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A COMPREHENSIVE HUMAN FACTORS ANALYSIS OF OFF-DUTY MOTOR VEHICLE CRASHES IN THE UNITED STATES MILITARY

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A COMPREHENSIVE HUMAN FACTORS ANALYSIS OF OFF-DUTY MOTOR VEHICLE CRASHES IN THE UNITED STATES MILITARY

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ABSTRACT

Researchers have always had great interest in traffic safety and the phenomenon of motor vehicle crashes (MVCs). Though scores of service members are severely injured or killed in off-duty MVCs each year, few studies have addressed the MVC phenomenon within the military population and none have conducted a comprehensive evaluation of the causal factors associated with MVCs involving military personnel.

The main purpose of this dissertation was to gain a greater understanding of the causal factors associated with serious and fatal off-duty personal MVCs for military service members with the ultimate goal of preventing future losses. The HFACS-MVC framework was developed based on the established human error framework HFACS and used to classify causal factors from archival narratives from Class A and B off-duty MVCs in the USAF, USN, and USMC. This study identified the human factors trends associated with off-duty military MVCs and compared main trends for four variables of interest, specifically for military branch, vehicle type, paygrade, and age group.

The main human factor trends associated with off-duty MVCs were skill based technique errors related to negotiating curves/turns and regaining road positions and procedural violations related to speeding and drunk driving. Significant differences were found between human factors trends associated with MVCs for both vehicle type and military branch. For vehicle type, the human factors trends for 4W MVCs were significantly different from those for 2W MVCs, especially at the preconditions level. However, for military branch, the human factors trends suggest differences in the investigation and reporting processes for the three branches.

DEDICATION

I would like to dedicate my dissertation to Christopher "CDUB" Coppola and Joe Figueroa whose memories inspire me to succeed. I would also like to dedicate this work to the brave men and women in the U.S. Armed Forces who risk their lives to protect our country. Thank you for your service.

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ACRONYMS / ABBREVIATIONS

AFQT: Armed Forces Qualification Test

AFSAS: Air Force Safety Automated System

AFSC: Air Force Safety Center

DoD: Department of Defense

DON: Department of the Navy

DOT: Department of Transportation

DSOC: Defense Safety Oversight Council

GAO: General Accounting Office

HFACS: Human Factors Analysis and Classification System

HFACS-MVC: Human Factors Analysis and Classification System – Motor Vehicle Crashes

MVC: Motor vehicle crash

NHTSA: National Highway Transportation Safety Administration

NSC: Naval Safety Center

PMV: Private (personal) motor vehicle

PMVTF: Private Motor Vehicle Task Force

SCM: Swiss Cheese Model

SIMS: Safety Information Management System

USAF: United States Air Force

USMC: United States Marine Corps

USN: United States Navy

WESS: Web Enabled Safety System

WHO: World Health Organization

TABLE OF CONTENTS

Page

LIST OF EQUATIONS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Around the world, motor vehicle crashes (MVCs) result in 1.2 million deaths and 20 to 50 million injuries each year (WHO, 2009). In the United States alone, five to six million MVCs occur annually resulting in more than 30,000 deaths and over two million injuries (NHTSA, 2010a). In fact, MVCs consistently rank among the top ten leading causes of unintentional deaths in the United States and are particularly detrimental to young males (Evans, 2004; Subramanian, 2009).

1.1 MVC Causal Factors

Causal factors for MVCs are commonly classified into one of three basic categories based on their source – driver, roadway environment, or vehicle. Driver factors include direct driver causes as well as driver conditions and states. Common driver factors include speeding, inattention, following too closely, alcohol impairment and inexperience (Treat, et al., 1979; Wierwille, et al., 2002). Common roadway environment factors are related to roadway design (e.g. grades, curves), weather, and lighting. Common vehicle factors are related to controls and displays (e.g. cruise control, ITS), visibility from the vehicle, and safety systems (e.g. safety belts, ABS). Of these three causal factor categories, driver factors are the leading cause of the large majority of MVCs (Sabey & Taylor, 1980; Treat, et al., 1979; Wierwille, et al., 2002).

Finding driver factors messy and nebulous, engineers who study MVCs have typically eschewed driver factors for roadway environment and vehicle factors. Civil engineers who design structural systems generally focus on roadway environment factors. Mechanical engineers who design mechanical systems typically focus on vehicle factors.

However, human factors engineers who apply their expertise knowledge of human behavior to the design of products, processes, and systems focus on driver factors and their interactions with roadway environment and vehicle factors ("Human Factors," 2011). Unfortunately, only a small fraction of existing MVC literature contains comprehensive human factors analyses of MVCs.

1.2 MVCs in the Military

The MVC studies that do exist have typically looked at the general, largely civilian population. However, MVCs have detrimental effects on the military population as well. With the large majority of military personnel being young males, it's not surprising that hundreds of our service members are involved in serious and fatal MVCs around the world each year (GAO, 2005). Sadly, off-duty personal MVCs have gravely impacted the military for decades.

The military is plagued by hundreds of accidental deaths to service members each year, of which approximately 40 to 55 percent are the result of MVCs (Ecola, Collins, & Eiseman, 2010). Losses suffered as a result of MVCs reduce combat readiness by undermining the ability of the military to successfully prepare and carry out missions (Markopoulos, 2009; Miles, 2008). The military is negatively affected by direct, medical, and lost productivity costs associated with severe MVCs. Direct costs include vehicle damage, property damage, and the costs associated with military training. Medical costs include amounts paid for hospital and rehabilitation services. Lost productivity costs include days in the hospital, lost work days, and workplace disruptions.

For over a decade, US military safety centers have collected and maintained both quantitative (personnel, roadway environment, vehicle, and event variables) and qualitative (narrative) information for all MVCs resulting in the hospitalization or death of a service member. Prior attempts at identifying human causal factors for these mishaps appear to be inadequate for a comprehensive analysis of MVC causal factors. At times causal factors were identified inconsistently or incorrectly.

The military has implemented a number of recreation and off-duty safety programs targeting off-duty MVCs over the years. Traffic safety strategies commonly used throughout the military include training courses (e.g. Motorcycle Safety Foundation Basic/Experienced Rider Courses, Military Sportbike Rider Course), educational classes (e.g. AAA Driver Improvement Program, Alive at 25 Driver's Awareness Course), and briefings (e.g. Safety Stand Downs). Off-duty MVC safety efforts often focus on preventing drinking and driving, drowsy driving, and distracted driving especially related to cell phone usage behind the wheel.

To further their safety efforts, the United States Air Force (USAF), Navy (USN), and Marine Corps (USMC) collaborated with researchers in the Industrial Engineering department at Clemson University to carry out a comprehensive classification and assessment of MVC causal factors plaguing the military. The records for severe off-duty MVCs involving military personnel are maintained at service-specific military safety centers. This research accessed the records of severe off-duty MVCs for the USAF, USN, and USMC. Approximately 10 years of USN and USAF data and almost five years of USMC data were provided. The qualitative narrative descriptions provide a rare opportunity to study severe off-duty MVCs in the military. Comprehensive classification and analysis of the causal factors involved in these MVCs exposes the hazards that pose the greatest threat to our service members on the road. These findings provide a sound foundation for the development of targeted, data-driven safety strategies.

1.3 HFACS Framework

To ensure that the various causal factors associated with MVCs are comprehensively classified, an appropriate human error framework must be selected for use. The Human Factors Analysis and Classification System (HFACS) framework (Figure 1) may be effectively applied to the MVC domain. Based on Reason's (1990) model of human error, HFACS was developed by Drs. Wiegmann and Shappell (2000) as a proactive tool for capturing and classifying causal factors in real world settings. HFACS has since proven its utility and has been successfully modified for use in several industries including aviation (military, general aviation, air transport, and commercial), railroad, mining, construction, and health care just to name a few. The HFACS framework and its applications are discussed in greater detail in Chapter 2 Section 3 "Human Error Models and Frameworks."

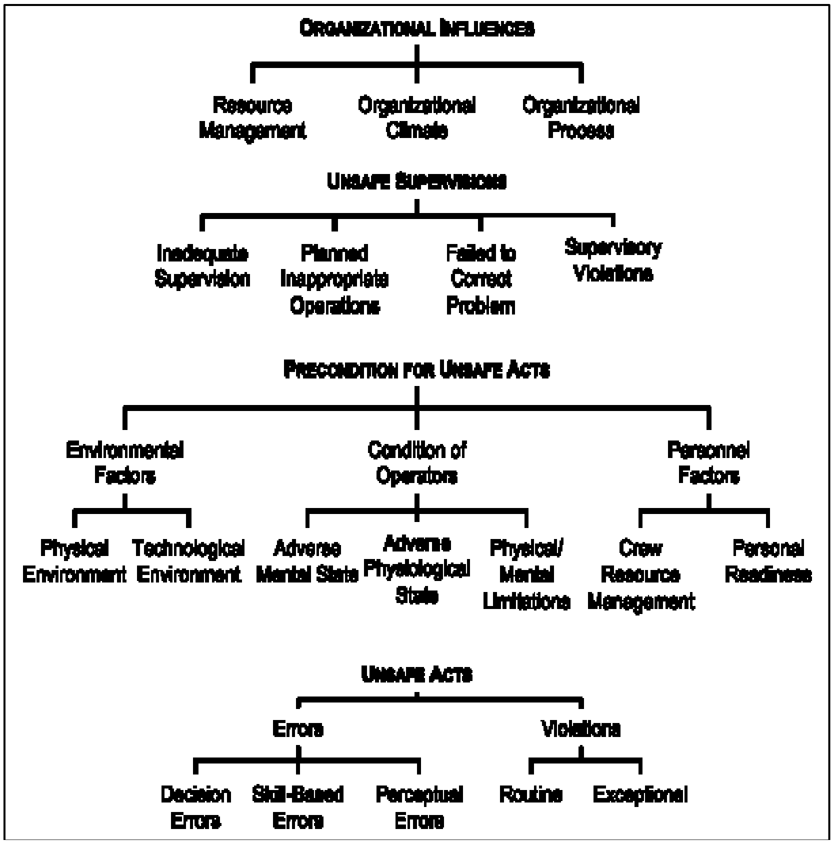

Figure 1: Original HFACS Framework (Wiegmann & Shappell, 2001)

Though successfully modified and applied to a wide range of domains, the HFACS framework has not yet been developed for use in the road traffic safety domain. This need was addressed by the development of the HFACS-MVC framework in the present study. The HFACS-MVC framework was then applied by HFACS experts to classify the causal factors associated with severe off-duty MVCs in the military.

1.4 OBJECTIVES

The findings of this study should provide a basis for developing effective and actionable MVC safety strategies. The military has little control over roadway environment and vehicle factors, but may be able to positively affect its personnel (Ecola, et al., 2010). To accommodate this constraint, each of the four independent variables selected for the present study was primarily related to the service member operating a motor vehicle and captured characteristics that change little over time and could be easily identified and classified prior to departure on the roads into categories that are distinctly different from one another.

Each of the branches of the military has a unique subculture that attracts particular types of people and personalities. The skills and knowledge required to safely operate two wheeled (2W) vehicles far exceed those required for four wheeled (4W) vehicles. Officers and enlisted service members have different requirements for entry into the military and work different types of jobs with different roles, responsibilities, and expectations. Young males perform the riskiest road behaviors and are the demographic with the highest rate of involvement for fatal MVCs around the world.

The main purpose of this dissertation was to gain a greater understanding of the causal factors associated with serious and fatal off-duty personal MVCs for military service members with the ultimate goal of preventing future losses of military service members to MVCs. The objectives of the present study were to identify the main causal factors involved in severe off-duty MVCs for military personnel and conduct comparisons of causal factor patterns for four independent variables: (1) military branches: USAF, USN, USMC, (2) vehicle types: 2W and 4W, (3) paygrades: enlisted and officer, and (4) age groups: 17-20, 21-25, 26-30, 31-35, 36-40, and >40 years old.

1.5 Research Questions

In the present study, the human factors trends were identified for service members seriously or fatally injured in off-duty MVCs and compared across different military branches, vehicle types, paygrades, and age groups. Identification of the human factors trends provide a basis for developing data-driven safety efforts targeted to the relevant issues experienced by service members on the roadways. Comparisons of the human factors trends amongst the groups of service members provide data-driven support for developing a one-size-fits-all approach or specific targeted (e.g. paygrade-based, age-based) approaches for different groups.

With the goal of preventing future military losses due to MVCs, the five main research questions addressed in the present study were:

Q1: What are the main human factors trends for serious off-duty MVCs involving military service members?

Q2: Are the main human factors trends different for MVCs involving service members from the USAF, USN, and USMC?

Q3: Are the main human factors trends different for MVCs involving 2W and 4W vehicles?

Q4: Are the main human factors trends different for MVCs involving enlisted and officer service members?

Q5: Are the main human factors trends different for MVCs involving service members in different age groups?

1.6 Contributions

This study provided a methodology for the systematic analysis of MVC causal factors. HFACS-MVC is a complete and comprehensive human error framework created for use with off-duty military MVCs. The creation and application of HFACS-MVC contributed to the existing literature supporting the use of HFACS in non-traditional, non-aviation platforms. The HFACS-MVC framework made it possible to systematically and comprehensively identify and capture causal factors within the road traffic safety domain.

The large majority of MVC research has focused on the general population with few specifically studying the MVC phenomenon in the military. For the present study, hundreds of severe off-duty mishaps involving service members serving in the USAF, USN, and USMC were classified using HFACS-MVC. This study has finally shed light on the specific types of human error affecting our service members on the roadways.

An understanding of specific driving and riding behaviors is necessary for the effective prevention of future MVCs. To illustrate this point, consider a hypothetical non-transportation situation in the medical field involving a doctor and two patients with the same illness. One patient tells the doctor that he feels sick while the other tells the doctor that she has a sore throat, swollen glands, and that her temperature has spiked in the past hour to 102 °F. How can the doctor help each patient? The doctor cannot accurately diagnose the first patient without additional information about his specific symptoms but has enough information to determine that the second patient has strep throat. While the second patient starts on antibiotics and feels better almost immediately, the first patient continues to suffer. Likewise, knowing that human error is a key component of MVCs does not help to prevent future crashes. But knowing that operator error in counter-steering is a key factor does contribute to MVC prevention efforts. Safety strategies can be tailored to address the specific driving and riding errors of our service members.

With only a finite amount of resources and funding for safety strategies, there is great value in identifying programs that provide the largest return on investment. This study provided a new perspective for how to evaluate both current and prior military MVC safety efforts. The success of a strategy has typically been determined based on the number or rate of fatalities before and after implementation. The contributions from this study provided a basis for the evaluation of safety initiatives based on their effects on specific driver and rider behaviors. By connecting the dates of implementation for individual safety programs with MVC causal factor patterns, the strengths and weaknesses of the individual safety programs can be assessed.

There has been recent consideration from the Department of Defense (DoD) to combine the individual safety centers into one entity that oversees safety for all services of the military. The present study supported these efforts by providing a universal human error framework for use throughout the military. Additionally, this study contributed a database filled with MVC causal factors for three of the four services of the military. The classification of MVC data with a universal set of HFACS-MVC causal factors provided the opportunity to compare the quality of MVC investigation and reporting practices between the military branches. Future efforts using on the causal factor database created in this study may be used to compare contributing causal factor trends between the branches to provide data-driven support for or against the unification of safety efforts for the entire military.

CHAPTER 2: LITERATURE REVIEW

2.1 Motor Vehicle Crashes (MVCs)

Motor vehicle crashes (MVCs) have elicited a great deal of concern since the advent of automotive transportation. Unfortunately, MVCs continue to plague countries around the world. Though technological and legislative changes have achieved significant improvements in motor vehicle safety, MVCs still injure and kill thousands each year. No one is immune to the devastation that results from MVCs including those serving in the military for our country.

Automotive transportation's history began back in 1769 with the Cugnot Steam Tractor, the world's first self-propelled vehicle (Bottorff, 2006) . By the early 1900s, companies in the US and Europe were commercially producing gasoline-powered automobiles and motorcycles. In 1910, there were already an estimated 130,000 cars and 150,000 motorcycles and tricycles in the US (Shaw, 1910). Motor vehicle production picked up in the 1950s after a slow spell in the years between the Great Depression and World War II. The number of vehicles on the road increased and by 1960, there were over 61,600,000 passenger cars and 574,000 motorcycles were registered in the US (DoT, 2011). These days, there are more than 137,000,000 passenger cars and 7,750,000 motorcycles registered for use on American roads (DoT, 2011).

With the advent of motorized vehicles came the danger of motor vehicle crashes. Reports of MVC injuries and fatalities were recorded almost immediately. The first automobile fatalities occurred in the late 19th century. Though the records may be a bit unclear, the first recorded MVC fatality occurred in Ireland in 1869 when Mary Ward was thrown from a homemade steam carriage making a sharp turn (Fallon & O'Neill, 2005). It appears that the first MVC fatality in the US occurred in Ohio a few decades later, in 1891 when James Lambert's automobile collided with a hitching post ("World's First Automobile Accident," 2006). In 1900, Harry Miles became the first person killed in a motorcycle MVC when he was ejected from a pacing machine during a race in Massachusetts ("Accident at Bicycle Meet," 1900).

Increased interest and demand of motor vehicles sparked concerns for the safety of all road users – drivers, passengers, motorcyclists, bicyclists, and pedestrians. Initial transportation safety efforts focused on making vehicles safer through design and technological modifications that increased crashworthiness. More recently, safety efforts have sought to modify driver and rider behaviors.

2.1.1 MVC Terminology and Definitions

There are a variety of terms that are used capture the basic elements of road traffic safety. A complete set of terminology and definitions used in the present study can be referenced in Appendix A.

The term "motor vehicle" is used to capture a privately owned non-government, non-commercial vehicle that can be operated on public highways including motorcycles, passenger vehicles, and light trucks. For the purposes of the present study, the two types of motor vehicles are two-wheeled (2W) and four-wheeled (4W) vehicles. The term "2W vehicle" is used for a powered motor vehicle with two wheels including cruisers, sport, touring, standard, and dual-purpose motorcycles. The term "4W vehicle" is used for a powered motor vehicle with four wheels including cars and light trucks.

An event in which two vehicles collide could be termed an accident, collision, or crash. An accident, however, implies that the events leading up to a MVC occur by chance rather than as the result of a combination of causal factors and as such, many have eschewed this term for more objective terminology. Consequently, the term "motor vehicle crash (MVC)" is used to capture this event as an event where a motor vehicle in motion collides with obstacle(s) in the environment and results in injury and/or property damage.

The US military has a unique set of safety terminology that is specific to adverse events involving service members. For example, a "mishap" is the term used by the military to define an adverse event or series of events that result in property damage, injury, or death. The DoD classifies mishaps according to the severity of their outcomes like injury, illness, or property damage (Table 1).

Table 1: Mishap Descriptions by Class Severity

Class	Description
A	Damage: total cost ≥ \$1 million or DoD aircraft destroyed Result: fatality or permanent total disability
B	Damage: \$200,000 ≤ total cost < \$1 million Result: permanent partial disability or 3+ personnel are hospitalized for inpatient care as a result of a single accident
C	Damage: \$20,000 ≤ total cost < \$200,000 Result: nonfatal injury that causes loss of time from work beyond that day/shift or nonfatal occupational illness or disability that causes loss of time from work or disability

There are four levels or classes of mishaps (A, B, C, and D), each with a lesser outcome severity than the last with Class D representing near-miss events. Class A mishaps are the most severe, resulting in permanent total disability or death. Each of the subsequent classes captures a lesser outcome severity. Class B mishaps result in permanent partial disability or the hospitalization of three or more people as a result of a single accident.

2.1.2 Operating a Motor Vehicle

Motorists must possess certain knowledge and skill sets in order to operate a motor vehicle. To safely operate a 2W or 4W motor vehicle on the roadway, a motorist must be able to search, evaluate, and execute (MSF, 2005). The skills required to accomplish these tasks include vigilant scanning, good judgment, and smooth control. Additional factors uniquely affect 2W vehicles such as balance, visibility, and lack of protection producing additional hazards for riders that do not affect drivers.

Motor vehicle operators must be able to vigilantly scan their environment. It is important for motorists to maintain awareness and sample their surroundings for the presence and position of other road users and obstacles. This skill is especially critical for motorcycle riders. The leading cause of fatalities for riders is the failure of another vehicle operator to detect, identify, and yield right of way to a 2W vehicle (SCDMV, 2009). Unfortunately, riders of 2W vehicles often find it challenging to vigilantly scan their environments. With only two mirrors (right side, left side) as opposed to three (right side, left side, rearview), sampling the surroundings on a 2W vehicle is more challenging and requires more physical movement than in a 4W vehicle. Rather than solely reference side mirrors, riders of 2W vehicles often compensate by performing head checks where they physically move their heads to sample the environment. As such, riders face an additional challenge in checking their surroundings without affecting their direction of travel.

Motor vehicle operators must be able to evaluate the information from their surroundings and adjust their behaviors accordingly. Motorists must be able to adequately judge and determine safe distances and speeds while travelling on the road. Operators must be able to determine whether they are travelling too fast to safely negotiate a curve or on a slick road. Taking a curve or turn too fast can cause a vehicle to depart from its lane of travel into another. This is especially critical for operators of 2W vehicles who take a turn or curve too fast which forces them to either slide out, lay down the motorcycle, or drift out of the lane. Operators must also be able to determine their distances relative to other road users and obstacles.

