver.. As a result, he was forced to "drop down from CDL" to a regular license so that he could get the waiver. He believed that he probably could have avoided the drop-down if the application process had been faster.

Driver 2 described the application process as "aggravating," and indicated that there were instances when he believed FMCSA was being too stringent. Even though he had the help of his employer, he found the process to be time consuming. Driver 2 indicated that there was "too much nitpicking" and indicated that there was one instance when clarification was requested because of a misspelling of one word.

Driver 2 indicated that responses from FMCSA were not timely.

Driver 2 does not believe that program participation affects how safely he operates a commercial motor vehicle. Driver 2 indicated that his doctor stated that his condition would not affect his ability to drive.

Driver 2 said that the program is not well publicized, and that "FMCSA needs to do something." In fact, he was not aware that the program existed; he learned about it because of the clerical error at the DMV.

Driver 2 stated that shortening the turnaround time was a key need, and that the ability to apply, obtain application status, and submit questions electronically at an FMCSA web site would "speed things up."

Driver 3

Driver 3 is a male for-hire driver born in the late 1960s who currently resides in Idaho. He operates both tractor-trailers and dump trucks in interstate commerce.

Driver 3 has 18 years of overall driving experience and 14 years of commercial driving experience. He drives mostly during the day, but sometimes at night. He drives through a wide variety of adverse weather conditions.

Driver 3 is blind in his left eye due to a shotgun accident at age 14. He wears a prosthetic in his left eye socket. He has had this deficiency for over 20 years. No corrective lens is required for his right eye. Driver 3 believes that the deficiency does not affect his driving. He said that he does not miss the eye. Driver 3 stated that he has never had an accident while driving a vehicle.

A previous employer helped Driver 3 with the application process. He never received the waiver, however, while working for his previous employer. Driver 3 called and requested the application and it was mailed to him. He said that the application was easy to understand. One issue he faced was a language barrier, and an interpreter was needed.

Driver 3 did not believe that that being a participant in the Federal vision program affects how safely he operates a commercial motor vehicle. On the other hand, he stated that he takes extra precaution to make certain mirrors are in place.

Driver 3 stated that during the vision exam, he "passed everything and was cleared."

As Driver 3's native language is not English, he experiences difficulty when receiving information from FMCSA. He stated a desire that information be made clearer or that access to an interpreter could be provided.

Driver 3 stated that the process to receive the waiver is too long; in his case it was almost a year and without it he could not work.

Driver 4

Driver 4 is a male driver born in the early 1940s who lives in Kansas. Driver 4 works for a private carrier, and is not a member of any special interest groups.

Driver 4 primarily operates a straight truck and operates in Kansas, Arkansas, Oklahoma, and Missouri.

Driver 4 has been driving for over 50 years, but has been driving commercially for only six years. He drives a combination of day and night shifts, including a mixture of adverse weather conditions.

Driver 4's condition is the result of being stabbed in the left eye 34 years ago. While he underwent medical treatment to correct his injury, it was not successful. He has a prosthesis in his left eye and wears glasses, mostly for reading.

Driver 4 states that the deficiency does not affect his driving, and reports no apparent differences in operation of commercial versus passenger vehicles.

Driver 4 was informed of the exemption program during his DOT-required physical, but the physician did not specifically discuss the impact of his deficiency on his driving. Driver 4 called the number provided by the physician and the information was mailed to him. He found the process satisfactory, and reported the application package was clear regarding requirements to be fulfilled.

Driver 4 reported the process was about seven months, and indicated he would have preferred a few weeks although he understands requirements must be met and confirmed.

As a participant in the Federal vision program, Driver 4 said he is more careful since losing his eye knowing he is not 100 percent. He compensates for his deficiency by being extra careful, not switching lanes as often, using a safe following distance, and using his mirrors. Driver 4 states that his biggest challenge is making sure he can see all around the vehicles, and he uses mirrors to his advantage.

Driver 4 believes the program is not well publicized and relies heavily on word of mouth. He recommended distributing information to physician offices.

Driver 4 likes the program as it allows him to continue to earn a living. He considers the program to be "fair." He suggests improving the program by reducing turnaround time for the application approval. Specifically, time off the road relates directly to lost wages to operators, making prompt approval a huge benefit.

Driver 4 said he would definitely access program information from a FMCSA web site.

Driver 5

Driver 5 is a male driver born in the late 1940s, residing in Oregon. Driver 5 works for a private motor carrier and typically operates single-axle trailers and box trucks. Driver 5 is classified as an interstate operator because he crosses the State line, but he does not travel far into neighboring states.

Driver 5 has been driving since 1967, and started driving commercially "sometime in the mid 1970s to early 1980s." He operates strictly during the daytime, and often faces adverse weather conditions, including snow, rain, sleet, and high winds.

Driver 5 suffers from Amblyopia in his left eye. He was diagnosed in the "mid 1980s or early 1990s." The eye was damaged in a fight while he was in elementary school. He can see road signs with his left eye, but is not able to read them.

Driver 5 was diagnosed too late to correct the condition surgically, but he does not wear corrective lenses. He reported that the optometrist talked about the eyesight but not specific to driving.

Driver 5 indicated that the condition does not seem to have any effect on his driving. He did indicate that he pays more attention to his surroundings when driving. He added that each driver must consider other drivers around their vehicle and act accordingly.

Driver 5 states that he operates both commercial and non-commercial vehicles in the same manner. He spends more time operating commercial vehicles and acknowledges driving slower than when he drives a car.

Driver 5 does not specifically remember learning about the Vision Exemption Program, but he said it was a word-of-mouth exchange after he was told he could no longer operate in Oregon. He was told to contact FMCSA, which he did. He requested the application from FMCSA, and the package was mailed to him. He found the process to be satisfactory.

Driver 5 stated the most difficult part of the process is obtaining the license information (driving record) in Oregon as the information provided by the DMV is "not really official" which caused some problems with FMCSA. He provided FMCSA with the DMV's phone number and FMCSA was able to obtain the necessary information.

Driver 5 indicated that notification of information that is needed is too close to the expiration date; if notified in a more timely manner, the applicant has more time to gather the required information.

Driver 5 said that being a participant in the Vision Exemption Program makes him more alert as an operator. He expressed concern about receiving traffic tickets or other violations that could jeopardize his participation in the program. Driver 5 stated it was important to use caution and not make any mistakes rather than take shortcuts and find yourself "kicked out of the program." He makes certain his equipment is in good shape and plans his routes to avoid heavy traffic as much as possible, which makes operation easier and simpler. These are factors that he also takes into consideration when driving a car. He does not consider his vision condition, however, to be an additional challenge.

Driver 5 does not believe information regarding waivers is as readily available as it should be. He indicated that he meets commercial drivers with conditions similar to his and they do not have a waiver; he sees a lot of drivers who do not have a waiver wearing eye patches. He indicated that he "just happened to find out" about the program. Doctors should be made aware of the program, he suggested. Additionally, he suggested the program be publicized in trucker journals, magazines, the Internet, and other sources of information.

Driver 5 likes the program because it allows him to have a job.

Driver 5 pointed to the two year basis of the waiver and recommends that it be extended to four years as the cost of the application process is significant. He stressed that both driver license and HAZMAT credentials are good for eight years. Companies often hold HAZMAT safety classes and classes pertaining to Federal laws and log books, yet there is no continuing education pertaining to vision issues.

Driver 5 expressed that the program should be administered on a case by case basis. He also is frustrated with the repetitive nature of some of the questions he was asked during the application process, the same questions that are asked by the DMV.

Driver 5 suggested limiting the length of time an operator may have a waiver. In some cases of diminishing sight operators should not be licensed. *(Note that this statement conflicts directly with his statement that the waiver should be four years.)* Driver 5 was in favor of a web site for the vision program where participants could submit information electronically.

Driver 6

Driver 6 is a male driver born in the late 1930s who resides in Utah. Driver 6 works for a for-hire motor carrier. At one time he was a member of the Teamsters, but has since retired from that organization. He operates a tractor and three trailers in interstate commerce.

Driver 6 began driving in 1956. He currently drives during the day and at times at night. He drives through a variety of adverse weather conditions.

Driver 6's condition is referred to as a "vein occlusion." In 2001, a blood vein behind his retina broke as a result of high blood pressure. He underwent surgery to attempt to repair the vein, but it did not sufficiently restore his vision. He was told he would likely experience this occlusion again, but to date it has not recurred.

Driver 6's condition is in his right eye. While the condition did not affect his peripheral vision (left-to-right) his short range vision requires bifocals for correction. Driver 6 wears corrective lenses for his left eye but there is no corrective lens for his deficient right eye.

Driver 6 reported that he must be careful as his depth perception is approximately six or seven feet. Beyond this limit he "relies on his brain" to perceive what is close and not close. He has driven for two years with a medical waiver for this condition and has had no accidents. Additionally, he reported difficulty when driving at night when glare conditions on the windshield are prevalent.

Driver 6 reported a long consultation with his physician who gave him a field of vision test, among a number of tests. His physician explained that his visual depth perception is only six feet and beyond that distance, his brain "would take over."

Driver 6 reported little difference between operating non-commercial equipment and commercial equipment. He did note an increased field of vision in a commercial vehicle cab because of the added height.

Driver 6 learned of the Vision Exemption Program from an employee in the CDL division of the Utah DMV. A colleague and friend was the first in Utah to receive the exemption and he helped Driver 6 through the process.

Driver 6 said the process was very easy. He called FMCSA and the waiver application was mailed within a week. The process was approximately 10 months to complete (he noted that this was quite lengthy). Overall, however, he was pleased with the exemption program.

The information packet was easy to understand; however, he reported it was difficult to gather all of the supporting documentation. For example, he needed to locate a number of safety directors at previous employers, but the companies were out of business.

Driver 6 found the questions to be self-explanatory, requiring no further clarification. He did receive a timely response to his application and suggested approximately 30 days would be an acceptable timeframe to ensure applicants do not lose their livelihood (house and income) during the waiting period. He added that "the person applying can usually drive so why prolong the down time." He added that if all information required by the application is submitted the process should not be prolonged.

Driver 6 said he thinks about his participation in the vision program all of the time as he absolutely cannot receive a ticket or be involved in an accident. He is very cautious. He also reports being much more aware of traffic ahead, not swerving, and getting in a lane and staying in that lane without switching. He added that his vehicle is equipped with "a lot" of mirrors which is very helpful. He stated that many carriers do not have the mirror on the fender, and that few provide the mirror that allows a driver to see straight down the vehicle's right door.

Driver 6 acknowledges additional responsibility for being a defensive driver and making certain he is in a position that avoids problems such as other vehicles being too close. He also makes concerted efforts to avoid sudden stops.

When his condition was first identified, Driver 6 was not proactively given any information regarding exemption options by his employer. Once he inquired about exemptions, he was assisted. Additionally, Driver 6 expressed discontent for the current revocation process in which the driver's license is taken immediately without the driver knowing about the alternatives to obtaining a waiver.

Driver 6 believes the vision program is "wonderful" as he can make a living again. The program also informs the employer that there is a problem requiring accommodation and understanding.

Driver 6 reported no discontentedness with the program. Additionally, he offered that the program representatives told him exactly what he needed to do for reinstatement of his license, and upon his compliance, they did everything they said they would do to help him receive his license.

According to Driver 6, decreasing turnaround time for processing the application would improve the program. He found some requests redundant and recommended reducing the paperwork. Driver 6 reported he would definitely access the application via the Internet as it would "make the process very fast."

Driver 7

Driver 7 is a male driver born in the early 1960s who lives in Washington and works for a private motor carrier operating a tractor-trailer on an interstate basis.

Driver 7 has 20 years of driving experience for both commercial and non-commercial vehicles. Most of his current driving is at night; he rarely drives during the day. He often operates during adverse weather conditions.

Driver 7 has an eye scar after being hit in the left eye with a baseball approximately thirty years ago. The condition cannot be corrected, but he is not required to wear corrective lenses.

Driver 7 indicated that his condition does not affect his ability to drive either a commercial or a non-commercial vehicle.

The Vision Exemption Program was brought to Driver 7's attention about four years ago by a friend who saw the information in a newspaper in Louisiana and sent the clipping to him. Driver 7 acquired the application via a phone call; he then passed it on to his company. The company compliance/safety officer helped him with the application process.

Driver 7 indicated that he faced many hurdles in obtaining his complete driving history (all hours spent driving were required). He needed a year and a half to pull all the necessary information together. Responses from FMCSA, however, were timely and more than adequate.

Driver 7 believes that being a participant in the Federal vision program affects how safely he operates a commercial motor vehicle. He is very careful about pre-trip planning and making certain that equipment and paperwork are in order. Driver 7 indicated that he is careful to avoid receiving traffic tickets for fear of being expelled from the program.