Motorists must be able to operate their vehicles in a smooth and controlled manner and maintain control while performing various operations. At times, motorists must react to avoid potential collision. However, sudden turns or lane changes can cause vehicle to skid, particularly with a slick or slippery road surface (NJMVC, 2011). Motor vehicle operators should be able to counter-steer (swerve) as necessary to avoid other road users and obstacles without losing control. Motor vehicle operators must be able to safely brake without losing control. Control skills are more integral for 2W vehicles than 4W vehicles, especially given that recovery from loss of control is extremely difficult with 2W vehicles and occur rarely (Elliott, Baughan, & Sexton, 2007).

To slow and stop a motor vehicle safely, the operator should apply steady, gentle pressure as opposed to slamming on the brake(s) (NJMVC, 2011). Hard braking can result in a skid, especially on slippery road surfaces like snow or ice surface. Braking for 2W vehicles is trickier than for 4W vehicles. Cars have one brake control which a driver controls with the right foot. Motorcycles have two brake controls. A rider controls the front brakes with the right hand and controls the rear brake with the right foot. To decelerate safely, breaking force should ideally come 70% from the front brake and 30% from the rear brake (MSF, 2005). If the braking force is applied too abruptly, the respective wheel can lock up causing a skid. As such, decelerating is more difficult for riders of 2W vehicles than it is for drivers of 4W vehicles.

While scanning, judgment, and control are important for both 2W and 4W motor vehicles, balance is basically a non-issue for drivers of 4W vehicles. Balance is critical for a safe riding experience and is sensitive to where riders should sit on the motorcycle and how they should hold their arms (CADMV, 2011). Riders have the additional challenge of checking their surroundings without it affecting their balance or direction of travel.

2.1.3 Fatal MVCs in the US

The topic of MVCs is relevant around the world and is extensively studied. International and national databases exist around the world to collect and track the characteristics of MVCs, especially fatal MVCs (Luoma & Sivak, 2007). In the US, fatal MVC records are maintained on both a federal system, NHTSA's Fatality Analysis Reporting System (FARS) and state-specific systems. The FARS database contains the characteristics for all MVCs occurring on public roadways around the US (all 50 States, District of Columbia, and Puerto Rico) that result in the death an involved person within 30 days of the crash. In each state, FARS analysts gather source documents, such as Police Accident Reports and State Driver Licensing Files, and enter the data elements into four forms (accident, vehicle, driver, and person). The accident form includes MVC demographics (e.g. date, location, weather, and number of vehicles involved). The vehicle form includes involved vehicle information (e.g. vehicle type, role in MVC, and impact points). The driver form includes driver qualifications (e.g. driving record and license status). The person form includes demographics for those involved in the MVC (e.g. age, role in MVC – driver, passenger, non-motorist, and severity of injuries) (NHTSA, 2005b). While FARS represents the entire population of fatal MVCs in the US, it lacks the ability to indicate when a road user is military. Therefore, MVCs that result in a military fatality are unable to be parsed from those involving civilians given the current FARS database. Furthermore, FARS does not contain personal information which prevents the collection of narrative summaries for the MVCs and restricts the level of detail for data collected about crash locations and involved individuals.

2.1.4 MVC Individual Factors

Historically, most studies have looked at the relationship between single elements (e.g. gender, age, intoxication, distraction, speeding, and crash demographics) and MVC involvement. Traditional analyses have identified the typical operator and crash characteristics. Common categories of demographics are operator (driver/rider), vehicle, crash, and environmental characteristics. Operator characteristics include age, gender, and race/ethnicity. Vehicle characteristics include the vehicle make, model, and year. Crash characteristics include time of day, location, number of vehicles involved, and configuration of involved vehicles. Environmental characteristics include atmospheric and lighting conditions. Some of the operator, vehicle, crash, and environmental characteristics commonly researched are reviewed in the following section.

Age and Gender

Both within and outside the US, the demographic of drivers with the highest crash and fatality rates are young males. In fact, males are twice as likely as females to be killed in MVCs (Evans, 2004). The general relationship between driver age and involvement in fatal and nonfatal MVCs is presented in Figure 2. In general, drivers involved in fatal MVCs are younger than drivers involved in non-fatal MVCs. While people between the ages of 15 and 34 make up 27.5% of the American population, they represent 42.5% of the drivers killed in MVCs (NHTSA, 2008). Moreover, the highest fatality and injury rates per 100,000 people are experienced by people aged 21-24 and 16-20 respectively (NHTSA, 2008).

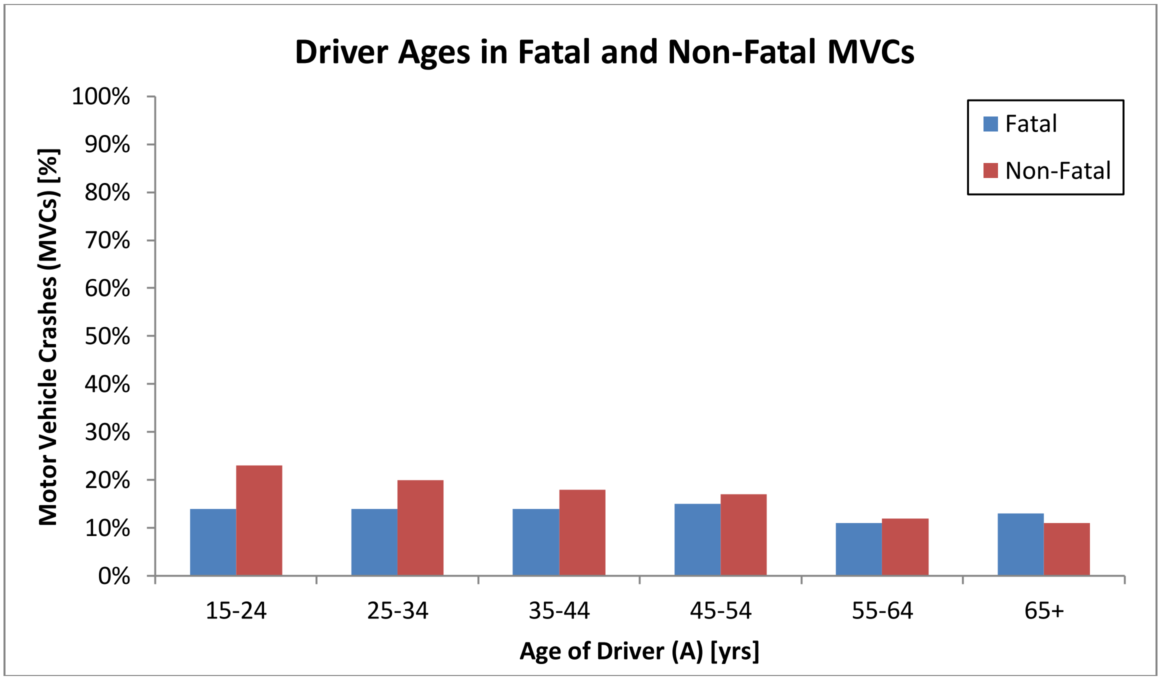

Figure 2: Driver Ages for Fatal and Non-Fatal MVCs in the US (NHTSA, 2008)

Alcohol Impairment

Drunk driving has received a substantial amount of attention as well. The probability of being involved in a MVC is at least two to ten times higher for a driver with a BAC of 0.08% than for an unimpaired driver (Compton, et al., 2002; Zador, 1991). Alcohol-impaired driving fatalities represented close to one-third of all US traffic fatalities in 2007 (NHTSA, 2008). Over one-third (35%) of drunk drivers (BAC of 0.08% or higher) involved in fatal MVCs in the US are between the ages of 21 and 25 (NHTSA, 2008). At the 0.08 BAC level, one's vision, balance, perception, reaction time, concentration, memory, judgment, reasoning, information processing, and speed control are all affected (NHTSA, 2005a). Observable cues that suggest that a vehicle is likely being operated by a drunk driver include problems maintaining lane position, speed and stopping problems, vigilance problems, and judgment problems (NHTSA, 2010b).

Inattention and Distraction

Driver inattention is involved in one-fourth to one-half of all MVCs in the United States (Stutts, Reinfurt, Staplin, & Rodgman, 2001). Behaviors such as texting, looking at external objects, and reaching for a moving object all serve to negatively impact a driver's attention. The risk of MVC involvement is two to six times higher for inattentive drivers compared to alert drivers (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006) Distraction, the primary form of inattention, occurs when the operator divests attention from the primary driving task in order to attend to an object or activity within or outside of the vehicle. Distraction comes from many sources – conversing with people in the car or on the phone, interacting with children in the backseat, or playing with the stereo to name a few. Young drivers, particularly those under the age of 20, are more likely than other age groups to be distracted when involved in a MVC.

Speeding

Speeding is a factor in approximately one-third of MVC fatalities (IIHS, 2010). Positive relationships exist between speed and both crash risk and injury severity; in high-income countries around the world, approximately 30% of fatal MVCs result from travelling at "excess or inappropriate" speeds (WHO, 2004). The relationship between speed and risk of MVCs is that the following three variables are exponentially increased when speed is increased – distance needed to stop, time needed to stop, and the energy at impact (IIHS, 2010). Even small increases in speed can increase the risk of a crash, of being injured, and of being killed. A mere increase in speed of 1 km/h (0.62 mph) may increase the risk of a fatal MVC by 4-5% (WHO, 2004).

Inexperience

A large majority of motorcycle riders involved in MVCs lack formal riding education. A large-scale motorcycle study found that the overwhelming majority of riders involved in MVCs were self-taught or taught by friends or family and over half had fewer than five months of experience riding the mishap motorcycle (Hurt, Ouellet, & Thom, 1981). While it is against the law to ride a motorcycle without an endorsement in the US, 25% of the riders killed on 2W vehicles in 2009 did not have motorcycle endorsements (IIHS, 2011). While it is also against the law in the US to drive a 4W passenger vehicle without a driver's license or permit, a smaller percentage (14%) of drivers in 4W fatal MVCs lacked licensure that same year (IIHS, 2011).

Drowsiness and Fatigue

Sleep, naps, and rest refresh the brain and its mental processing power. When fatigued, the brain's mental processing power and speed decreases which affects its ability to process and react to new information. Symptoms of mental fatigue while driving or riding include slower reaction times, reduced vigilance and awareness, impaired memory, impaired decision-making, loss of situational awareness, and degraded performance. On the road, drowsiness affects everyone; however inexperienced operators are affected more than experienced operators. Inexperienced operators have not had enough experience to automatically respond in a skilled manner to unexpected situations on the road.

2.1.5 MVC Human Factors

Though studying factors individually provides some insight into the causes of MVCs, it does not provide the whole picture. Traffic safety literature is replete with studies looking at the role of operator factors such as gender and age. Unfortunately, studying only traditional demographics restricts analyses to factors that cannot be controlled or modified. Ultimately the multifaceted causes of MVC are more complex than simple demographics can explain. A thorough understanding of MVCs requires an appreciation of the complexity of human error. Instead of looking at only one or two variables, a few researchers have sought to identify the variables involved in MVCs using a systems approach. These studies have greatly contributed to our understanding of MVC causal factors. Key studies that have comprehensively classified causal factors in MVCs include Indiana University's Tri-Level study, Veridian's Unsafe Driving Acts study, University of North Carolina's Serious MVC study, the 100-Car Naturalistic Driving study, and the Hurt Motorcycle study.

Tri-Level Study

The Tri-Level Study performed by researchers at Indiana University was one of the first major human factors assessment of causal factors for MVCs (Treat, et al., 1979) in which the definite, probable, and possible factors resulting in MVCs were identified and categorized. The study found that 71% of the MVCs involved definite human causal factors but only 4% and 13% involved definite vehicular and environmental causal factors respectively. The main human causal factors were found to be recognition errors (41.4%) and decision errors (28.6%).

Unsafe Driving Act (UDA) Study

The Veridian Unsafe Driving Act (UDA) Study used an 11-step process to evaluate the crash, primary cause, and contributing factors of 723 MVCs from four US locations between 1996 and 1997 (Hendricks, Freedman, Zador, & Fell, 2001). The UDA Study found that a driver behavioral error caused or contributed to 99% of the MVCs. The causal factors found to be frequently associated with driver behaviors were driver inattention (22.7%), vehicle speed (18.7%), alcohol impairment (18.2%), perceptual error (15.1%), decision errors (10.1%), and incapacitation (6.4%).

100-Car Study

The 100-Car Study in 2006 identified pre-crash causal and contributing factors from naturalistic data collected by in-vehicle sensors and cameras (Dingus, et al., 2006). A year of data was collected from each of 100 equipped vehicles provided to drivers in the Northern Virginia/Metropolitan Washington, DC area. The study focused on the following driver behavioral factors: driver inattention (including drowsiness), traffic violations, aggressive driving, and seat belt usage. Driver inattention was a factor in approximately 80% of the crashes and 60% of the near-crashes. Drowsy driving was a factor in 12% of the crashes and 10% of the near-crashes.

UNC Serious MVC Study

A 2002 study at University of North Carolina (UNC) Highway Safety Research Center identified the causal factors involved in over 1,200 serious MVCs in the state between 1993 and 1997 (Wierwille, et al., 2002). The study determined "willful inappropriate behavior" as a principal contributor in the majority of serious incidents (57%). Both "inadequate knowledge" and "infrastructure" were determined to be principal contributors, each influential in approximately one-fifth of serious incidents. Factors such as alcohol impairment, curves, low shoulders, trees, darkness, and the number of wheels on the vehicle were determined to also be significant.

Motorcycle Study

The first comprehensive assessment of contributing operator (motorcycle and car), roadway environment, and vehicle causal factors for motorcycle crashes in the US was the Hurt Motorcycle Study (Hurt, et al., 1981). Between January 1976 and December 1977, a multifaceted research team at the University of Southern California collected and reconstructed data for over 900 2W MVCs in the Los Angeles area resulting in a range of rider outcomes from no injury through fatality. Overall, the Hurt Study found that 2W MVCs were predominantly caused by other motor vehicle operators on the road who violated the motorcyclists' right of way. Roadway environment and vehicle factors rarely contributed to 2W MVCs with weather, lighting, road defects and vehicle defects each involved in only 2% to 3% of the MVCs. Common contributing human factors were incorrect selection of braking and evading actions (36%), inadequate execution of braking and evading actions (38%), attention issues (38%), and alcohol involvement. Overall motorcycle operators involved in MVCs lacked formal motorcycle training (92%) and proper motorcycle licensure (46%).

2.2 US MILITARY

The US military's roots trace back to the beginnings of our country as an independent nation in 1776 with the establishment of the Continental Army under the command of General George Washington. In 1948, the Department of Defense (DoD) was established as the civilian agency responsible for providing, coordinating, and developing the armed services of the US.

There are four services or branches of the US Armed Forces that operate under the DoD – Army, Navy (USN), Marine Corps (USMC), and Air Force (USAF). The US Army is responsible for military operations on land. The USN is responsible for military operations at sea. The USMC is responsible for amphibious military operations afloat and ashore. The USAF is responsible for military operations within the region of aerospace. An additional branch of the US military operates under the Department of Homeland Security in peacetime but under the USN in wartime or as directed by the President. This branch, the US Coast Guard (USCG) is responsible for maritime safety, security, and stewardship.

2.2.1 US Military Demographics

Paygrades

Each branch of the US military has its own system of ranks and titles. However, all services use the same paygrade system to represent both salary range and level of seniority for service members within the command structure. Paygrades may be categorized according to the three basic types of service members – enlisted, officers, and warrant officers. The former categories (enlisted and officer) exist for all military services while the latter category (warrant officer) exists for all services except the USAF. Officers outrank warrant officers who outrank enlisted personnel.

Paygrades use a letter-number format where the letter represents the grade group (E, W, and O for enlisted, warrant, and officer respectively) and the number represents level of authority and responsibility in an ordinal manner (larger numbers for greater levels of authority and responsibility). There are nine enlisted grades (E-1 through E-9), five warrant grades (W-1 through W-5), and 10 officer grades (O-1 through O-10). For enlisted personnel, the lowest grade is E-1 and the highest grade is E-9. For warrant officers, the lowest grade is W-1 and the highest grade is W-5. For officers, the lowest grade is O-1 and the highest grade is O-10. The large majority of service members (84%) are enlisted (BLS). The remaining service members are primarily officers (15%) and a mere fraction of the force (1%) are warrant officers.

Enlisted service members sign up to serve within the military structure for a period of two to four years. Each military service selects positions for its enlisted personnel based on its needs and the abilities of the service members, and then provides appropriate training for those positions. Junior enlisted personnel (grades E-1 to E-3/4) are basically apprentices whose role it is to learn, develop, and apply new (primarily technical) skills. More senior enlisted personnel (grades E-4/5 and above) include non-commission and senior non-commission officers with increasingly greater expectations and responsibilities.

Promotions at the lower enlisted grades (E-1 to E-3 for USN and USMC; E-1 to E-4 for US Army and USAF) are practically guaranteed as they are based on time in service and time in grade. Promotions to the higher enlisted grades are more competitive as they are based on multiple factors, the most restrictive of which are the number of vacancies for career fields within a grade. For example, in 2011 the chances for USN enlisted personnel to advance to the paygrades of E-4, E-5, and E-6 were 30.97%, 20.68%, and 10.75% respectively (Faram, 2011).

Officers hold commissions from the US to function in a leadership role within the military structure. A commission is a document that authorizes a service member to hold a position in the military for the entirety of one's term of service. To receive commission, one must meet certain standards of education and proven skill. A person can train to become an officer in the military by attending a service academy, going through Reserve Officer Training Corps (ROTC) or Officer Candidate School (OCS), or by receiving direct commission. The three service academies under the DoD are the Military Academy at West Point for the US Army, the Naval Academy at Annapolis for the USN and USMC, and the Air Force Academy in Colorado Springs for the USAF. Upon graduation from a service academy, one becomes commissioned as an officer in the military. The ROTC program acts as a preparatory school for commissioning. Many universities around the country provide ROTC courses that students can take while earning their college degrees. Upon graduation from college, ROTC students are eligible for commissioning as an officer in the military. OCS is a program for civilians with four year college degrees or enlisted service members with four year college degrees or equivalent amounts of training or specialized education. Direct commissioning provides civilians with specific expertise such as doctors, lawyers, and chaplains to be commissioned into the military as restricted officers.

Officers are required to be upstanding individuals who provide guidance and oversight to those under their command. With higher levels of responsibility and authority within the military structure, officers are typically held to higher standards than enlisted personnel and misconduct is not tolerated. Officer promotions in the military are regulated by the Defense Officer Personnel Management Act (DOPMA) enacted by Congress in 1981. DOPMA laws set the time in service required for promotion and the percent of applicants that must be denied or passed over for promotion. Promotions at the lower officer grades (O-2 and O-3) are pretty much automatic based primarily on time in service/grade with a promotion success rate close to 100% ("Navy - Officer Promotion Process," 2006). Subsequent promotions to higher officer grades are more restrictive. DOPMA specifies that 20%, 30%, and 50% of the applicants must be denied promotion to O-4, O-5, and O-6 positions respectively.

Warrant officers hold warrants from the US to function as highly trained specialists in the military structure. A warrant is a document that authorizes a service member to carry out a specific task based on one's expertise in one's field. Warrant officers make up only a miniscule fraction of the armed forces due to service restrictions and stringent qualification requirements. Only military personnel in the US Army, USN, and USMC can become a warrant officer; the USAF discontinued this rank in 1959. In general, warrant officers in the US Army and USMC are selected midcareer while those in the USN are selected late career (Fernandez, 2002). With few exceptions, an eligible enlisted USN or USMC service member can apply for a warrant officer position only after serving in the military for a minimum of 12 years and attaining at least a paygrade of E-7. With a requirement for applicants to have served in the military for a minimum of 12 years, warrant officers are especially likely to be older than other officers and enlisted personnel.

Warrant officers serve as technical experts in their fields and provide knowledge, skills, guidance, and oversight. Applicants for warrant officer positions must be upstanding individuals of good moral character whose records contain no disciplinary actions/convictions nor substantiated cases of drug/alcohol abuse for the prior three years (DoN, 2009). To even attain prerequisites for warrant officer positions, service members must perform as well as or better than their peers and build their skills, responsibilities, and leadership abilities as they move up the ranks. Indeed, warrant officers in the USN and USMC have slightly faster rates of promotion than their enlisted peers (Fernandez, 2002). Warrant officer positions are quite competitive and only a small fraction of applicants receive promotions, particularly in the USN and USMC. In fact, less than one-third of USN and USMC applicants (26% and 22% respectively) were promoted to warrant officer positions in 2000 (Fernandez, 2002).

The demographic characteristics of active duty enlisted personnel differ from those of both warrant and commissioned officers (Table 2). The average age for active duty enlisted service members is 27.1 years old with over half (52.5%) of active duty enlisted personnel 35 years of age or younger (Segal & Segal, 2004). Officers in the US military tend to be older than enlisted personnel. The average age of an active duty officer is 34.6 years old (Segal & Segal, 2004). The majority of active duty officers (85.8%) are over the age of 25 in comparison to fewer than half of enlisted personnel (47.5%) (Segal & Segal, 2004).

Table 2: Demographics for Active-Duty Enlisted and Officer Personnel (Segal & Segal, 2004)

	Enlisted			Officer		
	USAF	USN	USMC	USAF	USN	USMC
Male	80%	86%	94%	82%	85%	94%
Aged 30+	64%	67%	68%	97%	70%	70%
Married	56%	50%	41%	71%	66%	69%

Branches

Over one-third of the US Armed Forces active-duty personnel are in the US Army. This represents the largest single service component of the military. Smaller percentages of the US Armed Forces active duty personnel are in the USN and the USAF. Each of these service components represent approximately one-fourth of the military. The smallest single service component of the military is the USMC with a little more than one-tenth of the military.

Since 2000, between 1.3 and 1.4 million active-duty military personnel have served for our country each year. In 2007, there were a total of 1,365,371 active-duty DoD military personnel – 37.9% in the US Army, 24.3% in the USN, 24.1% in the USAF, and 13.7% in the USMC (OneSource). The demographic characteristics of enlisted and officer personnel in the USAF, USN, and USMC is presented in Table 3.

Table 3: Demographics for Active-Duty Personnel in USAF, USN, and USMC

	USAF Enlisted (Officer)	USN Enlisted (Officer)	USMC Enlisted (Officer)
Male	80% (82%)	86% (85%)	94% (94%)
Aged 30+	64% (97%)	67% (70%)	68% (70%)
Married	56% (71%)	50% (66%)	41% (69%)
High School (College)	80% (95%)	91% (57%)	95% (80%)

The demographics of the military personnel serving in each of the four services differ from one another (OneSource). The USMC has the youngest active duty force with an average age of 25.0 years. The US Army, USN, and USAF have slightly older active duty service members with average ages of 28.4, 28.7, and 29.6 years respectively. The USMC also has the largest percentage of active duty enlisted personnel with one officer for every 8.5 enlisted service members. The US Army and USN each have approximately one officer for every five enlisted service members. With the largest percentage of active duty officers, the USAF has one officer for every four enlisted service members.

2.2.2 Fatal MVCs in the US Military

Researchers have generally overlooked the MVC phenomenon in the military. Leadership in the military is concerned with the number of service members who are lost to non-operational, off-duty PVMCs. To preserve combat capability and save lives, the military is supported by service-specific safety centers that target the prevention of mishaps. Each safety center is responsible for maintaining a mishap reporting system and a mishap database for its service members. The Naval Safety Center (NSC) at Norfolk Naval Base in Norfolk, Virginia maintains the online reporting system Web-Enabled Safety System (WESS) for USN and USMC mishaps. The Air Force Safety Center

(AFSC) at Kirtland Air Force Base in Albuquerque, New Mexico maintains the online reporting system Air Force Safety Automated System (AFSAS) for USAF mishaps.

Prior research is inconclusive in its comparisons of MVC fatality rates for military and civilians. Some found service members to be more likely than the average civilian driver to be fatally injured during an MVC (Miller & Sack, 2004) while others have found MVC fatality rates for military personnel to be lower than the general population (Carr, 2001; Dellinger, Krull, Jones, Yore, & Amoroso, 2004; Markopoulos, 2009; OneSource, 2007). Estimated MVC fatality rates for both the US and military populations are presented in Table 4.

Table 4: MVC Fatality Rates for US and Military Populations (Ecola, et al., 2010)

Population		MVC Fatality Rate (per 100,000 population)
US	15-24 year old males	37.3
	24-35 year old males	24.1
	All	14.7
US Military	Army	17.7
	Air Force	11.9
	Coast Guard	19.6
	Marine Corps	27.1
	Navy	15.9

These MVC fatality rates were provided in a recent technical report prepared by the Private Motor Vehicle Task Force (PMVTF) for the Defense Safety Oversight Council (DSOC) (Ecola, et al., 2010). The US fatality rate used a seven-year average of MVC data from 2000 to 2006 and the military fatality rate used a ten-year average of MVC data from 2000 to 2009. All branches had MVC fatality rates that were lower than the US MVC fatality rate for 15-24 year old males and most had rates that were lower than the US MVC fatality rate for 24-35 year old males. The concerning exception was the MVC fatality rate for the USMC military branch.

2.2.3 Military MVC Individual Factors

Common factors involved in fatal USAF 4W MVCs are impaired driving, speed too fast for conditions, and fatigue or over-extending oneself (DoD, 2003). Common factors involved in fatal USAF 2W MVCs are exceeded capabilities/lacked proficiency, speed too fast for conditions, and impaired operators. Similarly, the most common factors involved in fatal USN and USMC 2W MVCs are speeding and loss of control.

2.2.4 Military MVC Human Factors

Though studying individual demographic and behavioral factors associated with MVCs in the military provides some insight, there is still much to be learned. Limitations of prior military MVC studies are that they failed to that they identify causal factors comprehensively or exhaustively, often used data that were previously collected containing potential classification errors or inconsistencies, and often targeted just included a few factors to research. However, even with their limitations, prior studies have contributed a great amount to what is known about the MVC phenomenon in the military. Some of the key studies on MVCs in the military are discussed in the following section. These include the US Army MVC Injury Study, the USMC MVC Fatality Study, the Fatal Military MVC Study, the USAF-US MVC Comparison Study, and the USAF MVC Modeling Study.

US Army MVC Injury Study

A longitudinal study was conducted in the 1990s to identify demographic and behavioral risk factors associated with serious MVCs in the US military (Bell, Amoroso, Yore, Smith, & Jones, 2000). After completing HRA surveys in 1992 to capture their health habits and behaviors, active-duty US Army personnel were followed until one of three events occurred – they were hospitalized due to injuries sustained in MVCs, they separated from the military, or the study period ended in 1997. During the six-year study period, 429 of the 99,981 Army personnel who had completed HRAs were hospitalized with injuries sustained in MVCs where they were acting as operators or passengers of 4W motor vehicles. Hazard ratios compared the times to event (hospitalization or separation/end of study) of the 429 injured and 99,552 uninjured service members to identify significant associations between demographic and behavioral factors and MVC injury hospitalizations.

Looking at the demographic factors, both age and paygrade were found to be significantly associated with MVC injury hospitalization. Compared to service members over the age of 40, the risk of MVC injury hospitalization was approximately 6 times higher for 18-20 year old service members (HR=5.89), 4 times higher for 21-25 year old service members (HR=3.89), and 2 times higher for 26-30 year old service members (HR=1.93). Compared to officers, the risk of MVC injury hospitalization was approximately 2.5 times higher for enlisted service members (HR=2.62).

Looking at the behavioral factors, both speeding and drinking and driving or riding with a drinking driver were found to be significantly associated with MVC injury hospitalization. The risk of MVC injury hospitalization was around 1.5 times higher for service members with typical speeding behaviors in excess of 10 mph over the limit than for service members with typical speeding behaviors within 5 mph of the limit

(HR=1.52). The risk of MVC injury hospitalization for service members who did not drive was twice the risk for service members with typical speeding behaviors within 5 mph of the limit (HR=1.98). The risk of MVC injury hospitalization for service members who indicated drinking and driving or riding with drinking drivers was around 1.5 greater than the risk for service members who did not (HR=1.45).

USMC MVC Fatality Study

Bowes and Hiatt (2008) identified and compared the contributing factors associated with MVC fatalities for USMC and US populations. The USMC dataset contained 464 USMC MVC fatalities (94 2W and 370 non-2W vehicles) that occurred between FY1999 and FY2007. The general US dataset contained NHTSA FARS data from the same time period adjusted to match the age-gender demographics of the USMC. Overall, the MVC fatality rates for the USMC population were lower than those for the general US population (29 deaths per 100,000 USMC compared to 34.5 deaths per 100,000 US).

By vehicle type, USMC rates generally exceeded US rates for MVCs with non-2W vehicles while US rates generally exceeded USMC rates for MVCs with 2W vehicles. Actually, MVC fatality rates for 2W vehicles were similar for the two populations until around 2001 when the rates for the USMC began to exceed those for the general US. Looking at age, the highest USMC fatality rates were found for 19 year olds for non-2W vehicles and for 25 to 32 years olds for 2W vehicles. Looking at paygrade, the highest USMC fatality rates were found for E-2 personnel followed by E-3 and E-4 personnel. Furthermore, the risk of MVC fatalities for USMC personnel were significantly higher for junior enlisted (E-1 to E-2) who joined the military at least six months prior and warrant officers compared to senior enlisted personnel (E-7 to E-9).

Fatal Military MVC Study

Hooper et al (2006) identified and quantified factors associated with fatal MVC events for military service members from all four branches between 1991 and 1995. Bivariate analyses were used to compare 980 male service member driver fatalities to 12,807 male service member non-MVC fatalities which served as the control group. This study found that male service members killed in MVCs were more likely to be younger, enlisted and in the USMC. Looking at age, male service member MVC fatalities were significantly more likely to be younger than 36 and specifically more likely to be under the age of 26. Looking at paygrade, male service member MVC fatalities were significantly more likely to involve enlisted personnel than officers. Looking at service, male service member MVC fatalities were significantly more likely to be in the USMC than in the USAF, USN, or US Army.

USAF-US MVC Comparison Study

Carr (2001) selected five operator factors of interest captured by the USAF (excessive speed, fatigue, impairment, inexperience, and recklessness other than speed) and quantified their associations with severe MVC events for the USAF and general US populations. The dataset contained a total of 893 MVCs (182 motorcycle and 711 non-motorcycle) that resulted in permanent disability or death of a USAF operator, passenger, bicyclist, or pedestrian between fiscal years 1988 and 1999. The most common event factors were impairment (40%), excessive speed (39%), and fatigue (19%). Looking at just the motorcycle MVCs, the most common event factors were excessive speed (48%), impairment (32%), and inexperience (16%). Linearity tests of annual trends indicated small but significant reductions of impairment and excessive speed event factors in USAF MVCs between FY1988 and FY1999. Multivariate analyses were performed to compare the risk of MVC fatality for USAF male operators (per 100,000 person years as estimated using averaged annual USAF personnel strength data from the 12-year period) to the risk of MVC fatality for licensed male US drivers (per 100,000 licensed drivers as estimated by NHTSA FARS licensed driver data from 1996). Results of these analyses indicated that MVCs took the lives of approximately 40% fewer USAF than US licensed male operators.

USAF MVC Modeling Study

Markopoulos (2009) selected factors of interest from those captured by the USAF including age and paygrade and studied their associations with off-duty USAF MVCs. The dataset contained a total of 12,403 2W and 4W MVCs involving USAF operators between FY1999 and FY2007 that resulted in minor injury, lost time, permanent disability, or death of one or more USAF service members. Categorical analyses were performed to determine how each factor related to the rate of MVCs and the severity of the resulting injuries. Looking at age for MVCs between FY1994 and FY2007 (age data were not captured prior to FY1994), the young service members between the ages of 17 and 24 had a significantly higher MVC rate than older age groups and were more likely to have MVCs that resulted in lost time cases and fatalities. Looking at paygrade, enlisted service members (Airman, NCO, and Senior NCO) were more likely than officers (company grade, field grade) to be involved in MVCs, particularly for MVCs that resulted in lost time cases and fatalities. Comparisons by vehicle type were limited in value in that they did not compare rates of MVCs for operators of 2W to those for operators of 4W vehicles but instead looked at the percentage of all MVCs that occurred on each type of vehicle. In this regard, Markopoulos found that significantly more of the MVCs involved 4W vehicles with a consistent ratio of two 4W MVCs to every one 2W MVC.

2.2.5 Military-Civilian Comparisons

It is tempting to merely extrapolate MVC trends identified in the general predominantly civilian population to the military population. In fact, several similarities do exist between civilian and military populations. However, there are also several differences that suggest that the military population is actually quite unique.

Starting with similarities between military and civilian, civilians and service members of similar ages typically die from the same causes (Segal & Segal, 2004). MVCs for both civilians and military personnel largely occur on roadways travelled by the general public.

Next, for both civilian and military populations in the US, young drivers are involved in more MVCs than other age groups. Military personnel are representative of the age group typically involved in or affected by MVCs in the general population. The percentages of people in three young age ranges (15 to 24, 25 to 34, and 35 to 44) are consistently higher for drivers involved in fatal MVCs than for the people in the general population. Almost one fourth (23%) of the drivers involved in fatal MVCs in the US are between the ages of 15 and 24. About one fifth of the drivers involved in fatal MVCs in the US are between the ages of 25 and 34 (20%) and 35 and 44 (18%). The percentages of the general population in these age ranges are 14% apiece. However, the percentages of people in these age ranges (15 to 24, 25 to 34, and 35 to 44) are consistently greater for those serving in the military than for both drivers in fatal MVCs and people in the general population.

Finally, factors commonly associated with fatal MVCs in the military are similar to those associated with fatal MVCs in the general population. For example, speed and impairment are significantly associated with fatal MVCs for Air Force service members {DoD, 2003, Department of Defense Motor Vehicle Safety Initiatives - Report to Congress}. These factors are common factors associated with fatal MVCs for the general population, especially for younger age groups (NHTSA, 2008, 2010a).

There are also a number of differences between civilians and military personnel (Lee & Mather, 2008). First of all, military personnel are younger than their civilian counterparts. One study found the average age of active duty service members to be 28 years with the average enlisted being 27 years of age and the average officer being 32 years of age. Almost one half (47%) of the active duty military personnel were between 18 and 24 years of age. In contrast, only about one third (37%) of the general population are between 18 and 24 years of age with a median age for people in the civilian workforce of 41 years.

The differences between US military and civilian populations encompass more than just age. Military personnel are less likely to be Hispanic, slightly more likely to be white or black, and much likelier to be American Indian or Alaskan native than their non-military peers (Watkins & Sherk, 2008). In addition, the marital rates for enlisted personnel (49.8%) and military officers (70.4%) differ from those for working civilians (57.0%) (GAO, 2002). Even more, American military personnel have more formal education than US civilians. Almost all military members (98%) have high school degrees compared to 90% of the civilian labor force and 80% of US civilian men between the ages of 18 and 24 (GAO, 2002; Watkins & Sherk, 2008).

Not everyone in the civilian population is eligible to work in the military. Service members must meet certain health, intelligence, education, and criminal background requirements in order to be eligible to join the military. For example, prior to being accepted to the military, recruits must take the Armed Forces Qualification Tests (AFQT). The AFQT tests four fields of knowledge – Arithmetic Reasoning, Math Knowledge, Paragraph Comprehension, and Word Knowledge. The military rejects at least 75% of applicants with scores in the bottom thirtieth percentile and 100% of applicants with scores in the bottom tenth percentile (Kilburn, Hanser, & Klerman, 1998).

Further, since serving for the military is a full time job, service members are automatically unlike the entire general population which contains both employed and unemployed people. The selection and retention criteria for military personnel make it so that service members are healthier, fitter, and more sober (use alcohol and drugs less frequently) than the civilian workforce population (Carr, 2001).

2.3 Human Error Models and Frameworks

Human error has been defined as a planned sequence of actions that fails to achieve its desired outcome (Reason, 1990). Numerous human error models have been developed to explain the breakdown between expected and actual outcomes. Human error models may be categorized by the perspective in which it was based - cognitive, ergonomic, behavioral, epidemiologic, and psychosocial. The cognitive perspective (Rasmussen, 1982) is based on mental processes. The ergonomic perspective (Edwards, 1988) is focused on aspects of design. The behavioral perspective (Petersen, 2003) is based on responses to external stimuli and the environment. The epidemiologic perspective (Suchman, 1960) is focused on at-risk populations. The psychosocial perspective (Helmreich & Foushee, 1993) is based on the effects of social factors.

Using the original single-faceted perspectives as a foundation, subsequent generations of human error models have taken a multifaceted systems approach to human error. These models assert that accidents are caused by the combination of multiple factors. Human error taxonomies that stemmed from these models include the SCM, SHEL, BeSafe, Wheel of Misfortune, ICAM, and HFACS models.

2.3.1 Swiss Cheese Model (SCM)

James Reason's model of accident causation commonly referred to as the Swiss Cheese Model (SCM), has greatly influenced the way that companies and professionals view human error (Reason, 1990). Reason categorized two types of errors – active and latent. Active errors are acts that result in immediate and observable outcomes. Latent errors are issues that may be present for longer periods of time, providing the opportunity for failures to occur. The SCM captures active and latent errors in a system of planes. Successful integration of the planes provides a safe environment for a productive system. Unsuccessful integration of the layers results in system breakdowns.

So far, Reason has developed three distinct versions of the SCM for various purposes – Mark I, II, and III. Mark I contained five layers of error - four productive planes (decision makers, line management, preconditions, and productive activities) and one destructive plane (defenses). Mark II integrated the defenses into the four productive planes. Mark III depicted SCM more abstractly and provided descriptions of both short-term breaches and long-lasting latent conditions.

Of the three versions of SCM, the structure of Mark II may be most applicable for error classification purposes. Mark II, as seen in Figure 3, has three planes each with areas where the system is protected and areas where the system is susceptible to problems. The planes show individual, task/environment, and organization levels of the system. The individual level relates to the person or people directly involved in an adverse event. Active failures at the individual level involve unsafe acts which may be categorized as errors or violations. The difference between an error and a violation is whether the incorrect selection or execution of an action is intentional (error) or unintentional (violation). The task/environment level relates to mediating conditions "in existence immediately prior or at the time of the incident that directly influence human and equipment performance" (De Landre & Bartlem, 2005). The organization level relates to management decisions, processes, and practices. These latent factors typically are not detected until an incident occurs.

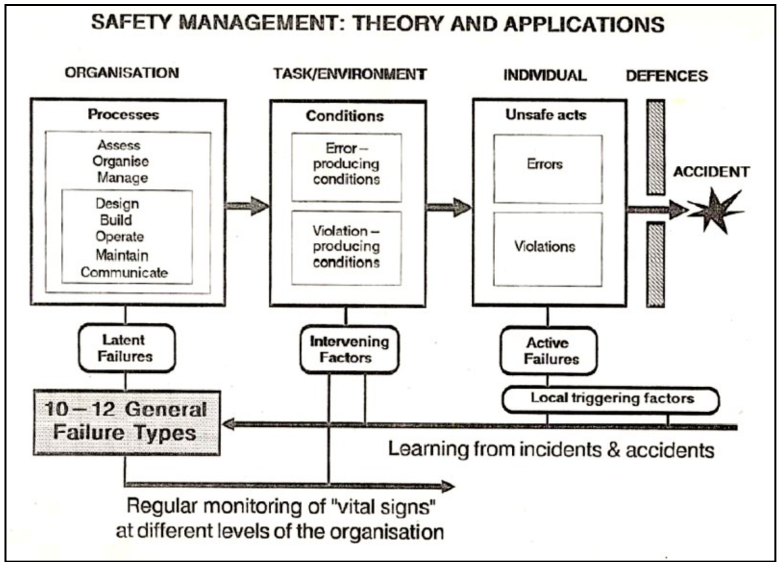

Figure 3: Mark II SCM (Reason, 1990)

2.3.2 Software Hardware Environment Liveware (SHEL) Model

The SHEL model was developed by Edwards (1972, 1988) to identify areas of potential failures in human-machine interactions. The SHEL model, as seen in Figure 4, involves three components (software, hardware, and liveware) that interact with one another within an environment. Software is the non-material aspect, hardware is the technical aspect and equipment, environment is the external influences, and liveware is the human aspect. The original SHEL model focused primarily on the relationships between these components as they relate to man-machine interfaces.

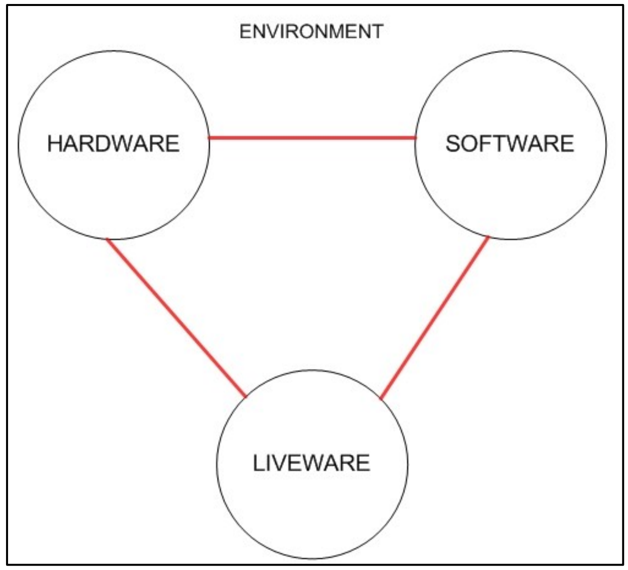

Figure 4: SHEL Model (Edwards, 1988)

2.3.3 Behavioral Safety (BeSafe) Method

The Behavioral Safety (BeSafe) method is a proactive evaluation tool based on Reason's (1990) human error framework created to identify and prevent potential human errors in a system (Benedyk & Minister, 1998). BeSafe, originally Potential Human Error Audits, targets accidents that could result from active failures, latent failures, and violations with a focus on the role of management. Primarily used for product design safety improvement, BeSafe has four main stages – discovery of active failures and violations, evaluation of organizational influences, identification of latent failures, and development of action plans in response to the findings. After determining the latent failures in the system based upon findings from the first three stages, a BeSafe analysis seeks to target these failures with preventative strategies.

2.3.4 Wheel of Misfortune

The Wheel of Misfortune is an abstract framework that can be used as an accident investigation tool (O'Hare, 2000). Drawing from Reason's SCM, Rasmussen's 'Skill-Rule-Knowledge' activities, and Helmreich's sphere model, the Wheel of Misfortune is a system with three levels – local actions, local conditions, and global context depicted as concentric circles as seen in Figure 5 below. The innermost disc represents local actions or the unsafe acts of individuals or teams. The middle disc represents local conditions or the internal and external precipitating task demand, interface, and resource factors. The outer disc represents the global context with recognized and unrecognized hazards related to the organization's philosophies, policies, and procedures.