Driver 7 indicated that at the time of his application he had been driving for about 15 to 20 years, but only in intrastate commerce, because he did not know about the exemption program.

As a driver with a vision deficiency, Driver 7 stated that making certain all mirrors are in their proper place and getting "a lot of rest" before a trip were important factors. He also emphasized being aware of other drivers, who may not be paying attention or are not courteous to trucks.

Driver 7 was pleased with how FMCSA disseminates information related to medical exemptions; information is well distributed to the trucking industry. He believed that requiring the yearly physical and eye exam is "a good thing."

Driver 7 does not own a computer, so he would not take advantage of a FMCSA web site for the Vision Exemption Program. He is, however, pleased with the current program.

Driver 8

Driver 8 is a male driver born in the early 1940s who resides in Texas. Driver 8 currently operates as an owner-operator pulling camper trailers leased to a larger company. He operates a pick-up truck with a bumper pull and fifth-wheel recreational vehicles. He operates in interstate operations, including Canada.

Driver 8 has been driving for over 45 years, commercially for over 40 years. He primarily operates during daylight hours, and prefers driving in early mornings. He operates under all weather conditions.

Driver 8 was born cross-eyed; after a series of surgeries when he was 12 to 22 months old he was left with vision in only his left eye. He does wear corrective lenses. Since he had driven in intrastate operations for nearly 40 years when he was examined, the physician understood the purpose behind the examination.

Driver 8 stated that since he has had vision in one eye almost since birth, he cannot provide any insight on what it would be like to drive with full vision. He indicated that he believes that he has slightly more depth perception problems than other drivers when he uses mirrors for backing up. However, he considers himself to be as good as any other driver.

When Driver 8 worked for a previous employer, his goal was to obtain a DOT physical and a CDL. He learned that he did not need a CDL because he was operating a vehicle less than 26,000 pounds. A clerk at the Texas State Driver's License Authority told him about the exemption program, and provided the number to call for an application.

The application was sent to him along with instructions. Driver 8 found the process to be time consuming and cumbersome, but he also stated that he understands and agrees with the reasons behind the process.

Driver 8 said that the application package outlined the required information in a format that was easy to understand. In his opinion, a same-day walk-in process should be available. He did indicate that responses from FMCSA to questions he had submitted were provided in a timely manner and were acceptable.

Driver 8 believes that he has extra awareness as a result of participation in the program. His biggest challenges are peripheral vision and depth perception; he is aware of both issues and has taken actions to overcome them.

Driver 8 indicated that the program is not well publicized. He said he attended a wedding a few months ago and met a driver with similar vision problems who was operating only on an intrastate basis because he could not pass the DOT physical. The man's employer wanted him to operate in other states. Driver 8 informed the driver about the Vision Exemption Program. Subsequently, the driver applied for and was granted a waiver. Driver 8 also pointed out that had he talked to a different clerk in Texas, he might not have heard about the program.

Driver 8 believes that FMCSA needs to take steps to make people more aware of the opportunities available through the vision program. He said that those who do not pass the DOT physical consider it "as a wall" but it does not need to be.

Driver 8 would not use any on-line functionality provided by FMCSA.

Driver 9

Driver 9 is a male driver born in the late 1950s, residing in Florida. He is currently employed by a private motor carrier, driver 9 currently does not belong to any special interest groups. Driver 9 mostly drives dump trucks hauling construction materials. Overall, driver 9 has been driving for over 30 years, with approximately 25 years of experience operating commercial vehicles. Driver 9 mostly operates during daylight hours, as a result of his geographic location, he typically faces rainy conditions as well as solar glare.

Driver 9 lost sight in his right eye in his early teens as a result of being hit in the eye with a ball. He has never undergone any medical procedures to correct the problem as the condition was deemed uncorrectable. Driver 9 only currently wears corrective lenses for reading. Driver 9 indicated that his condition does not have any effect on his driving, particularly since he has never known what it is to drive without the condition, he also pointed out that there were no apparent differences to him when driving a passenger vehicle versus a commercial vehicle. He did however indicated that he tries to do everything in his power to ensure that he does not lose his waiver and that the program keeps him focused on being a safe driver.

Driver 9 became aware of the program after he had trouble passing the DOT physical as a result of his vision deficiency. The waiver program was brought to his attention by one of his physicians. He researched the program and actively sought out information on the program. Driver 9 contacted several of the motor carrier agencies in the State of Florida until he was finally able to get in touch with someone who could provide him with information on the program. Once he received the correct information on the program he contacted FMCSA by telephone and an application was mailed to him.

Driver 9 indicated that obtaining the initial application, once he got the proper contact information was very easy, however once he got further into the process and was required to provide supplemental documentation, the process quickly became very cumbersome. Driver 9 indicated that FMCSA needs to be more specific in terms of what is needed from the applicant, he indicated that his application was held up because he was submitting incorrect information in terms of the type of vision test that was required of him, neither he nor his physician could figure out what was required by FMCSA from the requests they were being sent. He also indicated that the entire process took about six months, he felt that in his case the process could have been a lot quicker, if FMCSA provided specific guidelines on the type of vision test that was required. He also indicated that the ideal turnaround time would be about six to eight weeks, but stated he does understand why an application of this nature can take as long as six months to process.

In terms of areas of improvement, Driver 9 indicated that the program needs to be more publicized, he only became aware of the program after expressing his frustrations to his doctor when he failed his DOT physical year after year. Even after finding out that such a program exists, it still took some legwork on his part to get in contact with the right people in the State of Florida who could provide him with the phone number to call and receive an application. He indicated that FMCSA could perhaps create an informational pamphlet that maybe doctors that administer DOT physicals could have at their offices. In terms of web enabling the application process, he indicated that it might speed things up and make things easier and perhaps even improve the lines of communication between FMCSA and the applicant, however he indicated that he personally did not have a computer.

5.5 KEY FINDINGS

The feedback received from interviewed drivers about the Vision Exemption Program was mostly positive. Most of the criticism was constructive in nature about the process, most notably about the lack of publicity and the long turnaround time. Only one interviewee expressed that the program should be completely abolished.

More than half of the interviewees have had their vision deficiency condition since childhood, but there was no significant difference uncovered between those who were born with the condition or developed it at an early age and those who developed the condition later in life.

When asked directly, most drivers said that their condition did not affect their driving. On the other hand, several interviewees indicated that program participation made them more aware of their driving and caused them to take additional steps, such as enhanced pre-trip planning, to ensure that they were operating under the safest of conditions.

In terms of the overall program, almost everyone interviewed indicated that one of the biggest issues with the program was the application turnaround time. While some indicated that they understood the reasons behind the long turnaround time, nonetheless they believed that steps should be taken to speed up the process. In one case, a driver's CDL expired while he waited for his application to be approved.

The other significant issue raised consistently by the interviewees was the relative obscurity of the program. The drivers indicated that the program was not well publicized throughout the industry. Most of the interviewees learned about the program by happenstance. One interviewee commented that FMCSA needs to take steps to ensure that an individual who fails the DOT physical as a result of a vision problem is aware that the failure is not the end of their livelihood. Education is needed to raise awareness of the procedures in place that will allow these drivers to continue to operate in interstate commerce (in some cases, the program will allow drivers to *begin* interstate operations). Another interviewee also indicated that it is important to better educate state agency staff about the program.

One final issue implied by the interview results is that vision standards may not be adequately enforced by states. One driver mentioned a driver "wearing an eye patch" and indicated that the driver was engaged in interstate operations. While anecdotal, such comments should stimulate follow-up by FMCSA staff to ensure that state agencies understand all of the issues regarding vision qualification.

6.0 Quantitative Analysis

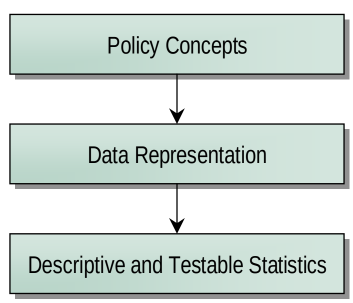
6.1 OVERVIEW

The quantitative analysis portion of the Medical Exemption Program Study considers the policies in place for acceptance into the program as well as continued participation in the program. The analysis considers each of the key elements of the current policy and defines tests for both tightening and relaxing these policy elements.

The purpose of quantitative analysis and hypothesis testing is to determine what, if any, impact the Vision Exemption Program has on crash rates and safety in general. To this end, the project team developed an analysis framework shown in Figure 6.1. The analysis framework involves the following three key components:

- Identify broad policy concepts in consultation with FMCSA;
- Define the policy concepts in terms of the data at hand; and
- Identify specific hypotheses that can be tested subject to the availability of sufficient data.

Figure 6.1 Overview of the Quantitative Analysis Framework



6.2 POLICY CONCEPTS AND DATA REPRESENTATION

In consultation with FMCSA, Cambridge Systematics identified four broad sets of policy concepts for evaluation using descriptive and/or statistical testing:

- Drivers with a vision deficiency are **"less safe"** than other drivers;
- For drivers who appear to **"have been safer in the past,"** the impact of their vision deficiency is negligible;

- Not all **"types of vision deficiency"** have equal impact on driver safety; and
- (To a lesser extent) The impact of a vision deficiency is affected by **"other factors"** reviewed during the exemption process and logged in the MANILA driver checklist.

The sections that follow discuss how each of these policy concepts will be defined and represented using the available data and also the specific hypotheses that will be formulated and tested.

"Less Safe"

The intent here is to quantify the safety level of a driver and to define a "metric" that would help define what is meant by "less safe" and "more safe." Variations of these definitions will then be used as proxies for quantifying the estimated safety of a driver after program acceptance (or for the control set, after the control date).

Possible characterizations for "less safe" could include:[1]

- More fatal crashes;
- More injury or fatal crashes;
- More tow-away, injury, or fatal crashes;
- More crashes and severe moving violations; and
- More crashes and violations of any kind.

Discussions with FMCSA staff indicated that the first two items are considered to be the key factors. Nonetheless, all characterizations were explored.

Unfortunately, the project team was unable to obtain violation data for the control set of drivers, and only the number of violations for the three years prior to acceptance for exempt drivers.

Therefore, three policy alternatives were proposed:

- Current policy:
  - Within the program: Crashes of tow-away or greater severity plus severe moving violations;
  - In comparison with the control set: Crashes of tow-away or greater severity;

[1] The current definition of safety for program acceptance includes a combination of the last three bullet points.

- Less restrictive policy: Injury and fatal crashes only; and
- More restrictive policy (within the program only): All crashes plus all violations.

"Safer in the Past"

The idea of "past safety" is important because past safety is a key factor for admitting drivers into the program. Varying the policy on past safety may have different impacts on the observed future safety (e.g., the "less safe" notion above).

Quantifying the past safety record of a driver will require the identification of not just the severity of the accidents but also the duration over which these occurred.

A general framework for quantifying the safety record of a driver includes the following dimensions:

- Less than *C* crashes;
- Of severity level *S* or worse;
- In a *Y* year-period; and
- Ending at time *T*.

The current acceptance criteria are:

- Less than one crash (no crashes at all);
- Of *basic* severity level;
- In a *three*-year period; and
- Ending at the *acceptance date*.

Changing the values of the parameters listed above will form different policies that can be tested. Both more lenient and more restrictive policy definitions will be considered.

- An example of a more lenient alternative to the current policy would be "less than one basic crash in a two-year period ending at the date of acceptance."
- Another more lenient alternative to the current policy would be "less than one injury crash in a five-year period ending at the date of acceptance."
- A more restrictive alternative to the current policy would be "less than one basic crash in a four-year period ending at the date of acceptance."
- An even more restrictive alternative to the current policy would be "less than one basic crash in a five-year period ending at the date of acceptance."

Note that for the control set, there is no "acceptance date" available. Therefore, a hypothetical acceptance date of December 31, 2003 has been assumed. This assumption will allow the comparison of crash rates before and after the "acceptance date."

"Types of Vision Deficiency"

The intent here is to identify logical "groups" of vision deficiencies to evaluate the impacts on safety. The approach for categorizing vision deficiency is described earlier in this report, in Section 3.2. To reiterate the approach, each program driver was categorized into one of the following categories of deficiency:

- Amblyopia (amblyopic drivers were by far the largest group, and it was decided that these drivers deserved their own category for analysis);
- Accident/Injury/Trauma;
- Congenital;
- Disease; and
- Unknown.

In addition, drivers were identified as either "blind" in one eye, or not.

"Other Factors" Reviewed in the Application

In addition to the vision deficiencies, other important factors available from the application summaries were used for statistical testing after controlling for factors such as age and geography.

The key factors included in the analysis were:

- Onset of deficiency;
- Eye with deficiency (right, left or both); and
- Field of vision.

After consultation with FMCSA staff, other factors on the application were discarded from the analysis.