Figure 5: Wheel of Misfortune (O'Hare, 2000)

2.3.5 Incident Cause Analysis Method (ICAM)

ICAM is a structured approach that allows for systematic safety investigations in different industries (De Landre & Bartlem, 2005; De Landre & Gibb, 2002). ICAM was developed jointly by Dr. James Reason, BHP Billiton, Dédale Asia Pacific, and the

Bureau of Air Safety Investigation (BASI, now part of the Australian Transport Safety Bureau). Some of the objectives of ICAM are to capture the facts, identify the active and latent hazards, gather the findings, and recommend corrective actions. The ICAM approach stresses the importance of not apportioning blame in order to focus on identifying the true issues in the system. The ICAM framework focuses on four main areas that correspond to Reason's Mark I SCM – absent/failed defenses, individual/team actions, task/environmental conditions, and organizational factors.

2.3.6 Human Factors Analysis and Classification System (HFACS)

HFACS is a comprehensive, user-friendly human error framework created by Drs. Scott Shappell and Douglas Wiegmann for use as an accident investigation and data analysis tool (Wiegmann & Shappell, 1997, 2001, 2003). With roots in established human error philosophies, HFACS provides a systematic way to classify the active and latent failures described in Reason's SCM of human error (Reason, 1990). With tiers that map to the layers of human error in the SCM, the HFACS framework defines the holes in the SCM to facilitate its application to accident investigation and analysis in real world operational settings. The four tiers of the HFACS framework are unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences.

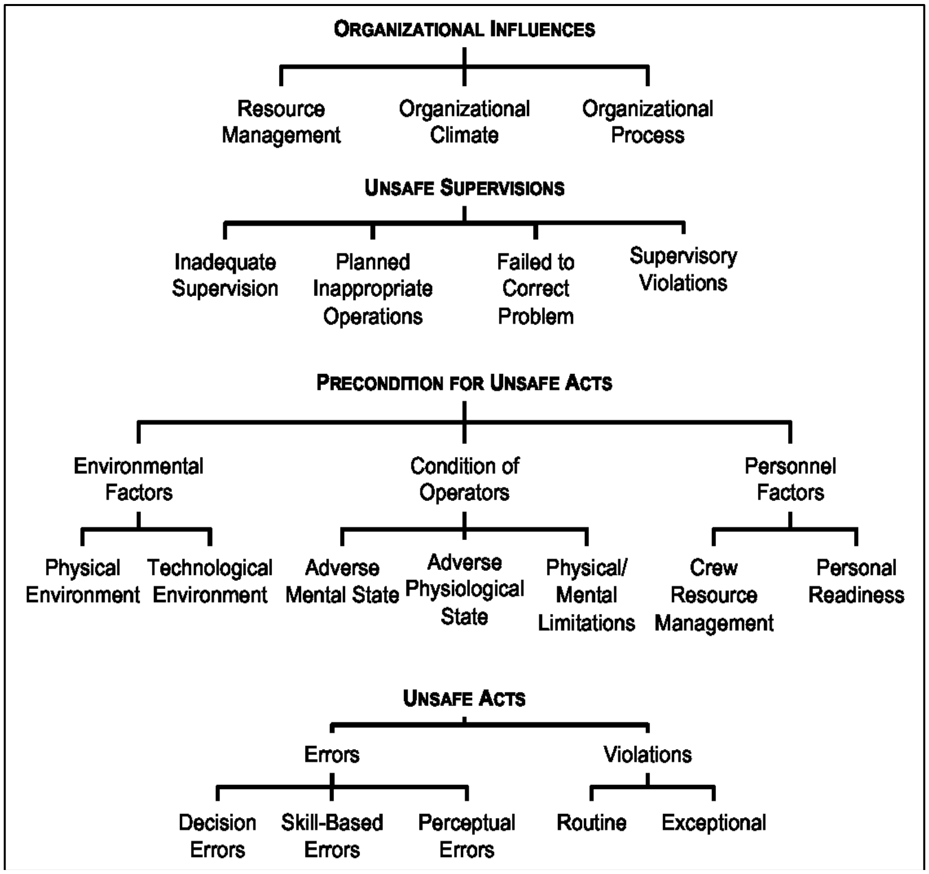

Figure 6: HFACS Framework (Wiegmann & Shappell, 2001)

Unsafe acts are errors (skill-based, decision, and perceptual) and violations that directly result in adverse events. Preconditions are physical, psychological, environmental, and interpersonal factors that affect the ability to perform tasks safely. Unsafe supervision refers to situations in the workplace in which workers are not provided with adequate support to safely complete required tasks. Organizational influences are the decisions by those in the topmost positions within the company related to resources, formal policies and procedures, culture, and climate.

The first tier of the HFACS framework captures the unsafe acts of operators that directly result in an adverse event (e.g. accident, incident, or near miss). There are five categories of unsafe acts in the HFACS-MVC framework in two groups – errors (skill based, decision, and perceptual) and violations (routine and exceptional).

The second tier of the HFACS framework captures the preconditions for unsafe acts relate to factors related to environmental, physical, and physiological conditions that affect performance of operators. The HFACS framework has seven categories of preconditions for unsafe acts in three groups – environmental factors (technical and physical), conditions of the operator (adverse mental states, adverse physiological states, and physical/mental limitations), and personnel factors (personal readiness and communication/coordination).

The third tier of the HFACS framework captures the unsafe leadership factors that may affect operator conditions and environmental factors. There are four categories of unsafe supervision causal factors – inadequate supervision, planned inappropriate operations, failure to correct known problem, and supervisory violations.

The fourth tier of the HFACS framework relates to organizational influences, decisions made by upper-level management that may have an effect on supervisory practices, operator and environmental preconditions, and subsequently the unsafe acts of its personnel. There are three categories of organizational influences – resource management, organizational climate, and organizational process.

Four criteria are especially important for validating a framework – reliability, comprehensiveness, diagnosticity, and usability. The HFACS framework has proven its validity by demonstrating that it meets all four of these criteria.

The first criterion that a framework must meet is reliability. A framework that is reliable as an investigative tool gathers approximately the same findings every time it is used. Estimates for reliability are often based on the results of reliability tests looking at testing various types of reliability such as test-retest, inter-rater, and parallel-forms reliability. Test-retest reliability indicates a framework's ability to gather the same findings consistently over time. Inter-rater reliability indicates a framework's ability to gather the same findings consistently between multiple independent investigators. Parallel-forms reliability indicates a framework's ability to gather the same findings consistently with related findings using other tools and techniques. The most relevant and valuable indicator of reliability for a framework to be used in operational settings by a variety of individuals throughout an organization is inter-rater reliability.

Inter-rater reliability may be measured statistically using Cohen's Kappa coefficient values. Kappa values range from 0.00 to 1.00 with 0.00 indicating no consistency between raters and 1.00 indicating perfect consistency between the raters. The better Kappa values range from 0.60 to 1.00 with scores above 0.60 indicating good consistency between raters, and scores above 0.75 indicating excellent consistency between raters (Fleiss, 1981). Inter-rater reliability Cohen's kappa values have been calculated at the tier and category levels for various domains. Inter-rater reliability was strong for raters applying the HFACS framework to military aviation accidents in the US with a Cohen's kappa of 0.94 (Wiegmann & Shappell, 2001). Inter-rater reliability was also strong for raters applying the HFACS framework to commercial aviation accidents with a Cohen's kappa score of 0.75 (Wiegmann & Shappell, 2001). For raters applying

HFACS to military aviation accidents in the Republic of China's Air Force, inter-rater reliability Cohen's kappa values for each causal category ranged from 0.44 for the lowest categories through 0.83 for the highest category (Li, Harris, & Yu, 2008). Of the 18 causal categories in the original HFACS model, kappa values were lower than 0.60 for only four of the 18 causal categories – one category in the preconditions tier, one category in the supervisory tier, and two categories in the organizational tiers (Li, et al., 2008).

The second criterion that a framework must meet is comprehensiveness. A framework that is comprehensive as an investigative tool captures all the different types of factors associated with an adverse event. With several tiers capturing a breadth of factors, the HFACS framework is able to capture a variety of factors. Within several industrial domains, the HFACS framework has proven to be a taxonomy that can comprehensively identify and address all contributing factors for adverse events.

The third criterion that a framework must meet is diagnosticity. A framework that is diagnostic as an investigative tool identifies trends and causes. With various levels of the framework at the tier, category, subcategory, and causal factor or nanocode, the HFACS framework allows both causes and trends to be tracked. Additionally, these causes and trends can be viewed at various layers of granularity.

The fourth criterion that a framework must meet is usability. A framework that is usable as an investigative tool is able to be transferred from theoretical to practical use. The HFACS framework has shown that is can easily be integrated and accepted for use in operational settings. HFACS has been adapted and modified to apply to a variety of industrial domains.

HFACS was originally designed for use within the USN and USMC to identify and examine common root causes among aviation-related accidents and has since been adopted for widespread use by the US Department of Defense (Belland, Olsen, & Lawry, 2009; O'Connor, 2008; O'Connor, Cowan, & Alton, 2010). Successful HFACS framework extensions and variations for use in industry include the application of HFACS to commercial aviation and general aviation in the US (Detwiler, et al., 2006; Shappell, Detwiler, Holcomb, Hackworth, & Wiegmann, 2007; Wiegmann, et al., 2005; Wiegmann & Shappell, 2001, 2003), civil aviation in India (Gaur, 2005), China (Li, et al., 2008) and Australia (Lenne, Ashby, & Fitzharris, 2008), and military aviation in China, Taiwan, and India (Li & Harris, 2006, 2007; Li, Harris, & Chen, 2007). Similarly, the HFACS framework has been applied to other aviation related fields such as air traffic control (ATC) (Broach & Dollar, 2002; Hanowski, Olson, Hickman, & Dingus, 2006; Scarborough, Bailey, & Pounds, 2005) and operations of unmanned aerial vehicles (UAVs) (Boquet, Detwiler, Roberts, Jack, & Wiegmann, 2004) and remotely-piloted aircraft (Tvaryanas, Thompson, & Constable, 2006). HFACS has also been successfully applied to non-aviation domains including construction (Walker, 2007), petroleum/gas (Aas, 2008), mining (Patterson & Shappell, 2010), maritime (Celik & Cebi, 2009), rail (Baysari, Caponecchia, McIntosh, & Wilson, 2009; Baysari, McIntosh, & Wilson, 2008; Reinach & Viale, 2006) and several areas of healthcare (Elbardassi, Wiegmann, Dearani, Daly, & Sundt, 2007; Maurizio, et al., 2010; Milligan, 2006).

Variations of the original HFACS framework have been created and applied across a range of industries. To accommodate the idiosyncrasies of their target audiences, the HFACS framework is modifiable for even the most minor modifications in order to accommodate the idiosyncrasies of an organization's target audience (Wiegmann & Shappell, 2003). Derivative HFACS frameworks are all based upon the basics of the original HFACS framework. These variations may appear different from the original HFACS framework due to their unique set of nanocode exemplars and modifications to wording conventions used in the model. These differences are negligible with regards to the framework's validation. Derivative HFACS frameworks have successfully been applied in a variety of industries. These derivative frameworks include HFACS-ME for aviation maintenance (Krulak, 2004), HFACS-MI for mining (Patterson, 2009), and HFACS-RR for railroad (Reinach & Viale, 2006).

Berry (2010) analyzed high-level human error trends across a variety of industries and created four sets of HFACS causal category benchmarking standards. Binary HFACS datasets from 17 sources across seven industry types were collected and compared in order to assess the appropriateness of each dataset for use in benchmarking standard calculations. For each of the main HFACS causal categories, statistical two-proportion Z-tests and False Discovery Rate methodology were applied to determine if any of the datasets were atypical and worthy of exclusion from calculations. Four sets of benchmarking standards were created for use in different circumstances (Accident and Near Miss Non-filtered, Accident and Near Miss Filtered, Accident Non-filtered, and Accident Filtered). Accident benchmarking standards sets are appropriate for datasets containing accident cases and lacking near miss cases. Filtered benchmarking standards are appropriate for higher quality datasets containing cases that have been thoroughly investigated, captured, and classified. A typical dataset consisting of accident cases without near miss cases that were not investigated in a consistent or comprehensive manner should be compared to the non-filtered accident benchmarking standards set as captured in Table 5.

Table 5: HFACS Trend Comparison for Off-Duty MVCs and Non-Filtered Accident Benchmarking Standards (Berry, 2010)

HFACS-MVC Category	Off-Duty MVCs %	Main / Secondary Grouping Accident Benchmarking Standards Mean	(LCI, UCI)
Outside Influences	5.4	-----	-----
Organizational Influences			
Organizational Climate	0.3	1.1	(0.2, 2.1)
Organizational Process	0.8	7.6 / 52.0	(4.8, 10.3) / (41.1, 62.9)
Resource Management	0.2	1.9	(0.8, 3.0)
Unsafe Supervision			
Inadequate Leadership	1.0	3.1 / 21.6	(1.5, 4.7) / (13.9, 29.4)
Planned Inappropriate Ops	0.6	3.7 / 22.1	(0.0, 7.4) / (13.6, 30.7)
Failure to Correct Problem	0.5	4.8	(0.5, 9.1)
Leadership Violations	0.1	2.3	(0.0, 4.8)
Preconditions for Unsafe Acts			
Environmental Conditions			
Physical Environment	18.2	41.0 / 13.4	(31.3, 50.7) / (10.4, 16.5)
Technical Environment	4.1	13.6	(7.8, 19.5)
Operator Conditions			
Adverse Mental State	21.5	5.3 / 26.4	(2.9, 7.7) / (24.2, 28.6)
Adverse Physiological State	34.7	1.7	(0.8, 2.7)
Physical/Mental Limitation	12.5	14.0 / 2.9	(7.4, 20.5) / (0.7, 5.1)
Operator Factors			
Comm., Coord., & Planning	4.8	6.9 / 18.8	(4.5, 9.3) / (10.1, 27.5)
Personal Readiness	0.2	1.3 / 10.8	(0.2, 2.4) / (1.9, 19.7)
Unsafe Acts of the Operator			
Skill Based Errors	70.7	64.7	(58.6, 70.5)
Decision Errors	28.8	43.1	(31.5, 54.7)
Perceptual Errors	0.8	5.2 / 32.5	(3.0, 7.3) / (23.6, 41.4)
Violations	54.0	10.5 / 25.0	(5.3, 15.7) / (21.3, 28.7)

2.3.7 Criticisms to Error Frameworks

Supervisory and organizational factors have historically been overlooked. There are a number of reasons that most accident databases contain few or even no supervisory and organizational factors. The higher the tier the harder it is to identify factors. Instead of observable actions or conditions which are clear-cut, these factors are less tangible and involve abstract concepts (Li & Harris, 2006). Investigators may not identify factors at higher levels if the process is disorganized or lacks a clear, comprehensive framework to guide the investigation (Wiegmann & Shappell, 2003). It is important to have good investigators who ask the right questions and a good framework with which it can be captured. Likewise, without good databases, coders may feel that they are inferring too much from the accident report narrative to be able to reliably assign codes at the organizational level (Li & Harris, 2006). Investigators and coders internal to or working for a company may be reluctant to identify factors for fear of reprisal if they make the company look bad (Patterson, 2009). On the flip side, outside personnel who investigate only certain situations (e.g. OSHA) may only look to identify factors that may have a larger breadth within the organization.

Various researchers have identified relationships between factors at various levels of the system for adverse events in different domains. A study comparing fatal and non-fatal mining accidents found that significantly more organizational factors were associated with fatal than with non-fatal accidents (Patterson, 2009). Another study describing relationship between factors identified at each of the HFACS levels concluded that basic relationships exist between organizational factors and factors at the supervisory, precondition, and unsafe act tiers.

Certain domains are more amenable to having factors at the supervisory and organizational levels. For example, it may be relatively straightforward to identify organizational factors in a company where there are clear delineations between people at the organizational level (head honchos), supervisory level (managers), and individual level (worker bees). However, in other domains identifying factors at the higher levels can be more difficult.

Some critics argue that error frameworks like HFACS capture arbitrary factors with no relation to the causes of future events (Dekker & Hollnagel, 2004). By modeling failures as stochastic rather than deterministic, some have deduced that past failures play no role in predicting future failures. While it is true that no one can completely predict the future, it seems plausible that some of the factors that have contributed to adverse events in the past continue to be involved in adverse events in the present and future. Predicting the future is not a perfect science, but to leave the past in the past only ensures status quo.

Critics claim that identifying individual factors oversimplifies the complexity of adverse events. In order to investigate human error, one must identify not only how a person "erred" but also what was happening at the time that made the selected behavior seem like the right choice at the time (Dekker, 2001). Critics maintain that identification of individual factors involved in an adverse event prevents identification of the effects of factor interactions at the heart of the problem. They speculate that factor interactions can be understood only by looking holistically by gathering thick behavioral descriptions for each complex event (Dekker, 2001; Snook, 2002). Ultimately, frameworks like HFACS actually facilitate the investigation, identification, and classification of factors involved in adverse events. Without a framework to ensure consideration of all areas which may have contributed to the event, investigators and researchers may miss factors and experience bias.

Studying traditional demographics provides some insight into operator characteristics, but cannot provide the type of insight necessary for MVC prevention. For instance, research has found the typical driver/rider involved in fatal MVCs to be a young male operating a vehicle at night in a rural area. Unfortunately, knowing this profile does not provide any insight that is easily actionable. In contrast, studying the behaviors that lead to MVCs and the motivations behind these behaviors provide a platform for targeted MVC prevention strategies.

CHAPTER 3: METHODS

3.1 HFACS FOR MOTOR VEHICLE CRASHES (HFACS-MVC)

Using Wiegmann and Shappell's HFACS model as a foundation, the HFACS-MVC framework was created to capture the contributing factors for MVCs in the military. Individual factors in the HFACS-MVC framework were identified by reviewing existing traffic safety literature and subset of military MVC narratives. While the fundamentals of the original HFACS model exist in the HFACS-MVC framework, some modifications were made (Table 6). These modifications affect the categories of the tiers in the model, the categories of unsafe acts in the model, and the perspective from which the model is framed.

Table 6: Causal Factor Components for HFACS and HFACS-MVC

	# Tiers	# Categories	# Nanocodes
HFACS	4	18	N/A
HFACS-MVC	5	19	

3.1.1 HFACS-MVC Framework

HFACS-MVC has five tiers – the four tiers of the original HFACS model (unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences) plus an additional tier (outside influences). Factors within three tiers (unsafe acts, preconditions for unsafe acts, and outside influences) are specific to the road user domain. Factors in the remaining two tiers, unsafe supervision and organizational influences, are more generic across a variety of domains. The basic framework of HFACS-MVC is presented in Figure 7. The full framework of HFACS-MVC with causal factor categories, subcategories, and nanocodes can be referenced in Appendix B.

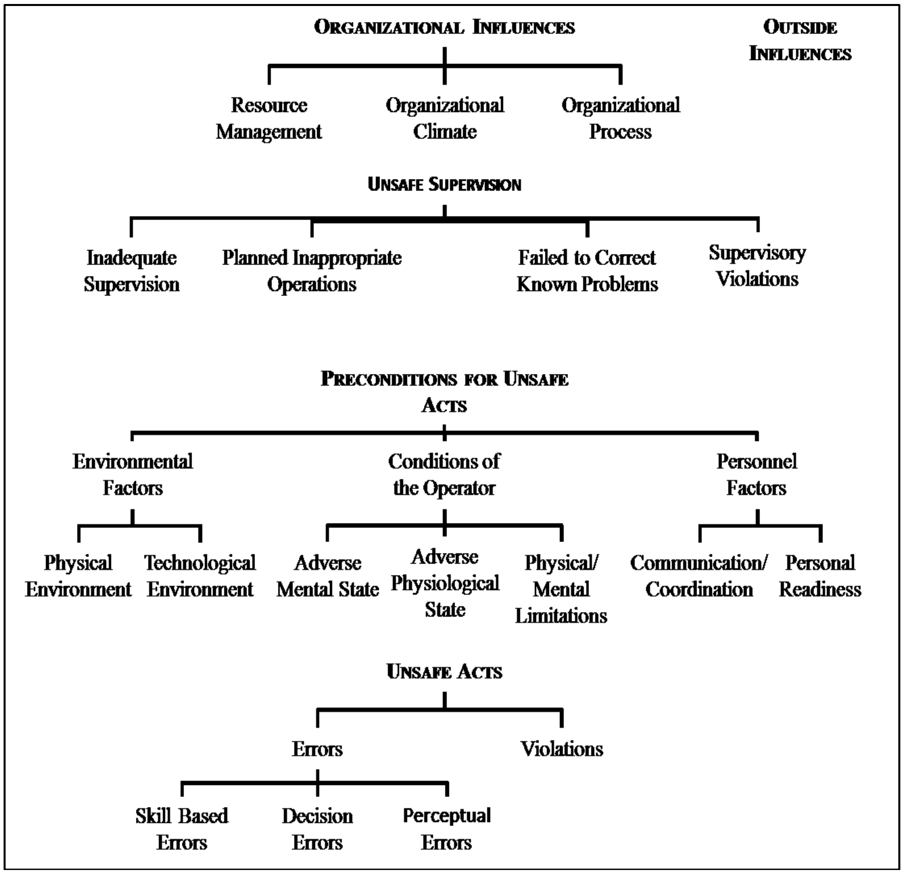

Figure 7: HFACS-MVC Framework

To focus on preventing severe personal MVCs affecting military personnel, HFACS-MVC is framed from the perspective of off-duty service members operating personal motor vehicles on the road. The unsafe acts and preconditions for unsafe acts are specific to the individual service members driving or riding motor vehicles. The supervisory factors are the acts of military personnel serving in leadership roles overseeing these service members driving or riding motor vehicles. The organizational factors are the influences of the military as an organization that employs the aforementioned service members. Outside influence factors capture the instances where MVCs occur due to no fault of the military motor vehicle operator. Detailed descriptions of these tiers are provided in a subsequent section.

At the unsafe acts tier, HFACS-MVC has four factor categories instead of the original five. Typically, HFACS frameworks have two distinct categories of violations for routine and exceptional violations. Differentiating between the two types of violations can be difficult increasing the potential for error during classification. Consider reading a narrative for a MVC which lists excessive speed (85 mph in a 65 mph zone) as a causal factor. Is this a routine or an exceptional violation? Turns out, it could be either. Additionally, exceptional violations, by definition, are rare, isolated events that cannot be predicted; as such, classifying a violation as routine or exceptional may not provide additional benefit in its prevention. To minimize unnecessary effort and prevent error, both violation types are captured in a single violations category in HFACS-MVC.

Unsafe Acts of the Operator

Unsafe acts refer to actions of a motor vehicle operator that directly precede and result in a MVC. The first tier of the HFACS-MVC framework captures the unsafe acts of motor vehicle operators in four causal categories (Table 7). The four categories of unsafe acts in the HFACS-MVC framework are skill based errors, decision errors, perceptual errors, and violations.

Table 7: Brief Descriptions of Unsafe Acts Causal Categories

UNSAFE ACTS
Errors
Skill Based Errors: These "doing" errors represent highly practiced behavior that occurs with little or no conscious thought. These errors frequently appear as breakdown in visual scan patterns, inadvertent activation/deactivation of switches, forgotten intentions, and omitted items in checklists often appear.
Decision Errors: These "thinking" errors represent conscious, goal-intended behavior that proceeds as designed, yet the plan proves inadequate or inappropriate for the situation. These errors typically manifest as poorly executed procedures, improper choices, or simply the misinterpretation and/or misuse of relevant information.

Perceptual Errors: These errors arise when sensory input is degraded as is often the case when operating a vehicle at night, in poor weather, or in otherwise visually impoverished environments. Acting on imperfect or incomplete information, drivers and riders run the risk of misjudging distances, rates, or incorrectly responding to visual illusions.

Violations

Violations: These intentional acts represent bending or breaking of established rules and regulations. Violations include habitual, rule-bending condoned by the organization as well as isolated, atypical rule-breaking not tolerated by the organization.

Skill Based Errors. Skill based errors are "doing" errors where highly practiced behaviors are inadequately performed. The error occurs not in the selection of a behavior but in its execution. The four general categories of skill based errors are attention failures, postural errors, technique errors, and timing errors. One example of a skill based error is a driver trying to answer his cell phone who fails to notice that the traffic light has turned red. Another example is a driver who drifts off the road inadvertently and reacts by jerking the steering wheel too hard in the opposite direction without thinking.

Decision Errors. Decision errors are "thinking" errors where an operator selected a behavior that proves to be inadequate. Here, the error occurs in the selection rather than in the execution of a behavior. The six general categories of decision errors are information processing, planning, prioritizing, situational assessment, procedural and vehicular. One example of a decision error is a person riding his motorcycle who fails to adjust his behavior when it starts to rain and starts to coat the road surface. Another example is a person chooses to pass another vehicle a bad point in the road.

Perceptual Errors. Perceptual errors are errors that occur due to degraded sensory input. This is often the case when operating a vehicle at night, in poor weather, or in otherwise visually impoverished environments. In situations with imperfect or incomplete information, operators run the risk of misjudging distances, rates, or incorrectly responding to visual illusions. For instance, an example of a perceptual error is a motorcycle rider whose vision is impaired by glare causing him to misread the sign for the exit. Another example is a driver whose perception of a single light on an unlit road at night leads her to misjudge the distance between her vehicle and the motorcycle in front of her.

Violations. Violations are conscious decisions to bend or break existing rules and regulations. Some violations are habitual and condoned by management while other violations are isolated occur with extreme rarity. The two general categories of violations are procedural and knowledge related. Speeding, or travelling above the posted speed limit, is a violation whether it's by five or 45 miles per hour. Operating a vehicle without proper licensure such as a valid driver's license or motorcycle endorsement is also a violation.

Preconditions for Unsafe Acts

Preconditions for unsafe acts are the surrounding environment, conditions of the operators, and road user factors that affect performance. The HFACS-MVC framework has seven categories of preconditions for unsafe acts (Table 8). There are two categories of environmental factors – technological environment and physical environment. There are three categories of factors related to conditions of the operator – adverse mental states, adverse physiological states, and physical/mental limitations. There are two categories of personal and interpersonal factors for road users – personal readiness and communication/coordination.

Table 8: Brief Descriptions of Preconditions for Unsafe Act Causal Categories

PRECONDITIONS FOR UNSAFE ACTS
Environmental Factors
Physical Environment: Issues related to both the operational and ambient environment such as visibility due to fog, rain, lighting, and road surface conditions.
Technological Environment: Issues related to manmade items in the environment such as the design and condition of the vehicle, roads, signs, medians, and safety devices.
Conditions of the Operator
Adverse Mental States: Acute psychological and/or mental conditions that negatively affect performance such as mental fatigue, pernicious attitudes, and misplaced motivation.
Adverse Physiological States: Acute medical and/or physiological conditions that preclude safe operations such as illness, intoxication, and the myriad of pharmacological and medical abnormalities known to affect performance.
Physical/Mental Limitations: Permanent physical/mental disabilities that may adversely impact performance such as poor vision, lack of physical strength, mental aptitude, general knowledge, and a variety of other chronic mental illnesses.
Operator Factors
Personal Readiness: Activities performed prior to operating the vehicle required to perform optimally on the road such as obtaining adequate sleep, limiting the effects of alcohol, and other preparatory activities.
Communication, Coordination, and Planning: Poor coordination/communication between road users (vehicle operators, passengers, bicyclists, pedestrians) and planning prior to operating the vehicle.

Physical Environment. Physical environment refers to factors in the operational and ambient environment surrounding the operator that affect performance. The two general categories of physical environment are visibility (due to weather or lighting) and road surface condition. Take a driver who encounters heavy fog which prevents her from seeing a vehicle merging into his lane. Or consider a rider who encounters gravel on the road causing him to lose traction.

Technological Environment. Technological environment refers to factors in the manmade and technological environment surrounding the operator that affect performance. The three general categories of technological environment are vehicle condition, road design, and protective devices on the road. One example is a driver whose brakes fail causing her to rear-end the vehicle in front of her. Another example is a rider who ends up on a portion of the highway with excessive curves because the road hazards were not pre-empted by any warning signs.

Adverse Mental State. Adverse mental state refers to mental conditions of the operator that affect performance. The four general adverse mental state categories are psychology (e.g. risk-taking personality), attitude (e.g. stressed), awareness (e.g. inattention), and drowsiness (e.g. sleepy but not asleep). One example of an adverse mental state factor is a distracted driver trying to type a text message who ends up running a red light without realizing. A second example is a rider, agitated and stressed after fighting with his fiancée, who takes out his aggression by riding aggressively.

Adverse Physiological State. Adverse physiological state refers to temporary medical and physiological conditions of the operator that affect performance. These are not permanent states, but may last several hours or even several days. The four general categories of adverse physiological states are physiological condition, medical condition, physical fatigue, and incapacitation. An example of an adverse physiological state factor is a person who falls asleep while driving causing the car to drift into oncoming traffic. Another example is a person riding his motorcycle under the influence of alcohol who is unable to negotiate a sharp curve in the road.

Physical/Mental Limitation. Physical/mental limitation refers to occasions where a person's physical or mental abilities are insufficient for adequate driving or riding performance. The three general physical/mental limitation categories are mental limitations, physical limitations, and sensory deficiencies. For the most part, physical/mental limitation factors may be thought of as conditions diagnosable by a physician, such as a chronic back problem. For example, a person suffering from sleep apnea who experiences difficulty staying awake while driving. One major exception to this generalization relates to a lack of sufficient knowledge for reasons such as inadequate training or lack of exposure or experience. For example, a person riding a motorcycle for the first time who applies too much pressure on the rear brake and sends the motorcycle into a skid.

Personal Readiness. Personal readiness relates to situations where people are physically or mentally unprepared for the safe operation of a motor vehicle. Activities performed or omitted before operating a vehicle can have detrimental effects on driving or riding performance. Take, for example, a person who decides to drive over 500 miles home for Thanksgiving with a terrible hangover. Or consider someone who heads off to the beach to watch the sunrise after staying up with friends until 03:00 in the morning.

Communication, Coordination, and Planning. This category relates to inadequate communication and coordination between various road users as well as planning carried out prior to getting on the road. For instance, a motorcycle rider who misinterprets gestures from a truck driver as meaning that the adjacent lane was clear of traffic when the truck driver is trying to convey his intent to yield right of way to the rider. Another example of a communication/coordination factor is a driver who enters the left lane ahead of another driver on the road without signaling.

Unsafe Supervision

Unsafe supervision relates to the effect of leadership on operator conditions and environmental factors. There are four categories of unsafe supervision causal factors – inadequate supervision, planned inappropriate operations, failure to correct known problem, and supervisory violations (Table 9).

Table 9: Brief Descriptions of Unsafe Supervision Causal Categories

UNSAFE SUPERVISION
Inadequate Supervision: Oversight and management of personnel and resources including training, professional guidance, and operational leadership among other aspects.
Planned Inappropriate Operations: Management and assignment of work including aspects of risk management, crew pairing, operational tempo, etc.
Failure to Correct Known Problem: Instances where deficiencies among personnel, equipment, training, or other related safety areas are "known" to the supervisor yet are allowed to continue uncorrected.
Supervisory Violations: The willful disregard for existing rules, regulations, instructions, or standard operating procedures by management during the course of their duties.

Inadequate Supervision. Inadequate supervision relates to the failure of leadership to provide its personnel with adequate and appropriate training, guidance, resources, and oversight. An example of an inadequate supervision factor is a supervisor who fails to provide adequate information to her service members about motorcycle training courses offered through the military.

Planned Inappropriate Operations. Planned inappropriate operations relate to the improper management of personnel by leadership. Inappropriate operations include poor project planning and scheduling of personnel. While acceptable during emergency situations, these plans are inadequate for normal non-emergency situations. An example of a planned inappropriate operations factor is a supervisor who creates a schedule assigning one of his service members to the early shift without considering that he and his wife have a newborn baby at home.

Failure to Correct Known Problems. Failure to correct known problems relates to inadequate correction by leadership of hazards and deficiencies known to affect its personnel. An example of a failure to correct factor is a supervisor who learns of his service members recent struggles with alcohol but does nothing to intervene.

Supervisory Violations. Supervisory violations relate to the willful disregard of an organizations rules and regulations by people in leadership positions. An example of a supervisory violation factor is a supervisor who is aware of shift-rest schedule regulations but decides to not abide by them when creating work schedules for her service members.

Organizational Influences

Organizational Influences. Organizational influences relate to the effects that decisions made by upper-level management have on supervisory practices, operator and environmental preconditions, and unsafe acts of its personnel. There are three categories of organizational influences – resource management, organizational climate, and organizational process (Table 10).

Table 10: Brief Descriptions of Organizational Influences Causal Categories

ORGANIZATIONAL INFLUENCES
Resource Management: How an organization manages its human, monetary, and equipment resources.
Organizational Climate: Prevailing atmosphere/vision within the organization including such things as policies, command structure, and culture.
Organizational Process: Formal process by which the vision of an organization is carried out including operations, procedures, and oversight among others.

Resource Management. Resource management relates to decisions made at the highest levels regarding the allocation and maintenance of organizational assets. Budget cuts, common in times of economic difficulty, can amplify these resource issues. An example of a resource management causal factor is an organization that replaces its full day training program with a cursory online module in an attempt to save money.

Organizational Climate. Organizational climate relates to an organization's policies both explicit and tacit that can set the stage for adverse events. An example of an organizational climate factor is an organization whose culture captured by Rear Admiral Grace Murray Hopper's quote "it's always easier to ask forgiveness later than it is to get permission" (Williams, 2004).

Organizational Process. Organizational process relates to the manner in which standard operating procedures are established, updated, and followed within an organization. An example of an organizational process factor is an organization without any formal process in place for updating established standard operating procedures as changes occur.

Outside Influences

Outside Influences. Outside influences captures MVCs that occur completely outside the control of a military road user that often result from unsafe behaviors of other road users completely outside the control of a military operator. An example of an outside influence factor is a service member struck head-on on his way home from work by a drunk driver travelling in the opposite direction of traffic.

3.1.2 HFACS-MVC Training

Becoming an HFACS-MVC specialist involves an extensive amount of training and experience in applying human factors principles to the management of human error. Expertise as an HFACS specialist and Certified HFACS Professional are prerequisites for becoming an HFACS-MVC specialist.

First, the specialists learned to use HFACS for accident analysis purposes. As such, the specialists participated in the Basic HFACS Training Workshop taught by the original creators of HFACS, Drs. Shappell and Wiegmann. During this intensive two-day course, HFACS specialists were taught how to use the HFACS framework to identify and manage human error. To gain proficiency, the specialists coded several sets of potential causal factors from different domains such as driving. A few of these are captured in Table 11; a complete set is provided in Appendix C. They also coded several sets of actual cases using real-world data.

Table 11: HFACS Category Coding Samples

Causal Factor	HFACS Category
While waiting to turn onto the highway, a driver started to inch forward when he saw an oncoming truck in the right lane of traffic. He tried to stop the vehicle, but accidentally hit the gas instead forcing the truck to swerve to avoid a collision.	Skill Based Error
The driver drove 10 to 15 mph over the posted speed limit on the highway.	Violation
The driver was physically impaired after going out for a few drinks.	Adverse Physiological State
Though considered an authority figure, an officer drove his police vehicle faster than the posted speed limit and did not signal before changing lanes.	Supervisory Violation
The state did not allocate adequate funding for road maintenance or sufficient highway patrol.	Resource Management

Then, the HFACS specialists became certified as HFACS professionals. Certified HFACS professionals must demonstrate advanced knowledge and skills using HFACS by passing a comprehensive written exam, applying HFACS to a practical real-world situation, and submitting a sample HFACS work product.

Finally, the HFACS professionals were trained to use the HFACS-MVC taxonomy. HFACS-MVC specialists became familiarized with the HFACS-MVC framework and nanocode guide (Appendix B). The HFACS-MVC nanocodes are arranged by causal category starting at the unsafe act level. To code a causal factor using the guide, go to the section containing the appropriate HFACS-MVC causal factor category, select the appropriate subcategory, and find the desired causal factor. The nanocode is the subcategory abbreviation followed by the number assigned the particular causal factor.

Training to be HFACS-MVC specialists was similar to the HFACS specialist training. Samples of causal factors specific to MVCs were again coded, this time at the nanocode level using the HFACS-MVC framework and nanocode guide. A few of these causal factors are captured in Table 12; a complete set is provided in Appendix D. The HFAC-MVC specialists also coded several complete MVC cases using real-world data.

Table 12: HFACS-MVC Nanocode Coding Samples

Causal Factor	HFACS-MVC Category	HFACS-MVC Nanocode
While waiting to turn onto the highway, a driver started to inch forward when he saw an oncoming truck in the right lane of traffic. He tried to stop the vehicle, but accidentally hit the gas instead forcing the truck to swerve to avoid a collision.	Skill Based Error	ATT4 Inadvertent operation of wrong control
The driver travelled 10 to 15 mph over the posted speed limit on the highway.	Violation	VPRO1 Speeding 10-19 mph over the speed limit
The driver was physically impaired after going out for a few drinks.	Adverse Physiological State	PC2 "Impairment due to drugs or alcohol"
Though considered an authority figure, an officer drove his police vehicle faster than the posted speed limit and did not signal before changing lanes.	Supervisory Violation	SV
The state did not allocate adequate funding for road maintenance or sufficient highway patrol.	Resource Management	RM

3.2 Military MVC Data

The military is supported by service-specific safety centers that focus on mishap prevention. Each safety center is responsible for maintaining a mishap reporting system and database for its service members. The Naval Safety Center (NSC) at Norfolk Naval Base in Norfolk, Virginia maintains the online reporting system for USN and USMC mishaps. The Air Force Safety Center (AFSC) at Kirtland Air Force Base in Albuquerque, New Mexico maintains the online reporting system for USAF mishaps.

Among the records maintained at the safety centers are those for severe (Class A and Class B) off-duty mishaps.

Over the past decade, the NSC has actually maintained two mishap reporting systems – Safety Information Management System (SIMS) and Web Enabled Safety System (WESS). Mishaps were initially reported through SIMS. However, with limited functionality for exporting data and reporting results, SIMS was replaced with a new system, WESS available for use starting in 2002 (DoD, 2001; "US Naval Safety Center Selects JReport 6," 2003). In 2004, NSC required that WESS be the exclusive mishap reporting system used for all USN and USMC mishaps. WESS contains fields for investigators to capture narrative summaries, contributing factors (personnel, roadway, environmental, vehicular, and event), and related recommendations. With both SIMS and WESS, NSC personnel review each report submitted for USN and USMC Class A and B mishaps and assign all applicable causal codes. The list of applicable causal codes may be referenced in the glossary of the Navy and Marine Corps Mishap and Safety Investigations Manual (DoN, 2005). The AFSC has maintained the mishap reporting system Air Force Safety Automated System (AFSAS) for many years. AFSAS contains fields for investigators to enter mishap details, record narrative synopses, indicate contributing causal and non-causal factors (personnel, roadway, environmental, vehicular, and event), and submit recommendations.

3.2.1 Data from Safety Centers

Based on the scope of the research, the populations of interest included all USN, USMC, and USAF cases where service members were victims of severe (Class A/B) off-duty MVC mishaps. With specific interest in 2W and 4W off-duty MVCs, mishaps involving service members as pedestrians (e.g. joggers, post-crash outside vehicle) or riders of bicycles or all-terrain vehicles were excluded from this study. The specific parameters for MVC demographic and narrative mishap data requested from the respective safety centers are presented in Table 13.

Table 13: Data Requested from Safety Centers

Data	Content
Population of Interest	USN, USMC, and USAF cases where service members were victims of severe (Class A/B) off-duty MVC mishaps
Requested Cases	Demographic and narrative data fields for the following cases: • Mishap Severity: A/B • Duty Status: Off-duty • Accidental Death Type: MVC • Vehicle Type: 2W/4W • Position of Service Member: Operator
Eliminated Cases	Service members acting as passengers, pedestrians, bicyclists, and riders of all-terrain vehicles Narratives containing insufficient detail

Upon completion of all appropriate services' documentation, the safety centers provided both quantitative (personnel, roadway environment, vehicle, and event demographics) and qualitative (narrative) information for each mishap stripped of any personal identifiers such as names and social security numbers to maintain the privacy of mishap victims. Sample mishap narratives from several MVCs are presented in Appendix E.

Demographic data were provided for each service as individual worksheets in separate Microsoft Excel files (Table 14). The USAF narratives were provided as individual Microsoft Word files with one document per case. Narratives for the USN and USMC were provided in two Notepad text files, one for each of the military services.

Unfortunately, the USMC data was limited in that only four years of cases were provided and the demographic file lacked data related to service member ages and paygrades.

Table 14: Data Provided by Safety Centers

Content	File Type	File Created	Dates Queried
USAF demographics	Microsoft Excel 97-2003 Worksheet (.xls)	2/02/2010	10/01/1998 – 9/30/2008
USAF narratives	Microsoft Word 97-2003 Document (.doc)	11/23/2009	
USN demographics	Microsoft Excel 97-2003 Worksheet (.xls)	6/27/2008	10/01/1999 – 5/30/2008
USN narratives	Text Document (.txt)	6/26/2008	
USMC demographics	Microsoft Excel 97-2003 Worksheet (.xls)	6/27/2008	10/01/2004 – 3/15/2008
USMC narratives	Text Document (.txt)	3/25/2008	

3.2.2 Data for Coders

The datasets provided by the NSC were modified prior to classification with HFACS-MVC. The demographic and narrative data for 1300 MVC cases were provided by the safety centers. The datasets provided contained all mishaps resulting in severe injury or death of any service member, regardless of his/her seating position (operator/passenger). With a focus on preventing military losses from MVCs, cases where service members acted as passengers in or on vehicles were eliminated. After eliminating these cases, there were 1161 off-duty MVCs available for classification – 474 USAF, 517 USN, and 171 USMC. The USAF cases occurred between October 1998 and September 2008. The USN cases occurred between October 1999 and May 2008. The USMC cases occurred between October 2004 and March 2008.

3.3 Data Classification

Data classification was conducted by eight HFACS-MVC specialists in teams of two. The coders were students in the Industrial Engineering department at Clemson University – four were undergraduate students and four were doctoral students with a concentration in Human Factors. All coders were highly trained in using HFACS and had extensive experience coding hundreds of cases from multiple domains with varying degrees of detail.