6.3 Limitations Due to Insufficient Data

Unfortunately, certain hypotheses of interest to FMCSA cannot be directly tested strictly within the set of exempt drivers. These hypotheses generally involve testing relaxation of current FMCSA policy. Because the policy has not varied significantly over the life of the program, the ability to consider drivers admitted using relaxed standards is impossible.

The team's approach for these hypotheses was to test the behavior of the control set. While not ideal, the observed results of control drivers under various policies provided insights into trends which can reasonably be expected to occur if FMCSA policies are relaxed.

One example is the question: "Are there any rejected exemption applicants who could have been allowed in the program?"

This question cannot be tested statistically because there is no information on the rejected applicants. All the transcribed summaries belong to those applicants who have been approved, as the data quality issues for the applications of rejected applicants were substantial enough to prevent them from being used.

Even if information were available, however, rejected applicants are no longer driving. Therefore, it is not known how they would have performed after acceptance.

A second example is the question: "Can the requirement for duration of 'safe driving' be reduced from three years to two years or even one year? Can it be changed to allow drivers with one contributing accident in the last five years, even if the accident was two years ago?"

This question cannot be directly tested because all the drivers currently in the program have been accepted after demonstrating a three-year safety record. Therefore, it is not possible to directly test the relative safety records of drivers who have remained crash-free for three years versus those who have remained crash-free for a shorter period of time. However, this type of question can be indirectly addressed using a set of control drivers.

6.4 Descriptive Characteristics of Program and Control Drivers

In this section, results of descriptive statistical analysis of the components of the policy concepts described above will be reviewed. The discussion begins with a review of information about the general characteristics of the drivers.

Driver Characteristics

Driver Age

The first question that the project team attempted to answer referred to driver age: "Does the age of a driver, combined with the driver's program status, affect the volume of crashes in which the driver is involved?"

The age of the driver was defined to be the age on June 15, 2006. Age of program drivers is categorized into bands of five years. The median age of program drivers is 52 years of age, and the distribution (as shown in Figure 6.2) of the five-year age bands between 41 and 65 is evenly balanced. By definition, the control group exhibits the same age characteristics.

Figure 6.2 Age Distribution of Program Drivers

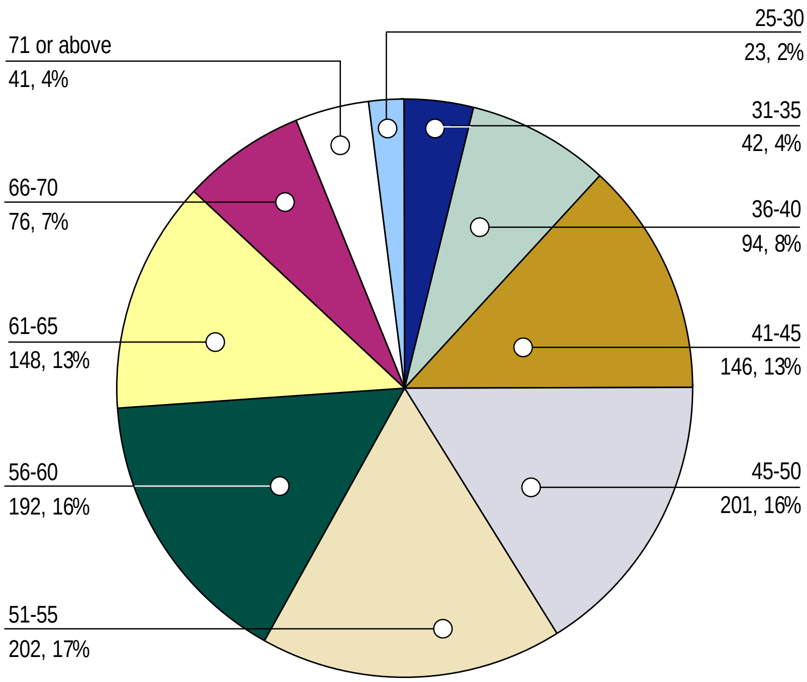


Table 6.1 below shows that the collision rates from January 1995 to May 2006 for program versus control drivers vary substantially with respect to driver age.

Table 6.1 Reported Collision Rates by Age for Program versus Control Drivers

Age Group	Average Fatal Collisions		Average Injury Collisions		Average Tow-Aways		Average Collisions of Any Kind		
	Program Drivers	Control Drivers	Program Drivers	Control Drivers	Program Drivers	Control Drivers	Program Drivers	Control Drivers	Difference (C – P)/C
25 to 30	0.00	0.01	0.00	0.07	0.13	0.13	0.13	0.21	38.1%
31 to 35	0.00	0.01	0.00	0.12	0.02	0.27	0.02	0.40	95.0%
36 to 40	0.00	0.01	0.07	0.15	0.05	0.25	0.12	0.41	70.7%
41 to 45	0.00	0.01	0.05	0.12	0.12	0.23	0.17	0.36	52.8%
46 to 50	0.00	0.01	0.05	0.13	0.08	0.23	0.12	0.37	67.6%
51 to 55	0.00	0.01	0.06	0.14	0.13	0.24	0.20	0.39	48.7%
56 to 60	0.01	0.01	0.06	0.13	0.16	0.24	0.23	0.38	39.5%
61 to 65	0.00	0.01	0.05	0.14	0.13	0.23	0.18	0.39	53.8%
66 to 70	0.01	0.01	0.07	0.11	0.14	0.26	0.22	0.38	42.1%
71 or older	0.03	0.01	0.08	0.15	0.18	0.25	0.28	0.41	31.7%
All	0.00	0.01	0.05	0.13	0.12	0.24	0.17	0.38	55.3%

In every age band, the control drivers had at least 30 percent more collisions per driver than the program drivers. Furthermore, for control drivers, the distribution of collisions per driver was reasonably uniform across age, while for the program drivers, an age over the median showed a trend towards higher tow-away rates. One confounding factor here, however, is the possibility that older drivers have higher reported collision rates.

The age of onset (as well as the related factor of the number of years since onset) of the deficiency was not studied in depth. An analysis of onset period showed a substantial similarity to the age of the driver, due to the number of amblyopic and monocular drivers whose deficiency onset was at birth or in early childhood. Furthermore, for over 400 program drivers, no onset period was given in the Federal Register documentation.

Driver Residency

Table 6.2 considers the geographic region in which the program driver resides. The columns compare the percentage of drivers living in the region versus the percentage of reported collisions for drivers living in the region. The region definitions and names are derived from the standard MCMIS regions.

Table 6.2 Distribution of Drivers and Reported Collisions by Geographic Region of Residence

Region	Drivers	Percentage	Collisions	Percentage
Northeast	94	8.1%	6	3.8%
East Central	141	12.1%	18	11.5%
Southeast	279	23.9%	36	22.9%
Midwest	239	20.5%	26	16.6%
South	120	10.3%	29	18.5%
Mid-Central	84	7.2%	3	1.9%
Central North	78	6.7%	15	9.6%
Southwest	60	5.2%	14	8.9%
Northwest	70	6.0%	10	6.4%
Totals	1,165	100.0%	157	100.0%

The very small sample size of collisions in the Northeast and Mid-Central regions precludes any rigorous comparison of percentages. The Southern region appears to have a disproportionate amount of reported collisions, but no association can be discerned when tested statistically.

Cause of Vision Deficiency

The analysis described in Section 3.2 to categorize vision deficiency was expanded to develop subcategories for drivers who are or were not blind in one eye. This additional category raises the total number of categories to nine.

Table 6.3 illustrates the distribution of drivers across these nine categories. Note that "AIT" refers to "Accident/Injury/Trauma." The table shows the number and percentage of drivers in each category and the distribution of reported collisions across the same nine categories. The two sets of percentages are very similar, with the difference in percentage caused primarily by the small sample size. No discernible association can be identified to link vision deficiency with reported collision rate.

Table 6.3 Distribution of Drivers and Reported Collisions by Cause of Deficiency

Deficiency	Drivers	Percentage	Collisions	Percentage
Other	73	6.3%	15	9.6%
Amblyopia	506	43.8%	66	42.0%
Blind-AIT	194	16.8%	29	18.5%
Blind-Congenital	5	0.4%	0	0.0%
Blind-Disease	10	0.9%	1	0.6%
Blind-Unknown	54	4.7%	7	4.5%
General-AIT	170	14.7%	16	10.2%
General-Congenital	53	4.6%	10	6.4%
General-Disease	90	7.8%	13	8.3%
Total	1,155	100.0%	157	100.0%

Acuity of Deficient Eye

For each program driver, the driver's level of visual acuity in the deficient eye was transcribed from the program application summary. Table 6.4 attributes reported collisions to categories of driver's visual acuity. Collisions are further segregated into fatal, injury, and tow-away.

Table 6.4 Distribution of Reported Collisions by the Visual Acuity of the Deficient Eye

Acuity of Deficient Eye	Fatal Collisions		Injury Collisions		Tow-Aways		All Collisions	
	N	Mean Per Person	N	Mean Per Person	N	Mean Per Person	N	Mean Per Person
20/40 or Better	0	0.00	0	0.00	0	0.00	0	0.00
20/41 to 20/50	0	0.00	1	0.02	6	0.15	7	0.17
20/51 to 20/70	0	0.00	5	0.05	10	0.09	15	0.14
20/71 to 20/100	0	0.00	2	0.02	6	0.06	8	0.07
20/101 to 20/199	0	0.00	2	0.12	3	0.18	5	0.29
Peripheral Vision Only	0	0.00	0	0.00	0	0.00	0	0.00
Legally Blind (20/200 or worse)	4	0.01	40	0.07	70	0.13	114	0.21
Blind	0	0.00	5	0.03	21	0.13	26	0.17
NA	0	0.00	5	0.06	9	0.10	14	0.16
Unknown	0	0.00	0	0.00	0	0.00	0	0.00

All four collisions resulting in a fatality involved drivers who were legally blind in one eye. Drivers who are legally blind in one eye account for 23 percent of the program drivers. While the data might suggest an association between fatal crashes and blind drivers that is stronger than for other program drivers, the very small sample size (four data points) precludes any conclusions.

The data suggests that drivers with vision acuity of 20/101 or worse have a higher incidence of reported collisions (0.17-0.29 per driver) than those drivers with acuity of 20/100 or better (0.14 to 0.17 per driver). However, this result is cautionary, and further oversight of drivers with lesser acuity is recommended. A larger sample size would support a cross-tabulation against duration since onset that could yield more solid results.

Reported Collisions Prior to Acceptance Date

The next set of descriptive statistics considers driver acceptance date (and the corresponding "control date" of December 1, 2003 for control drivers) and how reported collision distribution varies over time from the acceptance date. The analysis covers a maximum of five years (when data is available) on either side of the acceptance date.

Table 6.5 presents the average number of reported collisions for durations of one to five years before the acceptance date. For program drivers, the number for one to five years before acceptance is non-zero because the MCMIS data includes all collisions, including those for which the driver was not explicitly identified as at fault.

Table 6.5 Reported Collisions Prior to Acceptance Date

	Program Drivers, N = 1,155		Control Set Drivers, N = 9,758	
Variable	Mean	Sum	Mean	Sum
Fatal Collisions – One year before acceptance	0.001	1	0.002	18
Injury Collisions – One year before acceptance	0.004	5	0.019	183
Tow Away – One year before acceptance	0.009	10	0.034	332
Fatal Collisions – Two years before acceptance	0.002	2	0.002	22
Injury Collisions – Two years before acceptance	0.006	7	0.031	298
Tow Away – Two years before acceptance	0.015	17	0.056	543
Fatal Collisions – Three years before acceptance	0.003	3	0.003	28
Injury Collisions – Three years before acceptance	0.010	12	0.043	424
Tow Away – Three years before acceptance	0.023	27	0.079	770
Fatal Collisions – Four years before acceptance	0.003	3	0.004	42
Injury Collisions – Four years before acceptance	0.013	15	0.054	530
Tow Away – Four years before acceptance	0.031	36	0.099	966
Fatal Collisions – Five years before acceptance	0.003	3	0.005	47
Injury Collisions – Five years before acceptance	0.019	22	0.067	649
Tow Away – Five years before acceptance	0.042	48	0.118	1,153

While the mean number of fatal crashes is consistent between the program and control drivers, the data show a consistent and substantial difference for injury and tow-away crashes at all durations. The control set drivers are involved in a far greater number of reported collisions, over three times as many of both injury and tow-away collisions at each year of the progression.

The results could be construed as "self-selecting." By definition, drivers accepted in the program were not expected to have reported collisions in the three years prior to acceptance. The fact that there are reported collisions can be attributed to differences between MCMIS and CDLIS data (i.e., MCMIS counts all collisions and contains fewer collision attributes, CDLIS counts "at fault" collisions but contains additional attributes), and the fact that the acceptance criteria consider only "at fault" collisions.