Teams of coders generally classify cases with an HFACS framework using one of two methods – the arbitration method and the consensus method (Berry, 2010). Early HFACS studies typically used the arbitration method where a pair of experts classified each case independently and a third expert arbitrated any discrepancies. More recently, HFACS studies have increasingly gravitated towards using the more efficient consensus method in which two or more experts classify cases together. If disagreements arise during coding, the experts discuss the situation until they are able to reach a consensus. Previous studies have demonstrated high levels of inter-rater reliability for the HFACS causal categories (Shappell, et al., 2007; Shappell & Wiegmann, 2004; Wiegmann, et al., 2005; Wiegmann & Shappell, 2001, 2003). Furthermore, the consensus method fosters a shared understanding among the experts improving the consistency between experts at the nanocode level of detail. As such, the coders used the consensus method to classify the MVC mishaps in teams of two or three.

For each MVC, a team of coders read the narrative, determined its causal factors, and determined the appropriate nanocode for each factor using the HFACS-MVC framework and nanocode guide. Suppose a team read a case where a service member was unable to negotiate a curve due to his speed (90 mph in a 65 mph zone) and crossed over the center lane into oncoming traffic. Looking at the HFACS-MVC causal categories at the unsafe acts level, the coders would identify the service members speeding as a violation and his inability to safely negotiate a curve as a skill based error. Looking at the HFACS-MVC causal factor nanocodes, the coders would identify speeding as a procedural violation, specifically a VPRO2 “Speeding 20-29 mph over the speed limit” and the skill based error as a technique error, specifically a TQ7 “Failed to negotiate curve/turn/bend/ramp.” Whenever any debate arose as to whether a causal factor was a decision error or violation, the coders erred on the side of caution and classified these ambiguous factors as decision errors rather than as violations.

Initially, the coders were unsure how to classify the four main factors related to alcohol, drunk driving, buzzed driving, alcoholism, and driving with a hangover. The teams classified drunk driving using two codes – one in the unsafe acts tier (violation for drinking and driving – VDD) and one in the preconditions tier (physical condition for impairment due to alcohol – PC2). The teams used the latter precondition code, PC2 to classify buzzed driving, interpreted for this study as having positive blood alcohol content under the legal limit of 0.08%. Both alcoholism and hung over were classified with codes in the preconditions tier. The teams classified alcoholism as a physical/mental limitation factor (PMO) and hung over as a personal readiness factor (PR4).

Inevitably, not every case could be classified. Some narratives lacked adequate description or sufficient detail due to poor documentation practices. A narrative capturing only the paths travelled by vehicles involved in a MVC prior to collision from an aerial perspective or a narrative focusing on events post-MVC may prove inadequate for identifying the behaviors and conditions of the human operators. Other narratives were omitted completely due to the nature of the MVCs. It is not always possible to determine the chain of events leading up to a MVC, especially for single-vehicle crashes without passengers or witnesses.

3.4 Data Analyses

Data analyses were performed using Microsoft Excel 2010 and Minitab 16 Statistical Software. To determine the overall HFACS-MVC trends for the population, data were coded and organized using Microsoft Excel 2010. A master file was created that consolidated the Microsoft Excel files from the various branches of the military. Cases with only an outside influence causal factor were deleted; cases with an outside influence and at least one service member causal factor were retained. The presence or absence of a causal factor for each of the 19 HFACS-MVC categories was indicated with a binary variable of 0 (no causal factor from that category) or 1 (at least one causal factor from that category).

To compare the HFACS-MVC trends between subsets of the population, data were analyzed using Minitab 16 Statistical Software. First, a Chi-Square statistical test was performed to identify the existence of significant differences between subsets. If the Chi-Square statistic was significant, Odds Ratio statistical tests was performed to determine the direction and magnitude of significant difference(s).

3.4.1 Variables of Interest

This study looked at the relationships between each of four independent variables and one dependent variable (Table 16). Both the independent (vehicle type, service, paygrade, and age) and dependent (number of cases involving factors from each HFACS-MVC causal factor category) variables were categorical. Vehicle type reflected whether the military operator was riding a 2W or driving a 4W motor vehicle at the time of the MVC. Service reflected whether the military operator served as a member of the United States Air Force, Navy, or Marine Corps. Rank reflected whether the military operator served as an enlisted service member or as an officer. Age group reflected the age of the military operator was at the time of the MVC in one of six groups (17-20, 21-25, 26-30, 31-35, 36-40, or >40).

Table 15: Research Variables

Independent Variable	Variable Levels	Dependent Variable
Vehicle Type	2W, 4W	Number of cases with HFACS-MVC causal categories and nanocodes
Service	USAF, USN, USMC	
Rank	Enlisted, Officer	
Age Group	17-20, 21-25, 26-30, 31-35, 36-40, >40	

The six age groups selected for the present study were based on those for prior MVC studies. The age group sets used in prior MVC studies in the general population by NHTSA, the USAF population by Carr and Markopoulos are presented in Table 17. NHTSA provides information related to the vehicle occupants killed in fatal US MVCs such as age in its FARS database. Not including occupant age groups younger than 16 years of age, who were assumed to be passengers based on age restrictions for licensure, there are eight FARS age groups. The age groups used in the two USAF MVC studies by Carr and Markopoulos reflect the younger demographic of the US military with upper limits of 40 and 50 years of age compared to an upper limit of 74 years of age from FARS for the general US population.

Table 16: Comparison of Age Groups Used in MVC Studies

NHTSA FARS	USAF (Carr, 2001)	USAF (Markopoulos, 2009)	USAF, USN, USMC Present Study
16-20	17-20	17-25	17-20
21-24	21-25	26-30	21-25
25-34	26-30	31-35	26-30
45-54	31-35	36-40	31-35
55-64	36-40	>40	36-40
65-74	41-45		>40
>74	46-50		
Unknown	>50		

Contingency tables may be used to present the relationships between two categorical variables in matrix format with *r* rows and *c* columns with *r***c* cells. For this dissertation, the independent variables will be presented across the rows and the dependent variable will be presented down the columns. The individual cells contain counts for cases where a particular causal factor category was present or absent. The following 2x2 contingency table (Table 18) presents the relationship between vehicle type and number of cases with at least one violation.

Table 17: Sample Contingency Table

	HFACS-MVC Causal Category	(e.g. Violation)
Vehicle Type	Absence of Causal Category	Presence of Causal Category
2W	a	b
4W	c	d

Hypothesis testing for each independent variable compares the observed and expected values for each HFACS-MVC causal category at the different variable levels. The observed values represent the actual data while the expected values represent theoretical data where there are no differences between variable levels. The general null (H_0) and alternate (H_1) hypotheses are as follows:

$$H_0: \ O_i = E_i \text{ for all levels}, i$$

$$H_1: \ O_i \neq E_i \text{ for at least one level}, i$$

where O_i is the observed value and E_i is the expected value for variable level, i

3.4.2 Pearson's Chi-Square (χ^2)

Pearson's Chi-Square (χ^2) Test for Independence (Equation 1) is a nonparametric test that compares the distributions for two categorical variables using frequencies. It basically addresses whether the two variables in a contingency table are statistically related to one another (Scanlan, 2007). The null hypothesis for the Chi-Square Test for Independence assumes statistical independence between the independent variable (e.g. 2W, 4W) and dependent variable (causal factor patterns). The alternate hypothesis (H_1) states that there is a statistical relationship of the causal factor patterns between variables. In other words, different levels of the independent variable exhibit similar causal factor patterns. To determine the relationship between the independent and dependent variables of interest, the Pearson's Chi-Square Test of Independence was conducted at a significance level of p=0.05.

Equation 1: Pearson's Chi-Square (χ^2) Test of Independence

$$\chi^2 = \sum_{i=1}^{k} \left[\frac{(O_i - E_i)^2}{E_i}\right] \qquad v = k - p - 1 \qquad \chi_i \sim G, \ E_i \geq 5$$

Pearson's Chi-Square Test of Independence has two underlying assumptions: (1) sample is randomly selected and (2) expected frequencies are sufficiently large ("Electronic Statistics Textbook," 2011). To prevent the occurrence of Type II errors, sample sizes should meet expected cell count requirements or have the ability to be corrected using a statistical correction. For small (2x2) tables, the minimum expected count requirement for each cell is five. If the minimum expected count requirements are not met, statistical corrections such as Yates' correction or Fisher's exact test should be applied (McDonald, 2009). For small (2x2) tables, Fisher's exact should be used with small sample sizes (<1000) while Yates' correction should be used with large sample sizes (≥1000). For larger tables, the minimum expected count requirement is five for 80% of the cells and zero for none of the cells. For larger tables, an exact test or a randomized test should be used with small sample sizes (<1000) while no correction should be used for large sample sizes (≥1000).

3.4.3 Odds Ratio (OR)

While the Pearson's Chi-Square Test of Independence determines whether two variables are statistically related, it does not quantify this relationship. For determining the direction and strength of relationships between two categorical variables, the Odds Ratio (OR) descriptive statistic may be used. The odds ratio is a measure of effect size that compares the likelihood of a binary outcome for two or more levels of a categorical independent variable. Odds ratios are used with categorical independent variables and binary dependent variables.

To illustrate the basic concepts behind the odds ratio, a sample (2x2) contingency table is presented below with marginal totals for the variable levels and the grand total (Table 19). The independent variable, vehicle type, is in the rows and the dependent variable, HFACS-MVC causal category, is in the columns. The odds ratio for these variables compares the likelihood that a case contains a violation for 2W and 4W vehicle operators.

Table 18: Sample Contingency Table with Marginal and Grand Totals

	HFACS-MVC Causal Category - Violation		
Vehicle Type	Absence	Presence	Total
2W	a	b	a+b
4W	c	d	c+d
Total	a+c	b+d	a+b+c+d

Using the notations from the sample contingency table above, the odds ratio descriptive statistic is presented in Equation 2. Possible values for the odds ratio are rational values between zero and infinity with a neutral value of one (Declerq, 2001). When the odds ratio is equal to one, the outcome is equally likely for both levels of the independent variable. When the odds ratio is greater than one, the outcome is more likely for that level of the independent variable. When the odds ratio is less than one, the outcome is more likely for that level of the independent variable.

Equation 2: Odds Ratio (OR) Descriptive Statistic

$$OR = \frac{a/b}{c/d} = \frac{ad}{bc}$$

An odds ratio only looks at two levels for both the independent and dependent variables. To use the odds ratio statistic for an independent variable with three or more levels, each level may be captured in multiple (2x2) contingency tables and the odds ratios for each table should be calculated (Uebersax, 2006). For example, an independent variable with three levels would calculate the odds ratio for three separate (2x2) contingency tables.

CHAPTER 4: RESULTS, DATA AND OVERALL TRENDS

The military safety centers provided a total of 1300 Class A and B off-duty MVC cases that occurred between October 1999 and March 2008 (Table 20). Of these cases, 1161 involved military service members as motor vehicle operators. About one-fourth of the cases provided were eliminated from the dataset prior to analyses. Excluded cases were caused exclusively by sources external to the service member (lacked at least one unsafe act committed by the military operator) or were unable to be coded (lacked insufficient narrative information or detail). The final dataset contained at total of 883 cases, 797 Class A and 86 Class B mishaps, which resulted in 704 fatalities and 179 serious injuries. In each case, the involved service member was operating a motor vehicle on the roadway when he/she committed at least one unsafe act that contributed to the MVC.

Table 19: Cases Classified

	Dates	Provided [Operator, Passenger]	Eliminated [Without UA, Uncodeable]	Analyzed
Total	FY99-08	1300 [1161, 139]	278 [216, 62]	883

Some but not all of the years between FY99 and FY08 contained full datasets. MVC cases were provided for most, but not all, of FY2008. Some years, MVC cases came from all three branches (USAF, USN, and USMC) while other years, they came from only one or two of these branches. One military branch provided MVC cases for the one year period of FY1999. Two military branches provided MVC cases for the five year period from FY2000 through FY2004. All three military branches provided MVC cases for the four year period from FY2005 through FY2008.

An average of 73.6 MVC cases occurred each month. The distribution of MVCs over the 12 months of the year is presented in Figure 8. The month of March had the fewest cases per month with 55 cases. The months of July and August had the most cases per month with 90 cases each.

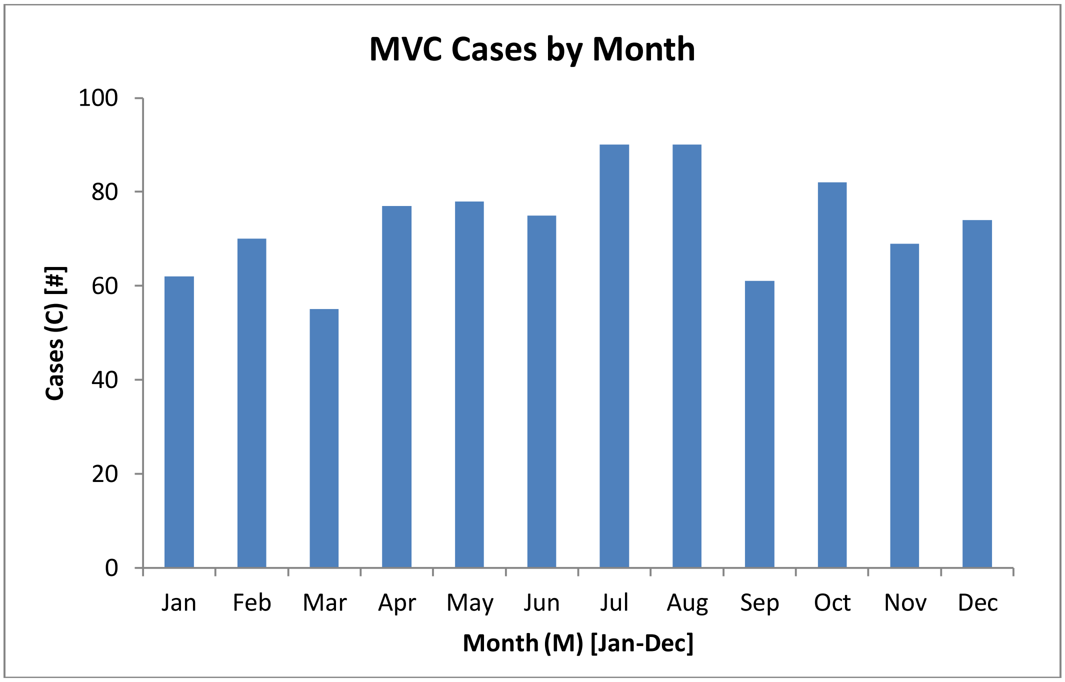

Figure 8: MVC Cases by Month

An average of 126.1 MVC cases occurred each day. The distribution of MVCs over the seven days of the week is presented in Figure 9. Wednesday had the least cases per day with 68 cases while Saturday had the most cases per day with 212 cases. More cases occurred on Saturday and Sunday than from Monday through Thursday combined.

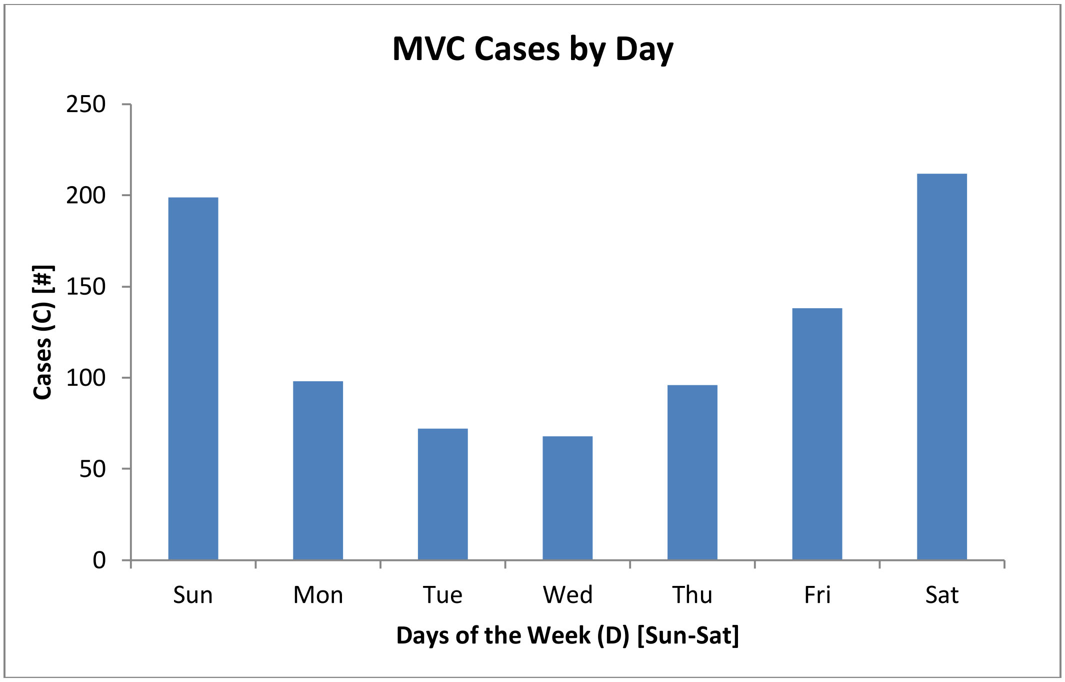

Figure 9: MVC Cases by Day of the Week

An average of 36.8 MVC cases occurred each hour. The distribution of MVCs over 24 hours in the day is presented in Figure 10. Fewer cases occurred in the morning and early afternoon hours with the least number of cases occurring between 0900 and 1000. More cases occurred in the late afternoon and late night hours with the greatest number of cases occurring between 0200 and 0300.

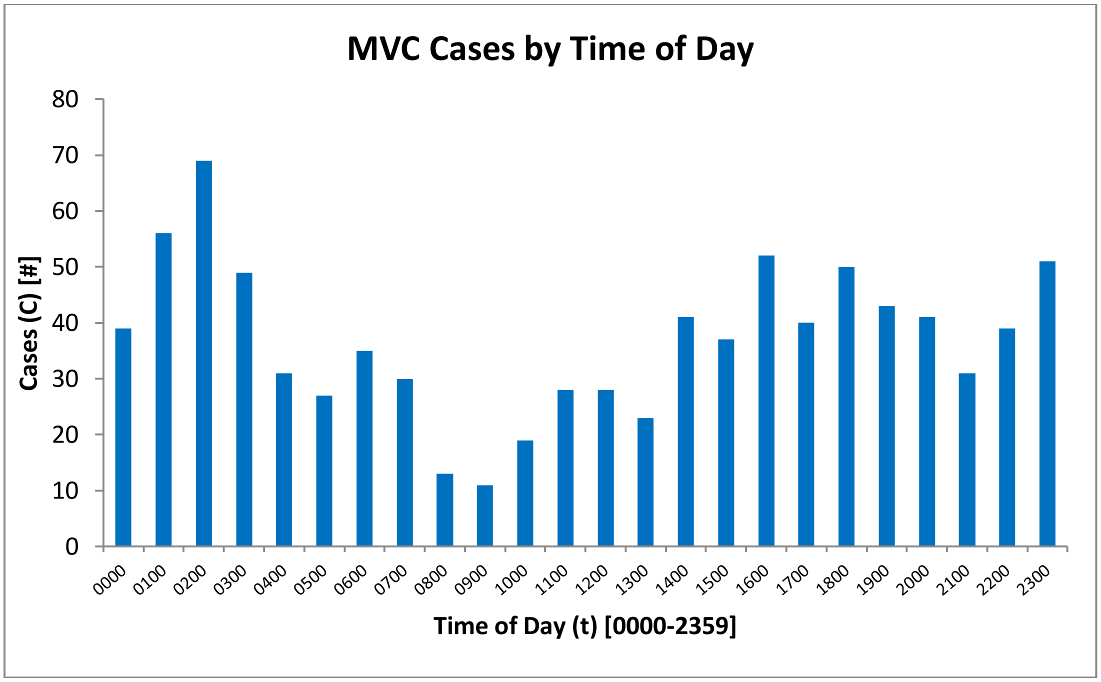

Figure 10: MVC Cases by Time of Day

4.1 HFACS-MVC TRENDS

The following section presents the HFACS-MVC trends associated with off-duty crashes. All cases in the final dataset contained at least one unsafe act. The dataset contained 883 cases with a total of 2,642 nanocodes across the five HFACS-MVC tiers (Figure 11). The overwhelming majority of nanocodes (n=2,559) were from the lower two tiers, unsafe acts (n=1,622) and preconditions to unsafe acts (n=937). The remaining nanocodes were from the upper two tiers, unsafe leadership (n=22) and organizational influences (n=13) and the fifth tier, outside influences (n=48).