Overall, the data show that program drivers are "more safe" than the population of general drivers represented by the control set. The implication is that "drivers who are safe generally stay safe." This is a key outcome, because it supports policy concepts that would allow a driver one "at fault" collision in a five-year period before acceptance, even if it is in one of the three preceding years.

Reported Collisions after Acceptance Date

Total Reported Collisions

Table 6.6 presents the average number of reported collisions for durations of one to two years after the acceptance date. In contrast to Table 6.5 that covers five years, this table covers two years, since the control set acceptance date was set at December 31, 2003.

Table 6.6 Reported Collisions after Acceptance Date

	Program Drivers, N = 1,155		Control Set Drivers, N = 9,758	
Variable	Mean	Sum	Mean	Sum
Fatal Collisions – One year after acceptance	0.000	0	0.001	11
Injury Collisions – One year after acceptance	0.008	9	0.014	137
Tow Away – One year after acceptance	0.017	20	0.028	275
Fatal Collisions – Two years after acceptance	0.000	0	0.003	27
Injury Collisions – Two years after acceptance	0.016	18	0.027	262
Tow Away – Two years after acceptance	0.033	38	0.054	527

Similar to the "before acceptance date" findings, control drivers are involved in more reported collisions than program drivers, but the ratio of collisions between control and program drivers has diminished substantially, to a ratio of approximately 3:2 (from 3:1 prior to acceptance).

The project team believes, but cannot prove, that this is an exposure phenomenon. Prior to acceptance, program applicants are only able to drive on an intrastate basis. Once drivers gain interstate driving privileges, it is plausible that their driving will increase.

In the absence of detailed driving volume data for program drivers, conclusions cannot be drawn about the basis for the changed collision ratio.

Reported Collisions by Age

Table 6.7 considers the reported collisions after acceptance, stratified by the current age of the driver. Excluding the small sample size for program drivers under 36 and over 71, the results are consistent between program and control drivers. Control drivers under 55 have similar reported collision rates to the program drivers, while control drivers over 55 have higher reported collision rates.

Table 6.7 Reported Collisions after Acceptance, by Driver Age

Age Group	Average Fatal Collisions		Average Injury Collisions		Average Tow-Aways		Average Fatal Injury		Average All Collisions	
	Program Drivers	Control Set Drivers	Program Drivers	Control Set Drivers	Program Drivers	Control Set Drivers	Program Drivers	Control Set Drivers	Program Drivers	Control Set Drivers
25 to 30	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.02	0.00	0.04
31 to 35	0.00	0.00	0.00	0.04	0.00	0.08	0.00	0.05	0.00	0.13
36 to 40	0.00	0.01	0.04	0.03	0.04	0.06	0.04	0.03	0.09	0.09
41 to 45	0.00	0.00	0.01	0.02	0.05	0.06	0.01	0.02	0.06	0.08
46 to 50	0.00	0.00	0.03	0.03	0.05	0.06	0.03	0.04	0.08	0.09
51 to 55	0.00	0.00	0.03	0.03	0.07	0.07	0.03	0.03	0.10	0.10
56 to 60	0.00	0.00	0.02	0.03	0.07	0.06	0.02	0.03	0.08	0.08
61 to 65	0.00	0.00	0.02	0.03	0.05	0.06	0.02	0.04	0.07	0.10
66 to 70	0.00	0.00	0.01	0.03	0.05	0.07	0.01	0.03	0.07	0.10
71 or Older	0.00	0.00	0.00	0.03	0.03	0.06	0.00	0.03	0.03	0.09
All	0.00	0.00	0.02	0.03	0.05	0.06	0.02	0.03	0.07	0.09

Reported Collisions by Deficiency

Table 6.8 considers reported collisions for program drivers after acceptance based on their vision deficiency. Note that fatal collisions are omitted, as no fatal collision has been reported for a program driver after acceptance.

Table 6.8 Reported Collisions after Acceptance, By Deficiency

Deficiency	Average Injury Collisions		Average Tow-Aways		Average All Collisions	
	N	Mean Per Person	N	Mean Per Person	N	Mean Per Person
Other	1	0.02	3	0.05	4	0.06
Amblyopia	15	0.03	27	0.05	42	0.08
Blind-AIT	3	0.02	14	0.07	17	0.09
Blind-Congenital	0	0.00	0	0.00	0	0.00
Blind-Disease	0	0.00	0	0.00	0	0.00
Blind-Unknown	1	0.02	4	0.08	5	0.10
General-AIT	0	0.00	3	0.02	3	0.02
General-Congenital	3	0.06	4	0.08	7	0.14
General-Disease	2	0.02	5	0.05	7	0.07
All	25	0.02	60	0.05	85	0.07

Three categories include the most number of program drivers: Amblyopia (506 drivers), Blind-AIT (194 drivers), and General-AIT (170 drivers). The General-AIT category has only three reported collisions, a far lower incidence than the

Amblyopia and Blind-AIT categories. Although care must be taken in drawing conclusions around small samples, this result appears to be an anomaly. Furthermore, the collision rate for amblyopic and blind-AIT drivers (0.08 to 0.09) is nearly identical to that of the control set (0.09). The "unknown" category contains drivers for whom insufficient information was available in the Federal Register information for FMCSA staff to reach a determination about categorization.

Reported Collisions by Visual Acuity and Field of Vision

Tables 6.9 and 6.10 present the distribution of reported collisions based on the visual acuity of the deficient eye and the field of vision of the driver, respectively. In both circumstances, the cells for which there is sufficient sample size show rates close to the reported control set mean of 0.09, and no concrete association can be identified.

The drivers with vision of 20/101 to 20/199 (Table 6.9), however, show a comparatively high rate. The sample size (three reported collisions) is extremely small, but the higher rate value is consistent with the data in Table 6.4. Consequently, this result should be considered in any future policy decisions.

Table 6.9 Reported Collisions after Acceptance by Visual Acuity

	Average Injury Collisions		Average Tow-Aways		Average All Collisions	
Acuity of Deficient Eye	N	Mean Per Person	N	Mean Per Person	N	Mean Per Person
20/40 or Better	0	0.00	0	0.00	0	0.00
20/41 to 20/50	0	0.00	2	0.05	2	0.05
20/51 to 20/70	4	0.04	6	0.06	10	0.09
20/71 to 20/100	1	0.01	4	0.04	5	0.05
20/101 to 20/199	1	0.06	2	0.12	3	0.18
Peripheral Vision Only	0	0.00	0	0.00	0	0.00
Legally Blind	14	0.03	24	0.04	38	0.07
Blind	3	0.02	15	0.10	18	0.11
NA	1	0.01	3	0.03	4	0.04
Unknown	0	0.00	0	0.00	0	0.00

Table 6.10 Reported Collisions after Acceptance, by Field of Vision

Field of Vision	Average Injury Collisions		Average Tow-Aways		Average Collisions of Any Kind	
	N	Mean Per Person	N	Mean Per Person	N	Mean Per Person
0 to 60	0	0.00	0	0.00	0	0.00
61 to 70	0	0.00	0	0.00	0	0.00
71 to 80	1	0.04	2	0.08	3	0.13
81 to 90	0	0.00	0	0.00	0	0.00
91 to 100	0	0.00	1	0.03	1	0.03
101 to 110	5	0.02	15	0.06	20	0.07
111 to 120	11	0.04	18	0.06	29	0.10
121 or More	1	0.01	1	0.01	2	0.02
Blind/Substandard Vision	0	0.00	1	0.11	1	0.11
Unknown	7	0.02	22	0.06	29	0.07

The Sub-Control Set: Control Drivers with No Reported Collisions during 2001 to 2003

To this point, the entire set of program drivers has been compared against the entire set of control drivers. In the following analysis, the control drivers will be constrained to a subset of those drivers with no reported collisions during the three years ending on the "control date" of December 31, 2003. Table 6.11 presents the reported collisions after the acceptance/control dates, comparing the program set versus components of the control set.

Table 6.11 Comparison of Reported Collision Rates after Acceptance Date

Type of Collision		Control Set Drivers (Classifed by Number of Collisions 2001 to 2003)		
	1,126 Program Drivers	8,392 Drivers with No Collisions	826 Drivers with 1+ Collisions	All 9,758 Drivers
Fatal Only	0.000	0.003	0.002	0.003
Injury Only	0.021	0.029	0.040	0.030
Tow Away Only	0.052	0.058	0.088	0.060
Fatal plus Injury	0.021	0.032	0.042	0.033
All	0.072	0.089	0.131	0.093

There is little difference in reported collision rate between the program and control sets. This is in contrast to the results of Table 6.6 which showed a ratio of reported collisions between control and program drivers of 3:2. This result lends credence to the assertion that "safe drivers are going to continue to be safe drivers," which is one of the key policy concepts for the Vision Exemption Program.

6.5 FORMAL HYPOTHESIS TESTING

The previous section summarized the differences in crash rates for various groups of drivers. The overarching objective of the hypothesis testing task is to identify whether these differences are systematic or are the result of random occurrence. To this end, several hypotheses had been formulated and tested.

The major hypothesis comprises the following statement:

Program drivers are no "less safe" than control set drivers.

To quantify this concept, several variations of the definition of "less safe" can be used, as described in Section 6.1. Specifically:

- Program drivers, on average, have no more fatal crashes per driver than the control set drivers;
- Program drivers, on average, have no more injury crashes per driver than the control set drivers;
- Program drivers, on average, have no more fatal or injury crashes per driver than the control set drivers;
- Program drivers, on average, have no more tow-aways per driver than the control set drivers;
- Program drivers, on average, have no more crashes (of any kind) per driver than the control set drivers; and
- Variations of the above, but adding the phrase "when controlling for the set of explanatory factors S," where S is any set of variables found in both the control set and the program set.

Because of the limitations of the control set, only age and geography of residence can be controlled in these analyses.

Control Set versus Program Set Membership

The test producing the most positive results involved the simple test of whether membership in the control set (1 if true, 0 if false) resulted in an increased likelihood of having a greater number of reported collisions. The analysis constrained the sample by controlling for the age of the driver, a variable which appeared from the descriptive statistics to have some potential effect. The analysis did not control explicitly for the geographic region of the driver, as the descriptive statistics did not show a relevant pattern to consider.

The analysis was constructed as a linear regression. The category bands for age were reduced to a smaller set of five bands (18 to 35, 36 to 45, 46 to 55, 56 to 65, and 66+) to eliminate the outlier categories at both extremes. Membership in the appropriate set of five bands was represented as a group of four dummy variables.

Table 6.12 summarizes the results of the analysis for the different combinations of types of collision. The incidence of tow-away collisions did not appear to be affected by the data set to which the driver belonged, once age was controlled. This behavior also had a diluting effect on the significance of the total set of reported collisions.

Table 6.12 Confidence Intervals for Program versus Control Group Membership, Controlling for Driver Age

Type of Collision	Control Set Parameter Value	Control Set t value	Confidence Interval
Fatal Only	0.00288	1.83	93.2%
Injury Only	0.00831	1.55	87.9%
Tow-Away Only	0.00494	0.63	47.2%
Fatal plus Injury	0.01122	1.94	94.4%
All Collisions	0.01732	1.41	84.1%

"As depicted in Table 6.12, the control set parameter value is systematically positive for all types of collisions. This indicates that controlling for age and location of residence, control set drivers on an average have *more* collisions (of any type) than the program drivers. The parameter value for fatal plus injury collisions implies that, after controlling for age, the control set drivers, on an average, have 0.011 crashes per driver more than their program counterparts.

Because the parameter value is merely a statistical estimate, the t-value is used as a measure of the significance of this estimate. Mathematically, the t-value is simply the ratio of the parameter value and its standard deviation. The higher the t-value the greater the confidence in the parameter value. The level of confidence is quantified by the confidence interval, presented in the last column. A t-value of 1.645 is generally used as a thumb rule for determining the significance of the parameter. This value corresponds to a confidence level of 90 percent. As indicated by the table, the t-values for the Fatal and Injury collisions are both greater than 1.645 and therefore indicate that the corresponding parameters are statistically significant."

Fatal and injury collisions, both individually and especially together, produced strong results. The confidence interval for fatal plus injury collisions is marginally less than would typically be expected for a "significant" result, but in the context of the overall formal hypothesis testing, the result is far more significant than any other.

These results are important, as they confirm the impact of the descriptive statistics which show higher reported collision rates for most aspects of control set drivers.

Tightening and Relaxing Admission Restrictions Using the Control Set as a Proxy

The next set of regression tests explored changes to the policy for the number of years which a driver must not have had a reported collision. Tests included both a tightening of the standard (from three years to four years) and a relaxation of the standard (from three years to two years), and considered the effect of controlling for these attributes on the number of reported collisions after acceptance.

Because the control data set should have no drivers with an at-fault crash in the third year before acceptance and therefore only a minimal number of reported crashes where the driver can be assumed to not have been at fault, the control set data was used to test this phenomenon. The assumption is that this was a valid use of the control set given the results of Table 6.11, which illustrates that drivers with no crashes for a three-year period before acceptance, regardless of the set to which they belong, show the same general shape of increases in reported crashes over time.

Table 6.13 presents the results of comparing the three-year measurement to the two-year measurement (tightening policy); Table 6.14 presents the results of comparing the three-year measurement to the four-year measurement (relaxing policy).

Table 6.13 Confidence Intervals for the Effect of Tightening the Definition for Acceptance

Type of Collision	Tightening Parameter Value	t value	Confidence Interval
Fatal Only	Only one data point, no analysis conducted.		
Injury Only	-0.0090	-0.28	21.8%
Tow-Away Only	0.2120	0.68	50.0%
Fatal plus Injury	0.0037	0.17	13.4%
All Collisions	0.0296	0.62	47.7%

Table 6.14 Confidence Intervals for the Effect of Relaxing the Definition for Acceptance

Type of Collision	Relaxing Parameter Value	t value	Confidence Interval
Fatal Only	Only one data point, no analysis conducted.		
Injury Only	0.0006	0.02	1.4%
Tow-Away Only	0.0398	1.13	74.1%
Fatal plus Injury	0.0164	0.67	49.8%
All Collisions	0.0770	1.44	85.2%

The results from these analyses are not significant, although the relaxing parameter for all collisions is encouraging. Even with a sample of nearly 10,000 drivers, there are not enough drivers which fit the profile to be either included or excluded from a changed policy. It is possible that increasing the number of drivers in the control set would provide enough data to allow a more significant set of results, especially for evaluating the "relaxing" policy.

In addition to the hypotheses discussed above, differences between crash rates of various groups of program drivers also were tested. Specifically, these tests determined whether the crash rates of program drivers were influenced by any of the following key vision-related attributes:

- Field of vision;
- Visual acuity;
- Vision deficiency; and
- Onset of deficiency

Due to the small sample of crashes for the program drivers, especially after acceptance, these tests did not indicate any significant differences in crash rates for various groups of program drivers. Therefore, these results have not been summarized in this section, but are available upon request.

6.6 Confounding Factors

The quantitative analysis presented above can identify only potential relationships. It was not possible to confidently identify factors that contribute to differences in reported collision volumes, aside from whether the driver resides in the program or control set.

There are a number of factors which confound the ability to perform a more complete quantitative analysis. The key factors which play a role are described below.

Volume versus Rate Information

The information available does not include any information about miles or hours driven. Without this information, it is not possible to address any hypotheses which speculate that while the control set drivers have higher reported collision volumes, they would not be higher if normalized by a metric such as "miles driven."

Sample Size

At 1,155 drivers, the program driver data set is small. With only 60 reported collisions after acceptance across all 1,155 drivers, the sample size of the outcome variable is extremely small. At a sample size of 60, the allocation of one additional collision causes a substantial shift in the percentages for whichever driver categories have the additional collision. Although an attempt was made to address the issue by over-sampling the control set at a ration of 8.5 to 1, issues still exist when trying to analyze program driver behavior.

Previous Driving Experience

This factor is linked with the rate factor above. Several drivers interviewed in Section 5.0 reported significant experience driving intrastate vehicles. Another driver, while older in age and onset of his medical condition, had been driving commercial vehicles for only six years. The current data for program drivers has insufficient information on previous driving experience to be useful in modeling that experience as a variable in the analysis.

6.7 KEY FINDINGS

The quantitative analysis yielded several key findings:

Program Drivers do not Generate Higher Reported Collision Volumes after Acceptance

One of the key questions under consideration was whether program drivers, after being accepted into the Vision Exemption Program, generated a higher number of reported collisions (thus being "unsafe"). It was found that program drivers do not generate higher collision volumes after acceptance. In fact, Table 6.12 indicates that the exact opposite scenario exists, in that program participation results in a lower number of reported collisions after acceptance.

Program drivers have lower reported collision volumes year after year (from five years before acceptance to two years after acceptance) compared to the overall control set. When compared to a subset of the control set that also had no reported collisions in the three years ending December 31, 2003, program drivers still exhibited a lower observed volume of reported collisions in the two years following that date.

Visual Acuity of Less than 20/100 May be an Issue

Drivers with vision acuity in their deficient eye of 20/100 or worse had a higher incidence of reported collisions than drivers with vision acuity in their deficient eye of 20/99 or better. While small sample size may be a confounding factor, and onset period is almost certainly a confounding factor, the results indicate that drivers with lesser acuity may deserve additional attention during the application review process.

Type of Deficiency and/or Cause Does Not Appear to Be Relevant

In general, the basis for a driver's participation in the Vision Exemption Program has minimal impact on the reported collisions for that driver. One exception was found in the General-AIT category, where the number of reported collisions appears to be substantially smaller than expected.

This finding, however, could support exploration of potential scenarios where policies are adjusted to "fast-track" the acceptance process for certain common deficiencies, such as Amblyopia or blindness due to trauma, in conjunction with a long onset period and an exemplary driving record.

The "Sub-Control" Set of Drivers Differs Substantially from the Rest of the Control Set

Analysis of the sub-control set found that the control drivers with no reported collisions in 2001 through 2003 had substantially fewer reported collisions in 2004 through mid-2006 compared to the entire control set. While this result could be expected, the fact that it displays a pattern similar to how program drivers compare to the entire control set indicates that it may be possible to conduct larger analyses of potential program driver behavior by using a sub-control set as a proxy group.

7.0 Findings and Recommendations

7.1 The Most Important Findings

The Exemption Programs Process is Effective.

Drivers in the Vision Exemption Program have 20 percent less reported collisions after program acceptance than control set drivers. Participation in the program set was shown to have a 94.4 percent confidence interval of reducing the number of reported collisions attributable to the driver. The specific cause of a driver's requirement to participate in the exemption program does not appear to impact the number of reported collisions.

The main conclusion of this project is that the Vision Exemption Program does not appear to be negatively impacting the safety of the nation's highways.

No evidence could be found in the execution of this study indicating that a significant subset of drivers in the Vision Exemption Program were involved in a greater number of reported collisions than a corresponding control set. The current program is built around the premise that "safe drivers stay safe drivers, even with a vision issue." Anecdotal interview evidence suggests that a substantial number of safe intrastate drivers would be able to make the transition to being safe interstate drivers, even with a vision deficiency.

The Original General Hypothesis Appears to Be Accurate.

While the overall program is effective, the original guiding hypothesis could not be rejected:

> **There are parts of the current policy which will appear to be too *lenient*, and other parts of the policy which will appear to be too *severe*.**

Regarding areas where the policy may be too lenient, the study found that drivers with lesser vision ratings and field of vision may require more detailed analysis and supervision. It may be prudent to shift some resources from general monitoring of all program drivers to additional monitoring and evaluation of these drivers.

Regarding areas where the policy may be too severe, the comparison of control drivers with no reported collisions from 2001 to 2003 indicates that the behavior between this control subset and the program drivers is similar. Cambridge Systematics recommends an evaluation of potential pilot programs that would test relaxation of the admission standards for drivers with a generally safe driving record over a four-to-five year period before acceptance, perhaps in conjunction with other factors such as a longer onset period.

The Literature Supports the Policy Approach.

A number of the key findings in the vision literature support the qualitative and quantitative findings elsewhere in the study. Examples of such support include:

- Drivers with a lesser field of vision appears to have a pattern of higher reported collision volumes than drivers with a better field of vision;
- When controlling for previous rates over a three-year period, collision rates for visually impaired drivers were not found to be higher than the non-impaired drivers;
- Compensatory viewing behavior is developed in order to mitigate the visual loss;
- Some drivers with visual defects tend to avoid challenging driving conditions;
- Monocular commercial drivers did not have significant differences in the performance of tasks involving safe driving; and
- Location of monocular eye is not significant.

Program Drivers Do Not Universally Deride the Program

It could be assumed that drivers would be opposed to what they perceive as government interference in their driving privileges. The interviews, however, demonstrated that the majority of the driver community is neutral or supportive of the program. Their criticism is represented by two questions:

- Why does it take so long to be approved; and
- How does this really affect my driving?

The answer to the first question is primarily based on the necessary lead time for the Federal Register process. Consideration should be given as to how the process operates, and if there are methods to streamline the process for drivers who have a demonstrated level of safe driving.

The answer to the second question is that, based on the study's findings, the program does not affect program drivers' driving, but only because they already have demonstrated themselves to be safe drivers.

7.2 Recommendations for Continuous Program Improvement

Collection of Rate-Based Data

The most serious limitation of the analysis was using only the total volume of reported collisions as an outcome variable. While there is substantial evidence that program drivers have fewer total crashes over time compared to corresponding control drivers, this evidence is based on the assumption that program drivers drive approximately as many hours (or miles) as the control set drivers.

A methodology can be developed and employed to capture the exposure level of control drivers at an aggregate level. At the program level, however, accurate individual estimates are necessary. The current data captured during the application process is not verified, and was discarded at the beginning of our analysis based on the recommendation of FMCSA's processing contractor (MANILA).

It is strongly recommended that FMCSA consider a policy change in the acceptance process which captures at least partial rate-based information. For example, all program drivers could be required to submit a simplified driving log summary for a random one week period twice each year. The summary would include daylight and nighttime information, both hours and miles driven, that would fit on one sheet of paper. A random sample of drivers could be asked to provide a full "hours of service" log book for the week in question.

Concrete knowledge of the driving habits of program drivers is imperative as a foundation for using comparisons of reported collision data as a basis for long-term policy change.

Improved Data Management Capabilities

The data analysis undertaken in this project provides FMCSA with a solid data foundation for future analysis. The advantages provided by the project for data management, however, will be diminished without a corresponding increase in the exemption program data management capabilities of the agency and its vendors.

Efforts currently are in progress for improving the data collection and workflow process for the exemption programs. Cambridge Systematics has provided FMCSA with all transcribed and analyzed data used in this project, and the data should be used as a starting point for a baseline of analytical data.

Planning for Before/After Analyses of Potential Policy Changes

One of the confounding factors in developing a methodology for this study was the lack of data to support a "before" scenario for the current programs. Without "before" data, an "after" analysis of the program's efficiency and effectiveness is by definition limited. This project sets a new baseline of a "before" scenario for any policy changes contemplated by FMCSA for the Vision Exemption Program.

As policy changes are considered and implemented, care should be taken to capture the measurements needed to evaluate the program changes in order to provide future researchers with the ability to develop more rigorous analysis methodologies. The specific information to be measured will differ based on the policy change being evaluated.

For the Diabetes Exemption Program, the small number of current program drivers affords FMCSA an opportunity to recreate the "before" conditions for the program. Care should be given to identifying potential policy changes, and quantifying and managing the currently limited program data to best leverage future analyses.

Formal Education Program for Program Drivers

Several drivers interviewed learned about the exemption program by chance, or educated another driver about the program. Drivers did not believe that their vision affected their driving ability, but several drivers took measures to enhance their ability to drive safely, consistent with the literature.

It is recommended that FMCSA consider a formal education program for both vision and diabetes program drivers. The program could combine structured continuing education, informal marketing of new findings and techniques, and opportunity for drivers to come together in a community setting through regional or national conferences.

Review of Intrastate Programs

One of the perceived issues with the current program is that a driver can be deemed inadequate to drive on an interstate basis, but can still be eligible to drive on an intrastate basis. It is recommended that FMCSA commission a review of intrastate medical review programs to gain information about state-specific policies and experiences for drivers with vision or diabetes deficiencies.

Pilot Studies to Gradually Relax Program Admission Standards

Both the descriptive statistics and the more formal statistical tests evidently reject the hypothesis that acceptance into the Vision Exemption Program is not sufficiently strict. Specifically, drivers with better vision (with respect to both visual acuity and field of vision) may be overly constrained by the "no accidents in three years" rule.

While further research is likely required, this project indicates that some of the admission policies can be relaxed for certain subsets of drivers, such as drivers with only one incident in both the three-year and five-year period before application. Wholesale relaxation of requirements is *not* appropriate at the present time, especially without reliable rate-based information. Nonetheless, the agency should consider innovative approaches to pilot a limited set of relaxed standards, within their legal ability to do so.

Collision Causation Studies for Program Driver Accidents

Several of the interviewed drivers identified fear of removal from the program as a major concern. The set of nearly 1,200 program drivers, however, has been involved in a total of only *85* reported crashes since acceptance. A formal causation study for reported collisions in which program drivers were involved would be an invaluable addition to the literature. Gathering additional detailed information about each collision (and perhaps a corresponding control sample of information about collisions not involving program drivers) would provide the research community with a wealth of data to advance scholarly research in this area.

A. Bibliography

A.2 VISION BIBLIOGRAPHY

Anderson, D.P. (2000), *Vision Standards for Driving in Canada,* Can J Ophthalmol, Volume 35, pp. 83-4 (Editorial).