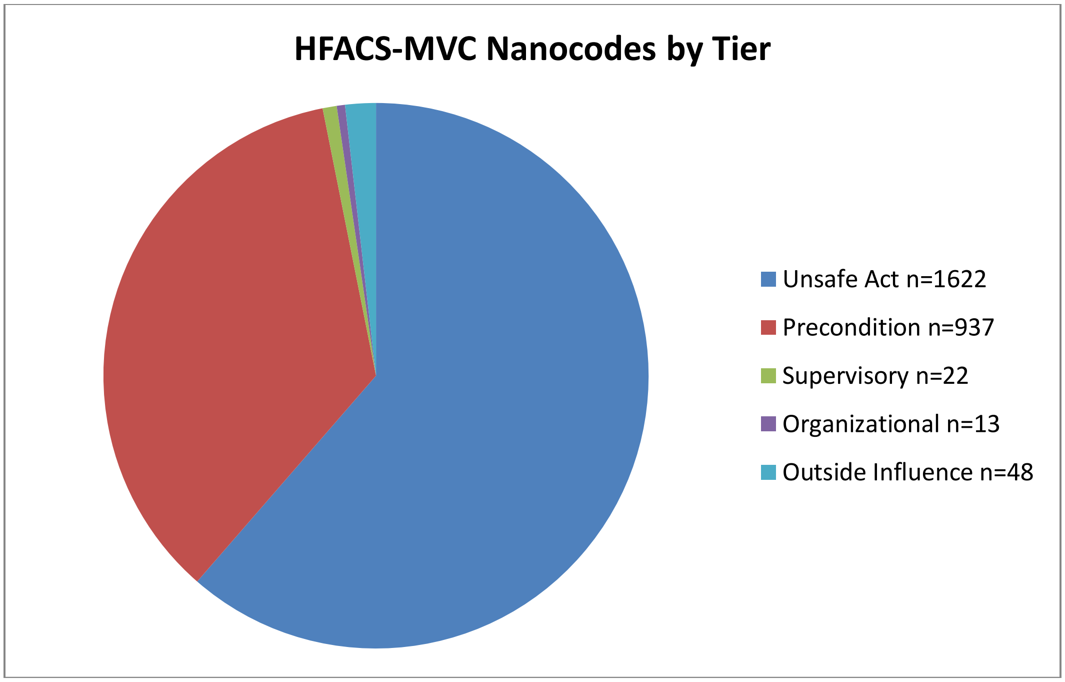

Figure 11: HFACS-MVC Tiers, percentage of nanocodes (N=2,642)

The frequencies and percentages of cases associated with the HFACS-MVC causal categories for all five tiers are presented in Table 21. Each case could contain factors from several causal categories. As such, it was possible for the sum of the percentages of cases associated with each causal category to exceed 100%.

Table 20: Frequency and Percentage of Cases, number and percent of cases with presence of at least one causal factor in category

HFACS-MVC Category	#	(%)
Outside Factors		
Outside Influences	48	(5.4)
Organizational Influences		
Organizational Climate	3	(0.3)
Organizational Process	7	(0.8)
Resource Management	2	(0.2)
Unsafe Leadership		
Inadequate Leadership	9	(1.0)
Planned Inappropriate Operation	5	(0.6)
Failed to Correct Known Problem	4	(0.5)
Leadership Violations	1	(0.1)
Preconditions for Unsafe Acts		
Environmental Conditions		
Physical Environment	161	(18.2)
Technical Environment	36	(4.1)
Operator Conditions		
Adverse Mental State	190	(21.5)
Adverse Physiological State	306	(34.7)
Physical/Mental Limitation	110	(12.5)
Operator Factors		
Communication, Coordination & Planning	42	(4.8)
Personal Readiness	2	(0.2)
Unsafe Acts of the Operator		
Skill Based Errors	624	(70.7)
Decision Errors	254	(28.8)
Perceptual Errors	7	(0.8)
Violations	477	(54.0)

* N = 883

The frequencies and percentages of cases associated with the HFACS-MVC causal factor subcategories for the two most populated tiers, preconditions for unsafe acts and unsafe acts, are presented in Tables 22 and 23. Again, cases could contain factors from several causal subcategories so the sum of the percentages can be over 100%.

Table 21: Preconditions for Unsafe Act Subcategories, number and percent of cases with presence of factor in subcategory

HFACS-MVC Precondition Subcategories	#	(%)
Physical Environment		
Surface Conditions	121	(13.7)
Visibility	49	(5.5)
Physical Environment, Misc.	7	(0.8)
Physical Environment, Other	3	(0.3)
Technological Environment		
Protective Devices on Road	14	(1.6)
Vehicular Tech. Environment	5	(0.6)
Design	17	(1.9)
Tech. Env. Other	2	(0.2)
Adverse Mental State		
Attitude	38	(4.3)
Awareness	55	(6.2)
Drowsiness	67	(7.6)
Psychology	58	(6.6)
Adverse Mental State, Other	2	(0.2)
Adverse Physiological State		
Physiological Condition	276	(31.3)
Medical Condition	9	(1.0)
Incapacitation	42	(4.8)
Adverse Physiological State, Other	1	(0.1)
Physical/Mental Limitation		
Mental Limitation	101	(11.4)
Sensory Deficiency	1	(0.1)
Physical Limitation	0	(0.0)
Physical/Mental Limitation, Other	8	(0.9)
Personal Readiness		
Personal Readiness	2	(0.2)
Personal Readiness, Other	0	(0.0)
Communication, Coordination, & Planning		
Communication	11	(1.2)
Coordination	1	(0.1)
Planning	31	(3.5)
Comm., Coord., & Planning, Other	1	(0.1)

* N = 883

The top three preconditions for unsafe act subcategories associated with MVCs in descending order were physiological conditions, surface conditions, and mental limitations. Approximately one-third of the MVCs contained at least one physiological condition causal factor. Much smaller percentages of the MVCs were associated with surface conditions and mental limitations, each present in only around one-tenth of the cases.

Table 22: Unsafe Act Subcategories, number and percent of cases with presence of factor in subcategory

HFACS-MVC Unsafe Act Subcategories	#	(%)
Skill Based Errors		
Attention Failure	92	(10.4)
Postural Error	1	(0.1)
Technique Error	428	(48.5)
Timing Error	15	(1.7)
Unknown Control Error	115	(13.0)
Skill Based Error, Other	4	(0.5)
Decision Errors		
Information Processing Error	5	(0.6)
Prioritization Error	53	(6.0)
Procedural Decision Error	61	(6.9)
Situational Assessment Error	147	(16.6)
Vehicular Decision Error	1	(0.1)
Decision Error, Other	1	(0.1)
Violations		
Procedural Violation, Speed	307	(34.8)
Procedural Violation, Drunk Driving	219	(24.8)
Procedural Violation, Other	78	(8.8)
Knowledge Violation	36	(4.1)
Violation, Other	8	(0.9)

* N = 883

The top unsafe act subcategories associated with MVCs in descending order were technique errors, procedural speeding violations, procedural drunk driving violations, situational assessment errors, unknown control errors, and attention failures. Of these unsafe act subcategories, four were errors (three skill based errors and one decision error) and two were violations (both procedural in nature). Almost one-half of off-duty MVCs contained at least technique error causal factor. Around one-third and one-fourth of MVCs contained at least one procedural speeding and procedural drunk driving violation respectively. Between one-tenth and one-fifth of MVCs were associated with each of the situational assessment error, unknown control error, and attention failure subcategories.

Two of the subcategories, physiological condition and drunk driving violation, are related. The drunk driving violation subcategory exclusively captured factors reflecting a conscious disregard of the laws related to being over the legal drinking limit and operating a motor vehicle (in the US, the legal drinking limit is below a blood alcohol content of 0.08%). The physiological condition subcategory exclusively captured factors related to being impaired due to the drugs or alcohol which relates to being intoxicated (drunk) as well as to being impaired (buzzed), hung-over, etc. Simply put, all cases with drunk driving violations will have physiological condition factors but not all cases with physiological condition factors will have drunk driving violations. In this dataset, 276 cases were associated with impairment from drugs or alcohol – 219 cases associated with operator intoxication from being drunk with a BAC over 0.08% and 57 cases associated with operator impairment from drugs or from being buzzed with a BAC under 0.08%.

The most common causal factor nanocodes associated with off-duty MVCs involving US military service members are presented in Table 21. Of the 15 most commonly classified nanocodes, 10 causal factors were at the unsafe act level (four skill based errors, one decision error, and five violations) and five causal factors were at the precondition for unsafe act level (one environmental condition factor and four operator condition factors). As discussed, PC2 and VDD are related to one another with PC2 capturing the physiological effects related to driving drunk (VDD) as well as other physiological impairments. Assuming all VDD factors are already captured by the PC2 nanocode, the top five nanocodes associated with off-duty MVCs were impairment due to drugs or alcohol/drunk driving (PC2), failure to negotiate curve or turn (TQ7), failure to modify behavior for hazards (SA2), lost control for an unknown reason (LCU), and over-steered or overcorrected to regain position on road (TQ6).

Table 23: Common causal factors associated with off-duty military MVCs

Ranking	Description of Nanocode	Nanocode	Tier
1	Impairment due to drugs or alcohol	PC2	PC
2	Failure to negotiate curve or turn	TQ7	UA
3	Drunk driving	VDD	UA
4	Situational assessment	SA2	UA
5	Lost control, due to unknown reason	LCU	UA
6	Over-steered or overcorrected to regain position	TQ6	UA
7	Limited experience or proficiency	ML4	PC
8	Speeding, unknown illegal speed	VPRO0	UA
9	Slippery road surface	SC1	PC
10	Mental fatigue, drowsy	AMF1	PC
11	Inadvertent drifting out of lane	ATT5	UA
12	Speeding, 20-29 mph over the speed limit	VPRO2	UA
13	Speeding, 10-19 mph over the speed limit	VPRO1	UA
13	Speeding, 40+ mph over the speed limit	VPRO4	UA
13	Personality style	PSY1	PC

Detailed analyses of HFACS-MVC categories, subcategories, and nanocodes were conducted for the lower two tiers, unsafe acts and preconditions to unsafe acts. The upper two tiers, unsafe leadership and organizational influences, were excluded from analysis due to the paucity of factors identified. The fifth tier, outside influences, was excluded from analysis because it captures factors associated with non-military personnel and is therefore outside the scope of this effort.

4.2 Unsafe Act Trends

All cases contained at least one unsafe act by the service member operating the motor vehicle. The 883 cases contained one (n=365), two (n=341), three (n=141), four (n=28) or even five (n=8) unsafe act causal factors per case. The percentage of cases containing at least one factor from each of the four unsafe act causal categories is presented in Figure 12. The leading unsafe act causal categories associated with off-duty MVCs were skill based errors and violations followed by decision errors. Of the 883 cases in the dataset, approximately three-fourths contained at least one skill based error, one-half contained at least one violation, and one-fourth contained at least one decision error. Only a handful of cases involved perceptual errors.

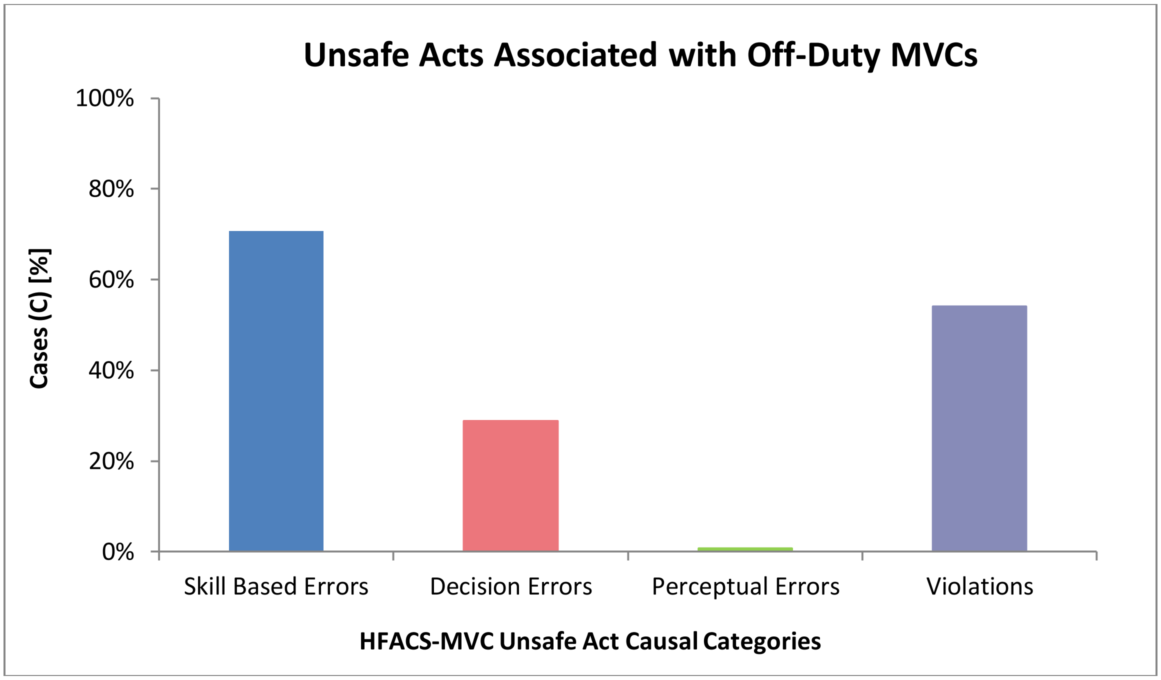

Figure 12: Unsafe Act Categories, percentage of total cases with at least one factor per category (N=883)

4.2.1 Unsafe Acts over Time

The trend lines for unsafe act categories involved in MVCs between FY1999 and FY2008 are presented in Figure 13. The temporal trends for all four unsafe act categories remained stable and some may have even increased slightly.

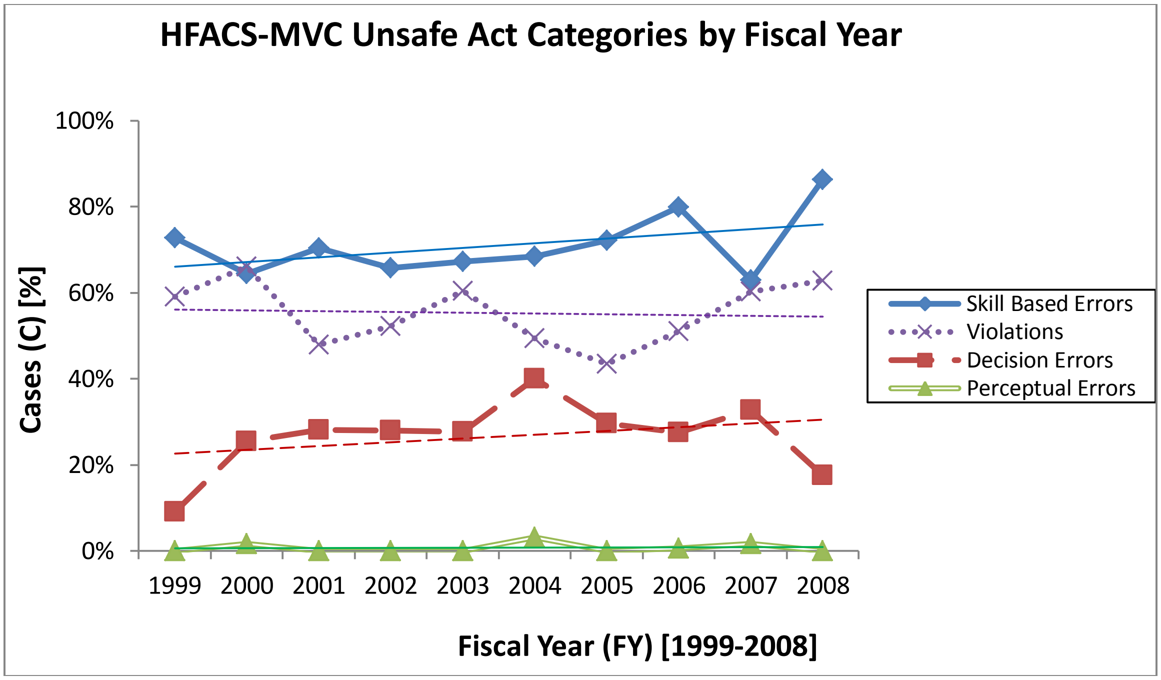

Figure 13: Unsafe Act Category Temporal Trends, percentage of cases per fiscal year with at least one factor per category

4.2.2 Skill Based Errors

Most cases (n=624) contained at least one skill based error. These 624 cases contained one (n=555), two (n=66), or three (n=3) skill based error nanocodes per case. A total of 696 skill based error nanocodes were identified. Breakdowns of decision errors associated with MVCs by subcategory and nanocode are presented in Figures 14 and 15.

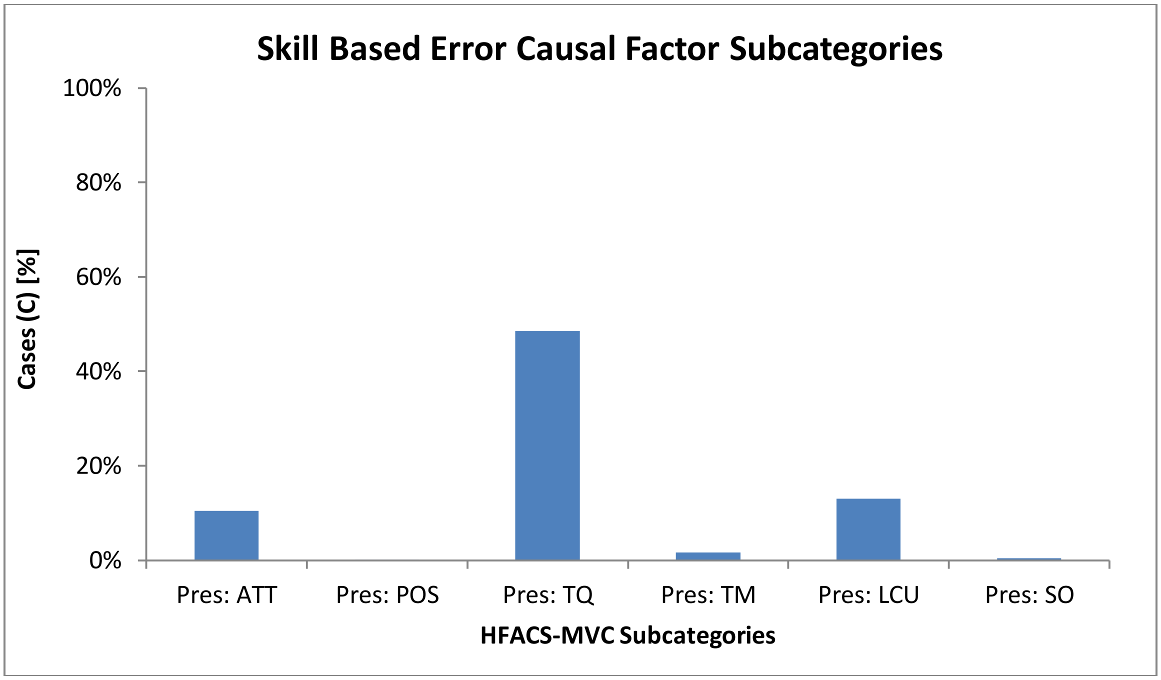

Figure 14: Skill Based Error Causal Factor Subcategories, percentage of total cases with at least one factor per subcategory (N=883)

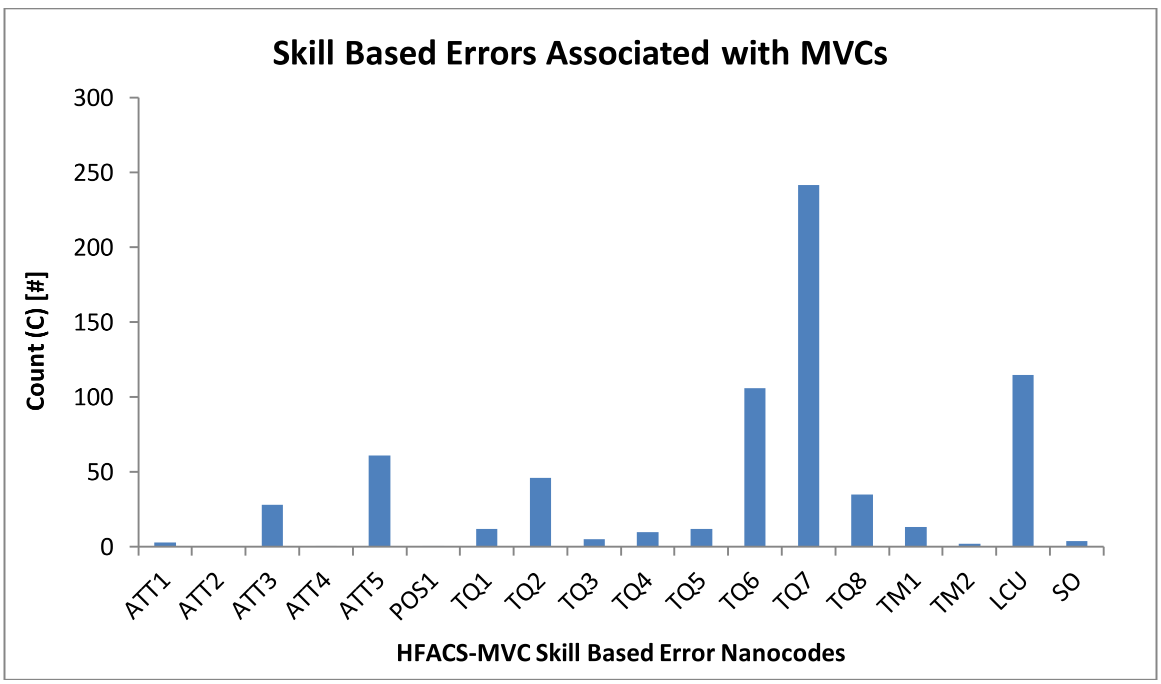

Figure 15: Skill Based Error Causal Factors, count of skill based error nanocodes (N=696)

The most common skill based error subcategory captured technique errors. These technique errors typically captured operators who travelled too fast to safely negotiate a curve or turn (TQ7) or who overcorrected trying to maintain or regain their position on the road (TQ6). Other common causal subcategories of skill based errors were control errors and attention errors.