Auffarth G.U., Hunold W, Hürtgen P, Wesendahl TA, Mehdorn E, (1994), *Night Driving Capacity of Pseudophakic Patients,* Ophthalmologe, Volume 91, pp. 454-9.

Babizhayev M.A., (2003), *Glare Disability and Driving Safety,* Ophthalmic Res, Volume 35, pp. 19-25.

Baker C.I., Peli E, Knouf N, Kanwisher N.G., (2005), *Reorganization of Visual Processing in Macular Degeneration,* J Neurosci, Volume 25, pp. 614-8.

Ball K., Owsley C., (2003), *Driving Competence: It's Not a Matter of Age,* J Am Geriatr Soc, Volume 51, pp. 1499-501.

Ball K., Owsley C., Sloane M.E., Roenker D.L., Bruni, J.R., (1993), *Visual Attention Problems as a Predictor of Vehicle Crashes in Older Drivers,* Invest Ophthalmol Vis Sci, Volume 34, pp. 3110-3123.

Bauer A., Kolling G, Dietz K, Zrenner E, Schiefer U., (2000), *Are Cross-Eyed Persons Worse Drivers? The Effect of Stereoscopic Disparity on Driving Skills,* (Article in German), Klin Monatsbl Augenheilkd, Volume 217(3), pp. 183-9.

Bauer, A., Klaus Dietz, Gerold Kolling, William Hart, Ulrich Schiefer (2001), *The Relevance of Stereopsis for Motorists: A Pilot Study,* Graefe's Archive for Clinical and Experimental Ophthalmology, Volume 239, No. 6, pp. 400-406

Bowers, A., Eli Peli, Jennifer Elgin, Gerald McGwin Jr, Cynthia Owsley,(2005), *On-Road Driving with Moderate Visual Field Loss,* Optometry & Vision Science, Volume 82(8), pp. 57-667.

Bowers, A., Peli,E., Elgin,J., McGwin Jr.,G. and Owsley, C., (2005), *Assessing Driving Performance with Moderate Visual Field Loss,* Proceedings of the 3rd International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Rockport, Maine (June 27-30).

Bowers, A.R., Apfelbaum, D.H. and Peli, E., (2005), *Bioptic Telescopes Meet the Needs of Drivers with Moderate Visual Acuity Loss,* Investigative Ophthalmology & Visual Science, Volume 46, No. 1

Brookhuis K.A., De Waard D, Fairclough SH, (2003), *Criteria for Driver Impairment,* Ergonomics, Volume 46, pp. 433-45.

Casson E.J., Racette L, (2000), *Vision Standards for Driving in Canada and the United States. A Review for the Canadian Ophthalmological Society*, Can J Ophthalmol, Volume 35, pp. 192-203.

Charman WN, (1997), *Vision and Driving – A Literature Review and Commentary,* Ophthalmic Physiol Opt, Volume 17, pp. 371-91.

Chernysheva S.G., Iachmeneva EI, (1997), *Binocular Vision and Its Role in Car Driving,* Vestn Oftalmol, Volume 113, pp. 0-42.

Clarke, N., (1996), An Evaluation of the Traffic Safety Risk of Bioptic Telescopic Lens Drivers, Research Report, Research and Development Branch Division of Program and Policy Administration California Department of Motor Vehicles.

Coeckelbergh T.R., Brouwer WH, Cornelissen FW, Van Wolffelaar P, Kooijman AC, (2002), *The Effect of Visual Field Defects on Driving Performance: A Driving Simulator Study,* Arch Ophthalmol, Volume 120, pp. 1509-16.

Coeckelbergh T.R., Cornelissen FW, Brouwer WH, Kooijman AC, (2002), *The Effect of Visual Field Defects on Eye Movements and Practical Fitness to Drive,* Vision Res, Volume 42, pp. 669-77.

Coeckelbergh, T.R.M., Wiebo H. Brouwer, Frans W. Cornelissen, and Aart C. Kooijman, (2004), *Predicting Practical Fitness to Drive in Drivers with Visual Field Defects Caused by Ocular Pathology,* Human Factors, Volume 46(4), pp. 748-60.

Coeckelbergh, T.R.M., Wiebo H. Brouwer, Frans W. Cornelissen, and Aart C. Kooijman, (2001), *Training Compensatory Viewing Strategies: Feasibility and Effect on Practical Fitness to Drive in Subjects with Visual Field Defects,* Visual Impairment Research, Volume 3 No. 2, pp. 67–83.

Colenbrander, A., Fletcher DC, (1992), *Low Vision Rehabilitation: Vision Requirements for Driving,* J Ophthalmic Nurs Technol, Volume 11, pp. 111-5.

Conwall Incorporated, (1997), Qualifications of Drivers – Vision Diabetes, Hearing and Epilepsy, Final Report, Prepared for FHWA.

Cosar CB, Saltuk G, Sener AB, (2004), *Wavefront-Guided Laser in Situ Keratomileusis with the Bausch & Lomb Zyoptix System,* J Refract Surg, Volume 20, pp. 35-9.

Crabb D.P., Fitzke F.W., Hitchings R.A., and Viswanathan A C, (2004), *A Practical Approach to Measuring the Visual Field Component of Fitness to Drive,* Br. J. Ophthalmol, Volume 88, pp. 1191-96

Crundall, D., Underwood G, Chapman P, (1999), *Driving Experience and the Functional Field of View,* Perception, Volume 28, pp. 1075-87.

Curcio, C.A., Owsley C, Jackson GR, (2000), *Spare the Rods, Save the Cones in Aging and Age-Related Maculopathy,* Invest Ophthalmol Vis Sci Volume 41, pp. 2015-18.

Decina, L.E., and Breton, M.E., (1993), *Evaluation of the Federal Vision Standard for Commercial Motor Vehicle Operators,* Transportation Research Record 1421.

Dörfler H., (2003), *Hypoglycemic and Vision Impaired. When is a Diabetic Patient Unfit to Drive?,* MMW Fortschr Med, Volume 145, pp. 33-6. (Full Text in German)

Eldred, K.B., Steiner N, (1997), *Visual-Field Measurements and Driving Eligibility,* J Am Optom Assoc, Volume 68, pp. 109-15.

FHWA (1995), An Assessment of the Risk Associated with the Disposition of the Vision and Diabetes Waiver Programs, Report.

Freeman, E.E., Muñoz B, Turano KA, West SK, (2005), *Measures of Visual Function and Time to Driving Cessation in Older Adults,* Optom Vis Sci, Volume 82, pp. 765-73.

Galski T., Ehle H.T., Williams J.B., (1998), *Estimates of Driving Abilities and Skills in Different Conditions,* Am J Occup Ther., Volume 52(4), pp. 268-75.

Goode, K.T., Ball, K.K., Sloane, M., Roenker, D.L., Roth, D.L., Myers, R.S., Owsley, C. (1998), *Useful Field of View and Other Neurocognitive Indicators of Crash Risk in Older Adults,* Journal of Clinical Psychology in Medical Settings, Volume 5, pp. 425-440.

Gupta B., Paliga J, Laderman DJ, Szlyk JP, (2005), *The Effect of Occlusive Patching on Visually-Directed Tasks,* J AAPOS, Volume 9, pp. 485-92.

Haim, M., N.H. Holm, and T. Rosenberg, (1992), *Prevalence of Retinitis Pigmentosa and Allied Disorders in Denmark,* ACTA Ophthalmologica, Volume 70, 178-186.

Higgins K.E., J.M. Wood, (2005), *Predicting Components of Closed Road Driving Performance from Vision Tests,* Optometry & Vision Science, Volume 82(8), pp. 647-656.

Higgins, K.E., Wood J., Tait A., (1998), *Vision and Driving: Selective Effect of Optical Blur on Different Driving Tasks,* Human Factors, Volume 40(2), pp. 224-32.

Hildreth E.C., Beusmans J.M., Boer E.R., Royden CS, (2000), *From Vision to Action: Experiments and Models of Steering Control During Driving,* J Exp Psychol Hum Percept Perform, Volume 26, pp. 1106-32.

Hodson T.J., (2002), *Vision Standards for Safe Driving,* Clin Experiment Ophthalmol, Volume 30 pp. 451 (Comment Letter); author reply 451-2.

Hom MM, (1999), *Monovision and LASIK,* J Am Optom Assoc., Volume 70, pp. 17-22.

Huss, C., (1996), West Virginia Low Vision Driving Study 1985-95, Results and Conclusions, West Virginia Rehabilitation Center, WV.

Jolly N, (2002), *Appropriate Vision Standards for Safe Driving: Experience of On-Road Driving Assessment,* Clin Experiment Ophthalmol, Volume 30, pp. 1-2 (Comment Letter).

Jory W, (2001), *Testing Night Vision for Driving,* BMJ, Volume 322, pp. 72 (Comment Letter).

Keeffe J.E., Jin C.F., Weih L.M., McCarty C.A., Taylor H.R., (2002), *Vision Impairment and Older Drivers: Who's Driving?,* Br J Ophthalmol, Volume 86, pp. 1118-21.

Kezirian GM, Stonecipher KG, (2004), *Subjective Assessment of Mesopic Visual Function after Laser in Situ Keratomileusis,* Ophthalmol Clin North Am, Volume 17, pp. 211-24.

Kooijman, A.C., W.H. Brouwer, T.R.M. Coeckelbergh, M.L.M. Tant, F.W. Cornelissen, R.A. Bredewoud, B.J.M. Melis-Dankers, (2004), *Compensatory Viewing Training Improves Practical Fitness to Drive of Subjects with Impaired Vision,* Visual Impairment Research, Volume 6 No. 1, pp. 1–27.

Lamble, D., Heikki Summala, Lea Hyvarinen,(2002), *Driving Performance of Drivers with Impaired Central Visual Field Acuity,* Accident Analysis and Prevention, Volume 34, pp. 711–716.

Lansdown, T.C., (2002), *Individual Differences during Driver Secondary Task Performance: Verbal Protocol and Visual Allocation Findings,* Accident Analysis and Prevention, Volume 34, pp. 655–662.

Lewis, H. (2003), *Peripheral Retinal Degenerations and the Risk of Retinal Detachment,* American Journal of Ophthalmology, Volume 136, Issue 1, 155-160.

Lovsund P, Hedin A, Tornros, (1991), *Effects on Driving Performance of Visual Field Defects: A Driving Simulator Study,* J. Accid Anal Prev. Volume 23(4), pp. 331-42.

MacDougall H.G., Moore S.T., (2005), *Functional Assessment of Head-Eye Coordination during Vehicle Operation,* Optom Vis Sci, Volume 82, pp. 706-15.

Mantyjarvi, M., V. Juntunen, K. Tuppurainen, (1999), *Visual Functions of Drivers Involved in Traffic Accidents,* Accident Analysis and Prevention, Volume 31, pp. 121–124.

McGhee CN, Craig JP, Sachdev N, Weed KH, Brown AD, (2000), *Functional, Psychological, and Satisfaction Outcomes of Laser in Situ Keratomileusis for High Myopia,* J Cataract Refract Surg, Volume 26, pp. 497-509.

McGwin G, Mays A, Joiner W, Decarlo DK, McNeal S, Owsley C, (2004), *Is Glaucoma Associated with Motor Vehicle Collision Involvement and Driving Avoidance?,* Invest Ophthalmol Vis Sci, Volume 45, pp. 3934-39.

McGwin G, Xie A, Mays A, Joiner W, Decarlo DK, Hall TA, Owsley C, (2005), *Visual Field Defects and the Risk of Motor Vehicle Collisions among Patients with Glaucoma,* Invest Ophthalmol Vis Sci, Volume 46, pp. 4437-41.

McGwin G., Owsley C., Ball K, (1998), *Identifying Crash Involvement among Older Drivers: Agreement between Self-report and State Records,* Accident Analysis and Prevention, Volume 30, No. 6, pp. 781-791.

McGwin Jr, G., Victoria Chapman, Cynthia Owsley, (2000), *Visual Risk Factors for Driving Difficulty among Older Drivers,* Accident Analysis and Prevention, Volume 32 pp. 35–744.

McKnight, A.J., Shinar, D., and Hilborn B., (1991), *The Visual and Driving Performance of Monocular and Binocular Heavy-Duty Truck Driver,* Accident Analysis and Prevention, Volume 23, No. 4, pp. 225-237.

Mills K.C., Spruill S.E., Kanne R.W., Parkman K.M., Zhang Y., (2001), *The Influence of Stimulants, Sedatives, and Fatigue on Tunnel Vision: Risk Factors for Driving and Piloting,* Human Factors, Volume 43, pp. 10-27.

Murray, D., Brewster, R., Lantz B., and Keppler, S., (2005), *Predicting Truck Crash Involvement: A Commercial Driver Behavior Based Indicator,* Proceedings of International Truck and Bus Safety and Security Symposium.

Owsley C, Ball K, McGwin G, Sloane ME, Roenker DL, White MF, Overley ET, (1998), *Visual Processing Impairment and Risk of Motor Vehicle Crash among Older Adults,* JAMA, Volume 279, pp. 1083-88.

Owsley C, McGwin G, Ball K, (1998), *Vision Impairment, Eye Disease, and Injurious Motor Vehicle Crashes in the Elderly,* Ophthalmic Epidemiol, Volume 5, pp. 101-13

Owsley C, Stalvey B, Wells J, Sloane ME, (1999), *Older Drivers and Cataract: Driving Habits and Crash Risk,* J Gerontol A Biol Sci Med Sci, Volume 54, pp. M203-11.

Owsley, C., (1994), *Vision and Driving in the Elderly,* Optom Vis Sci, Volume 71 pp. 727-35.

Owsley, C., McGwin, G Jr., Sloane, M.E., Wells, J., Stalvey, B.T., Gauthreaux, S. (2002), *Impact of Cataract Surgery on Motor Vehicle Crash Involvement by Older Adults,* JAMA, Volume 288, pp. 841-849.

Owsley, C., McGwin, G. Jr. (1999) *Vision Impairment and Driving,* Survey of Ophthalmology, Volume 43, pp. 535-550.

Owsley, C., Stalvey, B., Wells, J., Sloane, M.E., McGwin, G. Jr. (2001) *Visual Risk Factors for Crash Involvement in Older Drivers with Cataract,* Archives of Ophthalmology, Volume 119, pp. 881-887.

Owsley, C., Stalvey, B.T. and Wells, J.M., (2001), A Crash Reduction Strategy: Training Transportation Professionals in Alabama About How to Manage Drivers with Diminished Capabilities, Final Report, Report Prepared to University Transportation Center of Alabama.

Peli, E. (2002) *Low Vision Driving in the USA: Who, Where, When, and Why?,* CE Optometry, Volume 5, No. 2, pp. 54-58.

Peli, E. (2001), *Visual Field Requirements in the USA,* Vision in Vehicles IX, Elsevier Sciences Publishers B.V. Amsterdam.

Peli, E. and Peli, D., (2002), Driving with Confidence: A Practical Guide to Driving with Low Vision, World Scientific, NJ.

Peli, E., A. R. Bowers, A. J. Mandel, K. Higgins, R. B. Goldstein, L. Bobrow, (2005), *The Design of Driving Simulator Performance Evaluation for Driving with Vision Impairments and Visual Aids,* Journal of the Transportation Research Board, No. 1937, pp. 128-135.

Perdriel G., (1994), *Visual Information and Road Safety,* Bull Acad Natl Med, Volume 178, pp. 075-82; Discussion 1082-6.

Piper H.F., (1998), *Automobile Driving Fitness of Patients with Nystagmus,* Ophthalmologe, Volume 95, pp. 247-52.

Racette, L., E.J. Casson, (2005), *The Impact of Visual Field Loss on Driving Performance: Evidence From On-Road Driving Assessments,* Optometry & Vision Science, Volume 82(8), pp. 668-674.

Recarte M.A., Nunes LM, (2003), *Mental Workload While Driving: Effects on Visual Search, Discrimination, and Decision-Making,* J Exp Psychol Appl, Volume 9, pp. 119-37.

Resch M, Szentmáry N, Nagy ZZ, Czumbel N, (2004), *Comparison of Results of Photorefractive Keratectomy and Laser in Situ Keratomileusis in the Treatment of Hyperopia Using A Flying Spot Eximer Laser,* Orv Hetil, Volume 145, pp. 573-8.

Roge J, Pebayle T, Campagne A, Muzet A, (2005), *Useful Visual Field Reduction as a Function of age and Risk of Accident in Simulated Car Driving,* Invest Ophthalmol Vis Sci. Volume 46(5), pp. 1774-9.

Roge J, Pebayle T, Lambilliotte E, Spitzenstetter F, Giselbrecht D, Muzet A, (2004), *Influence of Age, Speed and Duration of Monotonous Driving Task in Traffic on the Driver's Useful Visual Field,* Vision Res, Volume 44, pp. 737-44.

Schiefer U, Hofer R, Vischer PM, Wilhelm H, (2000), *Perimetry Findings and Driving Performance. "How Much Visual Field" Does a Motorist Need?,* Ophthalmologe, Volume 97, pp. 491-7.

Schrader WF, Hauptmann S, Hamburger G, (1999), *Automobile Driving Capacity after Retinal Detachment Surgery,* Ophthalmologe, Volume 96, pp. 102-7.

Scilley, K., G.R. Jackson, A.V. Cideciyan, M.G. Maguire, S.G. Jacobson and C. Owsley, (2002), *Early Age-Related Maculopathy and Self-Reported Visual Difficulty in Daily Life,* Ophthalmology, Volume 109(7), pp. 1235-1242.

Sheedy J.E., Bailey IL, Buri M, Bass E.,(1986), *Binocular vs. Monocular Task Performance,* Am J Optom Physiol Opt, Volume 63(10), pp. 839-46.

Shipp M.D., Daum KM, Weaver JL, Nakagawara VB, Bailey IL, Good GW, Maizel MB, Park WL, (2000), *Motorist Vision Policy,* Optometry, Volume 71, pp. 449-53.

Sims R.V., Owsley C, Allman RM, Ball K, Smoot TM, (1998), *A Preliminary Assessment of the Medical and Functional Factors Associated with Vehicle Crashes by Older Adults,* J Am Geriatr Soc, Volume 46, pp. 556-61.

Steeves J.K., Gray R, Steinbach MJ, Regan D., (2000), *Accuracy of Estimating Time to Collision Using Only Monocular Information in Unilaterally Enucleated Observers and Monocularly Viewing Normal Controls,* Vision Res., Volume 40(27), pp. 3783-9.

Straus, S.H., (2005), New, Improved, Comprehensive, and Automated Driver's License Test and Vision Screening System, Final Report 559(1), Research Report prepared for Arizona Department of Transportation.

Szlyk J.P., Alexander KR, Severing K, Fishman GA, (1992), *Assessment of Driving Performance in Patients with Retinitis Pigmentosa,* Arch Ophthalmol Volume 110, pp. 1709-13.

Szlyk J.P., Mahler CL, Seiple W, Edward DP, Wilensky JT, (2005), *Driving Performance of Glaucoma Patients Correlates with Peripheral Visual Field Loss,* J Glaucoma, Volume 14, pp. 145-50.

Szlyk J.P., Mahler CL, Seiple W, Vajaranant TS, Blair NP, Shahidi M, (2004), *Relationship of Retinal Structural and Clinical Vision Parameters to Driving Performance of Diabetic Retinopathy Patients,* J Rehabil Res Dev, Volume 41, pp. 347-58.

Szlyk J.P., Pizzimenti CE, Fishman GA, Kelsch R, Wetzel LC, Kagan S, Ho K, (1995), *A Comparison of Driving in Older Subjects with and Without Age-Related Macular Degeneration,* Arch Ophthalmol, Volume 113, pp. 1033-40.

Szlyk J.P., Seiple W, Stelmack J, McMahon T., (2005), *Use of Prisms for Navigation and Driving in Hemianopic Patients,* Ophthalmic Physiol Opt, Volume 25, pp. 128-35.

Szlyk J.P., Severing, K., Fishman, G.A., (1991), Peripheral Visual Field Loss and Driving Performance, Research Report Prepared for AAA Foundation.

Tagarelli A, Piro A, Tagarelli G, Lantieri PB, Risso D, Olivieri RL, (2004), *Colour Blindness in Everyday Life and Car Driving,* Acta Ophthalmol Scand, Volume 82, pp. 436-42.

Taylor J.F., (1987), *Vision And Driving*, Ophthalmic Physiol Opt, Volume 7, pp. 187-9.

Taylor J.F., Livingston, p.m., Stanislavsky, Y.L., and McCarthy, C.A., (1997), *Visual Impairment in Australia: Distance Visual Acuity, Near Vision, and Visual Field Findings of the Melbourne Visual Impairment Project,* American Journal of Ophthalmology, Volume 123, pp. 328-337.

Van Newkirk, Weih, L.A., McCarry, C.A., and Taylor, H., (2001), *Cause Specific Prevalence of Bilateral Visual Impairment in Victoria, Australia; the Visual Impairment Project,* Ophthalmology, Volume 108, pp. 960-967.

Van Rijn LJ, Wilhelm H, Emesz M, Kaper R, Heine S, Nitsch S, Grabner G, Völker-Dieben HJ, (2002), *Relation between Perceived Driving Disability and Scores of Vision Screening Tests,* Br J Ophthalmol, Volume 86, pp. 1262-4.

Watson SL, Bunce C, Allan BD, (2005), *Improved Safety in Contemporary Lasik,* Ophthalmology, Volume 112, pp. 1375-80.

Weih, LA, C.A. McCarty and Hugh R Taylor, (2000), *Functional Implications of Vision Impairment,* Clinical & Experimental Ophthalmology, Volume 28(3), p. 153.

Westlake, W., (2001), *Is a One Eyed Racing Driver Safe to Compete? Formula One (Eye) or Two?*, Br. J. Ophthalmol, Volume 85 pp. 19-624.

White, J. E., S. C. Marshall, K. L. Diedrich-Closson and A. L. Burton, (2001), *Evaluation of Motor Vehicle Driving Performance in Patients with Chronic Diplopia*, Journal of American Association for Pediatric Ophthalmology and Strabismus, Volume 5(3), pp. 184-188.

Wilkinson M.E., (1998), *Driving with a Visual Impairment,* Insight, Volume 23, pp. 8-52.

Wilkinson U.M., (2003), *Driving with a Visual Impairment: New Guidelines Are Needed* (Editorial), Optometry, Volume 74, pp. 7-10.

Wood J.M., (1999), *How Do Visual Status and Age Impact on Driving Performance as Measured on a Closed Circuit Driving Track?,* Ophthalmic Physiol Opt, Volume 19, pp. 34-40.

Wood J.M., (2002), *Age and Visual Impairment Decrease Driving Performance as Measured on a Closed-Road Circuit,* Human Factors, Volume 44, pp. 482-94.

Wood J.M., Mallon K., (2001), *Comparison of Driving Performance of Young and Old Drivers (With and Without Visual Impairment) Measured During In-Traffic Conditions,* Optom Vis Sci, Volume 78, pp. 43-9.

Wood J.M., Owens D.A., (2006), *Standard Measures of Visual Acuity Do Not Predict Drivers' Recognition Performance Under Day Or Night Conditions,* Optom Vis Sci, Volume 82, pp. 698-705.

Wood J.M., Troutbeck R., (1992), *Effect of Restriction of the Binocular Visual Field on Driving Performance,* Ophthalmic Physiol Opt., Volume 12(3), pp. 291-8.

Wood J.M., Troutbeck R., (1994), *Effect of Visual Impairment on Driving,* Human Factors, Volume 36, pp. 476-87.

Wood, J.M., (2002), *Age and Visual Impairment Decrease Driving Performance as Measured on a Closed-Road Circuit,* Human Factors, Volume 44, No.3, pp. 482-94.

Wood, J.M., A. Chaparro, T. Carberry, L. Hickson, (2006), *How Does Multi-Tasking Interact with the Effects of Visual Impairment and Age on Measures of Driving Performance?,* Proceedings of 85th Transportation Research Board Annual Meeting, Washington, D.C.

A.3 DIABETES BIBLIOGRAPHY

Fridulv Sagberg (2006), *Driver Health and Crash Involvement: A Case-Control Study,* Accident Analysis and Prevention, Volume 38, Issue 1, pp. 8-34.

Canine Detection of Hypoglycaemic Episodes Whilst Driving, Diabetic Medicine, Volume 23, No. 3 (2006), pp. 35. (Letters)

Diamond TH, Collins J. Rohl P, (2005), *Motor Vehicle Accidents During Episodes of Hypoglycaemia-Case Reports and Lessons to be Learnt,* Australian family physician, Volume 34, No. 3, pp. 151-154.

E. Peli, A. R. Bowers, A. J. Mandel, K. Higgins, R. Goldstein, L. Bobrow (2005), *The Design of Driving Simulator Performance Evaluations for Driving with Vision Impairments and Visual Aids,* 2005 Transportation Research Board Annual Meeting CD-ROM.

Hypoglycaemia and Driving, Diabetic Medicine, Volume 22, No. 9, (2005), pp. 1289-1290. (Letters)

Cox DJ, Schachinger H., (2004), *Driving Accidents and Diabetes: Risks and Prevention,* Journées annuelles de diabétologie de l'Hôtel-Dieu, Volume 185, No. 5, pp. 181-185. (Full Text in French)

Gilbey S. G., (2004), *Insulin-Treated Diabetes and Driving,* Diabetic Medicine: A Journal of the British Diabetic Association, Volume 21, Suppl. 3, pp. 0-13.

Finck H, Rinnert K., (2004), *Diabetes Mellitus-Fitness to Drive Private and Commercial Vehicles,* MMW Fortschritte der Medizin, Volume 146, pp. 47-50. (Full Text in German)

Graveling, A. J., Warren, R. E., Frier, B. M. (2004), *Hypoglycaemia and Driving in People with Insulin-Treated Diabetes: Adherence to Recommendations for Avoidance,* Diabetic Medicine, Volume 21, No. 9, pp. 014-1019.

Dorfler H, (2003), *Hypoglycemic and Vision Impaired. When is a Diabetic Patient Unfit to Drive?* MMW Fortschritte der Medizin, Volume 145, No. 23, pp33-36. (Full Text in German)

Cox DJ, Penberthy JK, Zrebiec J, Weinger K, Aikens JE, Frier B et al., (2003), *Diabetes and Driving Mishaps: Frequency and Correlations from a Multi-national Survey,* Diabetes Care, Volume 26, No. 8, pp. 2329–2334.

Kenneth M. Adams, (2003), *Driving and Diabetes, One Piece of Picture,* Diabetes Care, Volume 26, pp. 464–2465. (Editorial)

Razvi, S., Myers, L., Patton, K. (2003), *Screening for Diabetic Retinopathy, a Cause for Concern in People Who Drive,* Diabetic Medicine, Volume 20, No.10., pp. 12-915.

Mansell, P. (2002), *Diabetes and Driving,* Diabetic Medicine, Volume 19, No. 8, pp. 17-618.

Gill, G., Durston, J., Johnston, R. (2002), *Insulin-Treated Diabetes and Driving in the UK*, Diabetic Medicine, Volume 19, No. 6, pp. 35-439.

Emesz M, Egger SF, Nitsch S, Ruckhofer J, Hitzl W, Grabner G, (2001), *Automobile Drivers with Retinal Diseases-A Prospective Analysis,* Klinische Monatsblätter für Augenheilkunde, Volume 218, No. 10, pp. 70-676. (Full Text in German)

Cox DJ, Conder-Frederick LA, Kovatchev BP, Clarke WL, (2001), *Self-Treatment of Hypoglycemia While Driving,* Diabetes Research and Clinical Practice Volume 54, pp. 17-26.

Bailey, C.C., Sparrow, J.M, (2001), *Visual Symptomatology in Patients with Sight-Threatening Diabetic Retinopathy,* Diabetic Medicine, Volume 12, No. 11, pp. 83-888.

Cox DJ, Conder-Frederick LA, Kovatchec BP, Julian DM, Clarke W.L., (2000), *Progressive Hypoglycemia's Impact on Driving Simulation Performance. Occurrence, Awareness and Correction.,* Diabetes Care, Volume 23, No. 2, pp. 63-170.

Flanagan DE, Watson J, Everett J, Cavan D, Kerr D, (2000), *Driving and Insulin-Consensus, Conflict or Confusion?,* Diabetic Medicine: A Journal of the British Diabetic Association, Volume 17, No. 4, pp. 16-320.

Clarie Laberge-Nadeau, Georges Dionne, Jean-Marie Ekoe, Pavel Hamet, Denise Desjardins, Stephane Messier, Urs Maag, (2000), *Impact of Diabetes on Crash Risks of Truck-Permit Holders and Commercial Drivers,* Diabetes Care, Volume 23, No. 5, pp. 12-617.

Marrero, David, Edelman, Steve (2000), *Hypoglycemia and Driving Performance: A Flashing Yellow Light?,* Diabetes Care, Volume 23, No. 2, pp. 146-147. (Editorial)

Frier, Brian, Frcpe, (2000), *Hypoglycemia and Driving Performance,* Diabetes Care, Volume 23, No. 2, pp. 148-150. (Editorial)

Barry-Bianchi, Susan (2000), *"Real-Life" Driving Behavior While Hypoglycemic?,* Diabetes Care, Volume 23, No. 8, pp. 1210-1212. (Comments)

AC Burden, N Spiers, (2000), *Progressive Hypoglycemia's Impact on Driving Simulation Performance: Occurrence, Awareness, and Correction,* Diabetes Care, Volume 23, pp. 1866-1867. (Comments)

Cox, Daniel J., Gonder-Frederick, Linda A., Kovatchev, Boris, Clarke, William L. (2000), *Hypoglycemia Driving Research,* Diabetes Care, Volume 23, pp. 1866-1867. (Comments)

Gallo JJ. Rebok GW., Lesikar SE, (1999), *The Driving Habits of Adults Aged 60 Years and Older,* The Journal of the American Geriatrics Society, Volume 47, pp. 335-341.

MacLeod KM, (1999), *Diabetes and Driving: Toward Equitable, Evidence-Based Decision-Making,* Diabetic Medicine, Volume 16, pp. 282-290.

Amiel S.A.A. (1999), *Diabetes and Driving – An Insular Approach,* Diabetic Medicine, Volume 16, Issue. 4, pp. 271-272.

Weinger K, Kinsley BT, Levy CJ, Bajaj M, Simonson DC, Cox DJ, Ryan CM, Jacobson AM, (1999), *The Perception of Safe Driving Ability during Hypoglycemia in Patients with Type 1 Diabetes Mellitus,* The American Journal of Medical Electronics, Volume 107, No. 3, pp. 246-253.

Mc Gwin G Jr, Sims RV, Pulley L, Roseman JM(1999), *Diabetes and Automobile Crashes in the Elderly: A Population-Based Case-Control Study,* Diabetes Care, Volume 22, No. 2, pp. 220-227.

Lucas P (1999), *Driver's License: Responsibility, Ethics and Deontology,* Revue Médicale de Bruxelles, Volume 20, No. 4, pp. A225-229. (Full Text in French)

Clarke, William L., et al. (1999), *Hypoglycemia and the Decision to Drive a Motor Vehicle by Persons with Diabetes,* Journal of the American Medical Association, Volume 282, No. 8, pp. 750-754.

Pearson AR, Keightley SJ, Casswell AG (1998), *How Good Are We at Assessing Driving Visual Fields in Diabetes,* Eye, Volume 12, pp. 938-942.

D.J. Cox, W.C. Quillian, F.P. Thorndike, B.P. Kovatchev, G. Hanna (1998), *Evaluating Driving Performance of Outpatients with Alzheimer Disease,* Journal of American Board Family Practice, Volume 11, pp. 264–271.

McGwin G, Roseman J (1998), *Diabetes and Accident Insurance,* Diabetes Care, Volume 21, No. 5, pp. 77. (Comments)

Laberge-Nadeau C, Maag U, Cédras L, Desjardins D, Messier S.(1998), A Study of the Risk Associated With the Operation of CMVs by Insulin-Using Diabetic Drivers, Final Report for Transport Canada, November 1998, Montréal, Québec, Canada, Laboratory on Transportation Safety of the CRT, Université de Montréal, (No. CRT-98-57).

B Mathiesen, K Borch-Johnsen (1997), *Diabetes and Accident Insurance. A 3-year Follow-up of 7,599 Insured Diabetic Individuals,* Diabetes Care, Volume 20, No. 11, pp. 781-1784.

Brunner GA, Semlitsch B, Siebenhofer A, Pieber TR (1996), *Driver's License, Driving Habits and Traffic Safety of Patients with Diabetes Mellitus,* Wien Klin Wochenschr, Volume 108, No. 22, pp. 31-736. (Full Text in German)

Veneman TF (1996), *Diabetes Mellitus and Traffic Incidents,* The Netherlands Journal of Medicine, Volume 48, No. 1, pp. 4-28.

Ysander, L. (1996), *The Safety of Drivers with Chronic Disease,* British Journal of Industrial Medicine, Volume 23, pp. 28-36.

Distiller LA, Kramer BD (1996), *Driving and Diabetics on Insulin Therapy,* South African Medical Journal, Volume 8, pp. 1018-1020.

Claire Laberge-Nadeaua, Georges Dionneb, Urs Maagc, Denise Desjardinsd, Charles Vanassed and Jean-Marie Ékoé (1996), *Medical Conditions and the Severity of Commercial Motor Vehicle Drivers' Road Accidents,* Accident Analysis and Prevention, Volume 28, Issue 1, pp. 3-51.

Rehn, C.G, Ross, S.E. (1995), *Syncope as Etiology of Road Crashes Involving Elderly Drivers,* American Surgeon, Volume 61, pp. 006-1008.

Mathieu F, Bergeron J, Dupuis G, Ekoe JM, Laberge-Nadeau C (1994), *Diabetes and Road Safety,* Diabete Metab, Volume 20, No. 4, pp. 05-14.

Gold A.E. et al. (1994), *Frequency of Severe Hypoglycemia in Patients with Type 1 Diabetes with Impaired Awareness of Hypoglycemic,* Diabetes Care, Volume 17, No. 7, pp. 697-703.

Gresset, J., Meyer, F.(1994), *Risk of Automobile Accidents among Elderly Drivers with Impairments or Chronic Diseases,* Canadian Journal of Public Health, Volume 84, No. 4, pp. 282-285.

W.C. Quillian, D.J. Cox, L.A. Gonder-Frederick, N.R. Driesen, W.L. Clarke, (1994), *Reliability of Driving Performance during Moderate Hypoglycemia in Adults with IDDM,* Diabetes Care, Volume 17, pp. 1367–1368.

B. Driver and Collision Data Schema

The following table enumerates the statistical variables used in the transformation of driver and collision data into a format suitable for use with the SAS statistical analysis package.

For variables listed in the format A1-A137, there are 137 instances of this variable. Each instance represents a sequential month from January, 1995 through May, 2006.

Table B.1 SAS Schema for Exemption Data

Variable	Description	Data Source
lastname	Last Name	Control and Exempt Driver Data
firstname	First Name	Control and Exempt Driver Data
middlename	Middle Name	Control and Exempt Driver Data
birthdate	Birth date	Control and Exempt Driver Data
license	License	Control and Exempt Driver Data
licensesta	License State	Control and Exempt Driver Data
age	Age	Control and Exempt Driver Data
ftl1-ftl137	Fatal Crashes (one column each for each month starting from January 1, 1995)	Control and Exempt Driver Data
inj1-inj137	Injury Crashes (one column each for each month starting from January 1, 1995)	Control and Exempt Driver Data
tawy1-tawy137	Tow Aways (one column each for each month starting from January 1, 1995)	Control and Exempt Driver Data
ftldum1-ftldum137	Indicators for Fatal Crashes (= 0 if no crash, = 1 if crash occurred)	Control and Exempt Driver Data
injdum1-injdum137	Indicators for Injury Crashes (= 0 if no crash, = 1 if crash occurred)	Control and Exempt Driver Data
tawydum1-tawydum137	Indicators for Tow Away Crashes (= 0 if no crash, = 1if crash occurred)	Control and Exempt Driver Data
ftlsum	Total Fatal Crashes from January 1, 1995	Control and Exempt Driver Data
injsum	Total Injury Crashes from January 1, 1996	Control and Exempt Driver Data
tawysum	Total Tow Aways from January 1, 1997	Control and Exempt Driver Data
crashdummy	Indicator for presence of crashes of any kind since January 1, 1995	Control and Exempt Driver Data

Variable	Description	Data Source
app_no	Application Number	Exempt Driver Data Only
frdate	Federal Register Date	Exempt Driver Data Only
age_fr	Age at the Time of Federal Register Entry	Exempt Driver Data Only
status	Status of Application	Exempt Driver Data Only
deficiency	Deficiency	Exempt Driver Data Only
def_loc	Location of Deficiency	Exempt Driver Data Only
acuity_r_eye	Acuity of Right Eye	Exempt Driver Data Only
acuity_r_cat	Acuity of Right Eye (Categorized)	Exempt Driver Data Only
onset_right_rev	Onset of Deficiency for Right Eye	Exempt Driver Data Only
n_onset_right	Onset of Deficiency for Right Eye - Numerical Form	Exempt Driver Data Only
r_fov	Right Eye Field of Vision	Exempt Driver Data Only
rfov_stan	Right Eye Field of Vision Categorized	Exempt Driver Data Only
acuity_l_eye	Acuity of Left Eye	Exempt Driver Data Only
acuity_l_cat	Acuity of Left Eye (Categorized)	Exempt Driver Data Only
onset_left_rev	Onset of Deficiency for Left Eye	Exempt Driver Data Only
n_onset_left	Onset of Deficiency for Left Eye – Numerical Form	Exempt Driver Data Only
l_fov	Left Eye Field of Vision	Exempt Driver Data Only
lfov_stan	Left Eye Field of Vision Categorized	Exempt Driver Data Only