4.2.3 Decision Errors

Several hundred cases (n=254) contained at least one decision error. These 254 cases contained either one (n=239) or two (n=5) decision error nanocodes per case. A total of 269 decision error nanocodes were identified. The breakdowns of decision errors associated with MVCs by subcategory and nanocode are presented in Figures 16 and 17.

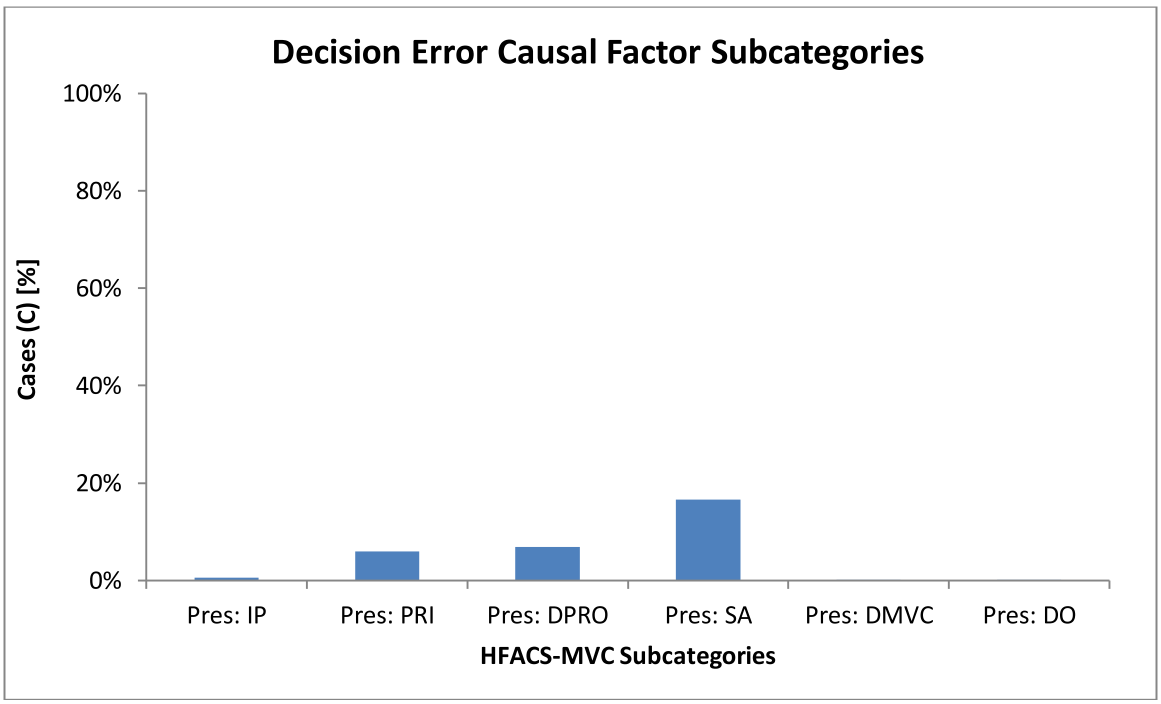

Figure 16: Decision Error Causal Factor Subcategories, percentage of total cases with at least one factor per subcategory (N=883)

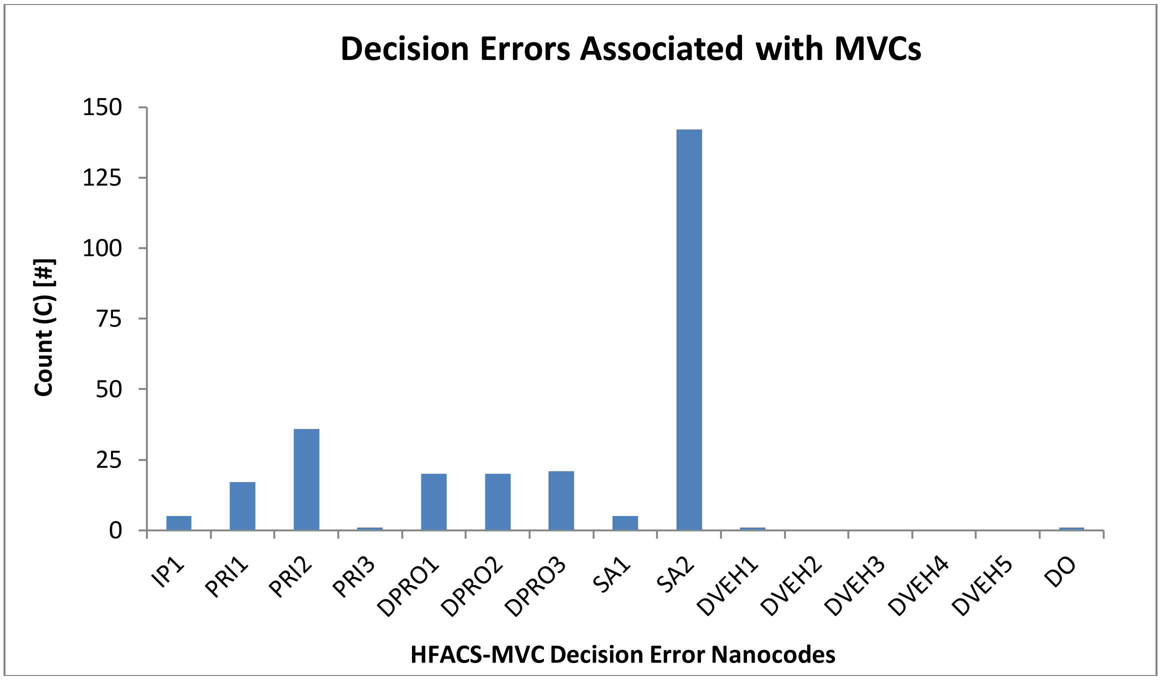

Figure 17: Decision Error Causal Factors, count of decision error nanocodes (N=269)

The most common subcategory of decision errors was related to situational awareness. In particular, these decision errors were made by operators who should have but did not modify their behaviors on the road to accommodate for travel conditions (SA2). Other common sub-categories of decision errors were procedural errors and prioritization errors. Prioritization decision errors were often committed by operators who made decisions based on inappropriate prioritizations (PRI1) or ignored cautions or recommendations from others (PRI2). Procedural decision errors typically involved operators who selected an inappropriate maneuver (DPRO2), decided to pass or change lanes at an improper time or location (DPRO3), or failed to yield the right of way (DPRO1).

4.2.4 Violations

Over half of the cases (n=477) contained at least one violation. These 477 cases contained one (n=327), two (n=129), three (n=19), or four (n=2) violations per case. A total of 650 violation nanocodes were identified. The breakdowns of violations associated with MVCs by subcategory and nanocode are presented in Figures 18 and 19.

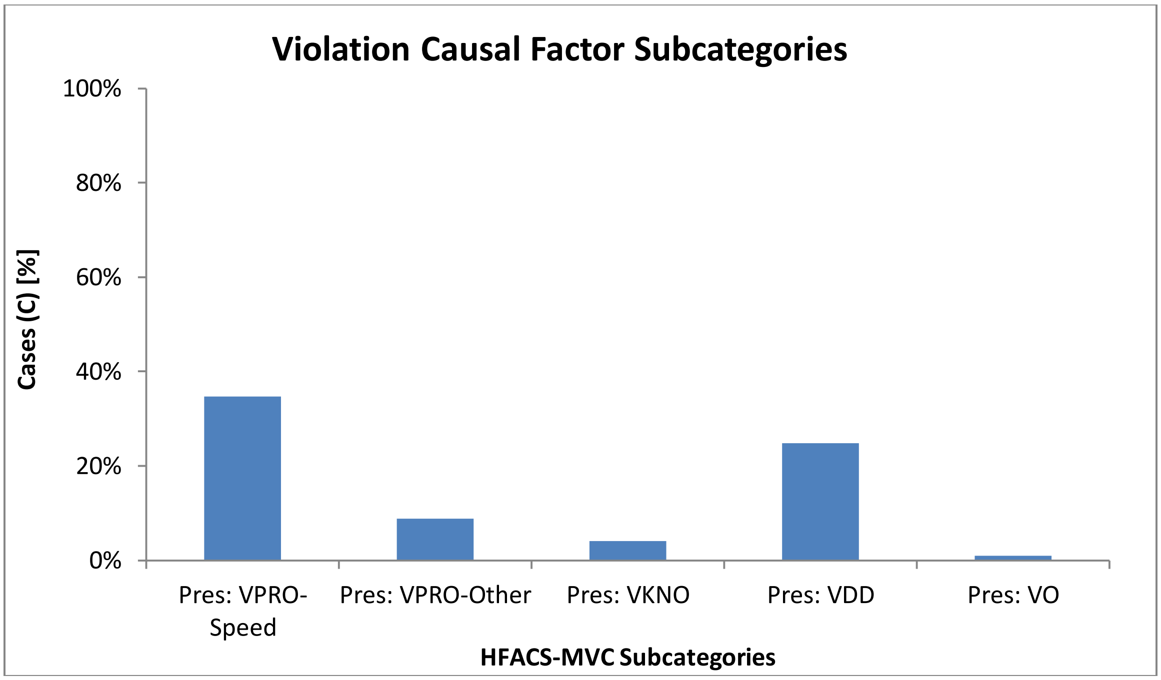

Figure 18: Violation Causal Factor Subcategories, percentage of total cases with factor in subcategory (N=883)

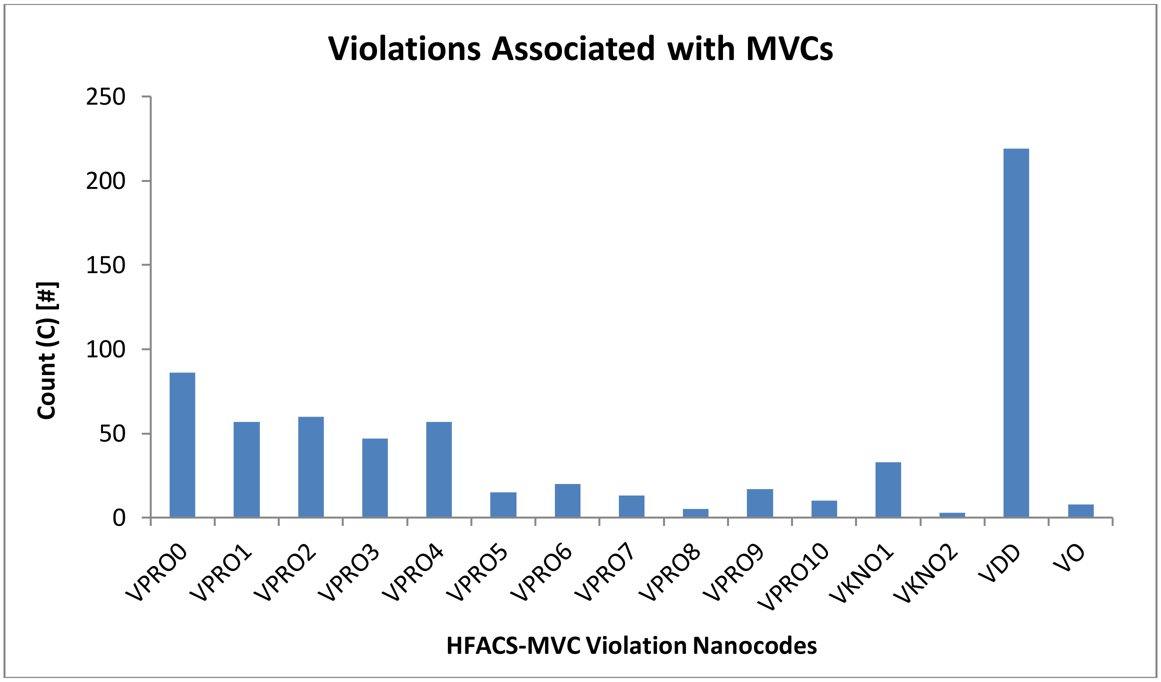

Figure 19: Violation causal factors, count of violation nanocodes (N=650)

The most common violation subcategories were procedural in nature. Over one-third of the cases contained procedural violations were related to speeding. One-fourth of the cases contained drunk driving violations. In fact, the top violation nanocode was VDD which captured service members who operated motor vehicles with a BAC of 0.08% or greater.

4.3 Precondition Trends

Most cases contained at least one causal factor from the preconditions tier (n=583). The 583 cases with preconditions had one (n=351), two (n=153), three (n=52), four (n=18), five (n=9), or even six (n=2) precondition causal factors per case. The percentage of cases associated with each of the three groups of precondition subcategories (environmental conditions, operator conditions, operator factors) is presented in Figure 20.

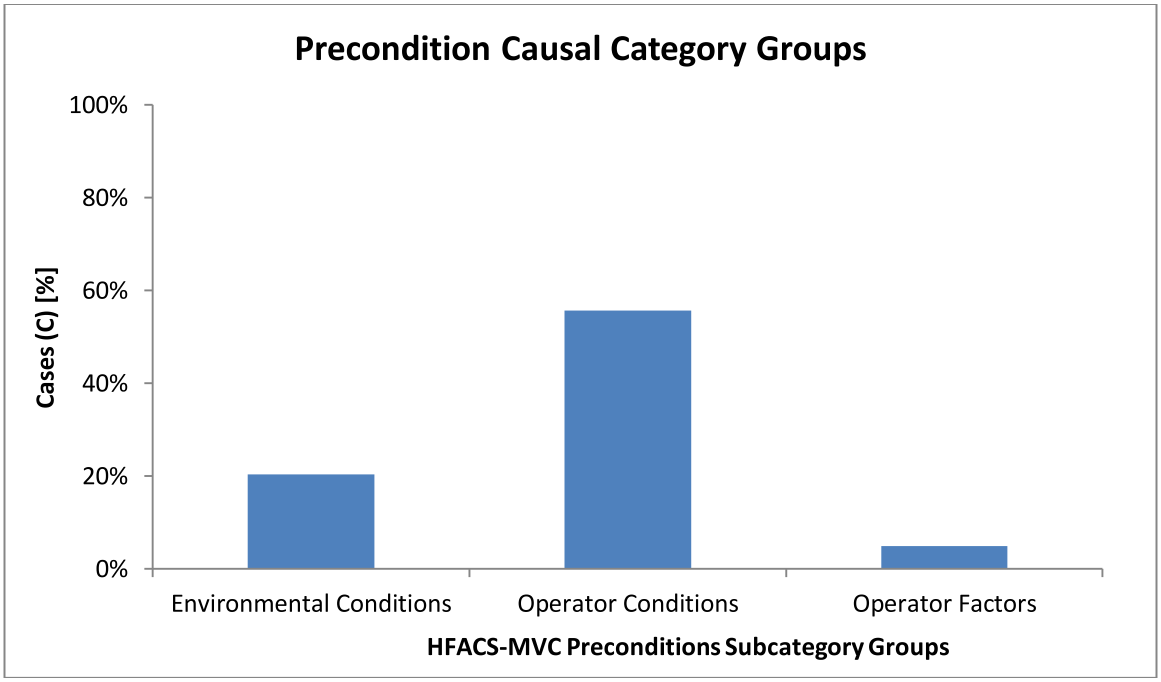

Figure 20: Precondition Causal Category Groups, percentage of total cases with at least one factor per group (n=883)

The most common groups of precondition causal categories associated with off-duty MVCs were operator conditions followed by environmental conditions and finally operator factors. Of the 883 MVC cases in the dataset, over half contained operator conditions, one-fifth contained environmental conditions, and one-twentieth contained operator factors.

4.3.1 Preconditions over Time

The trend lines for the three groups of precondition causal categories involved in MVCs between FY1999 and FY2008 are presented in Figure 21. The temporal trends for all three precondition groups remained stable suggesting no real changes in the trends over time.

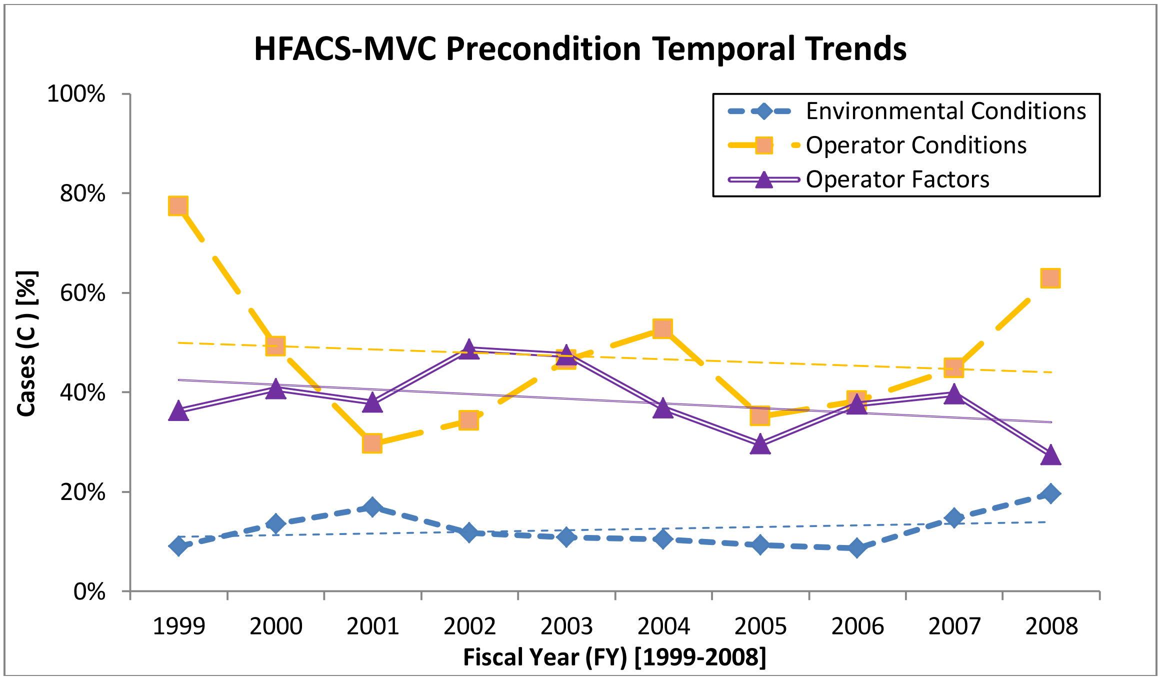

Figure 21: Temporal Trends of Precondition Causal Category Groups

4.3.2 Environmental Conditions

Environmental conditions include physical environment and technological environment causal categories. A large majority of the cases classified lacked any environmental condition causal factors (n=703). Figure 22 shows the percentage of cases associated with each of the two environmental condition categories.

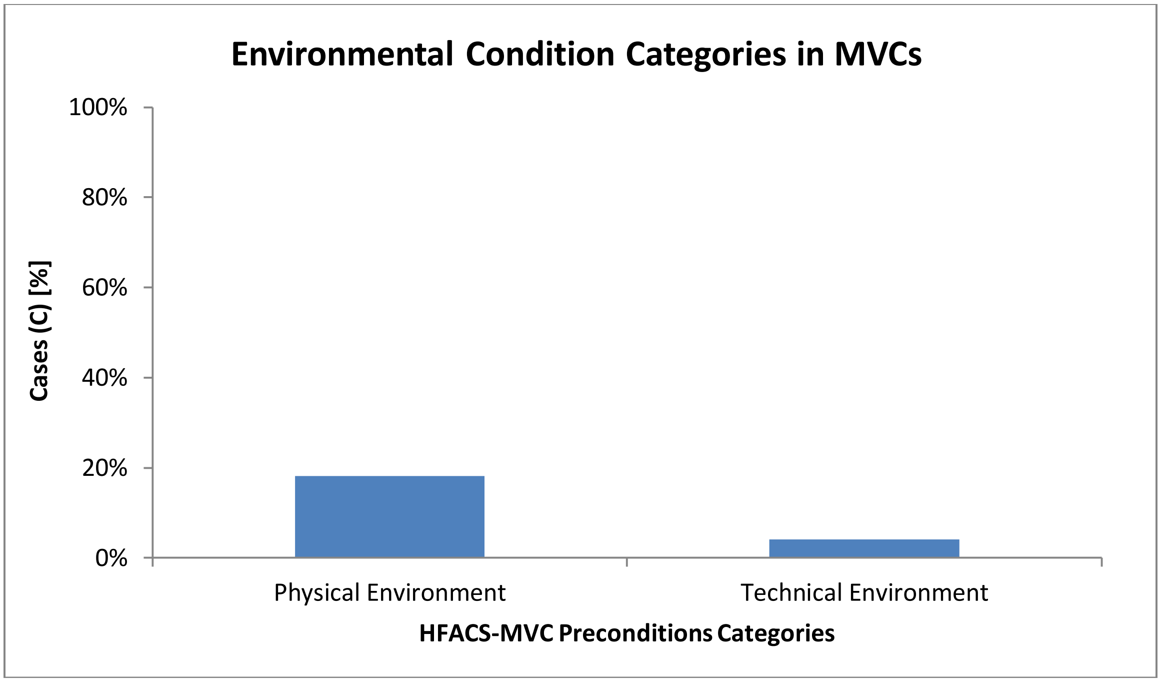

Figure 22: Environmental Condition Categories, percentage of total cases with at least one factor per category (N=883)

One-fifth of the cases (n=180) contained at least one physical or technical environmental condition factor. The 180 cases containing environmental conditions had one (n=142), two (n=32), or three (n=6) environmental condition nanocodes per case. A total of 224 environmental condition nanocodes were identified. Breakdowns of environmental conditions associated with MVCs by subcategory and nanocode are presented in Figures 23 and 24.

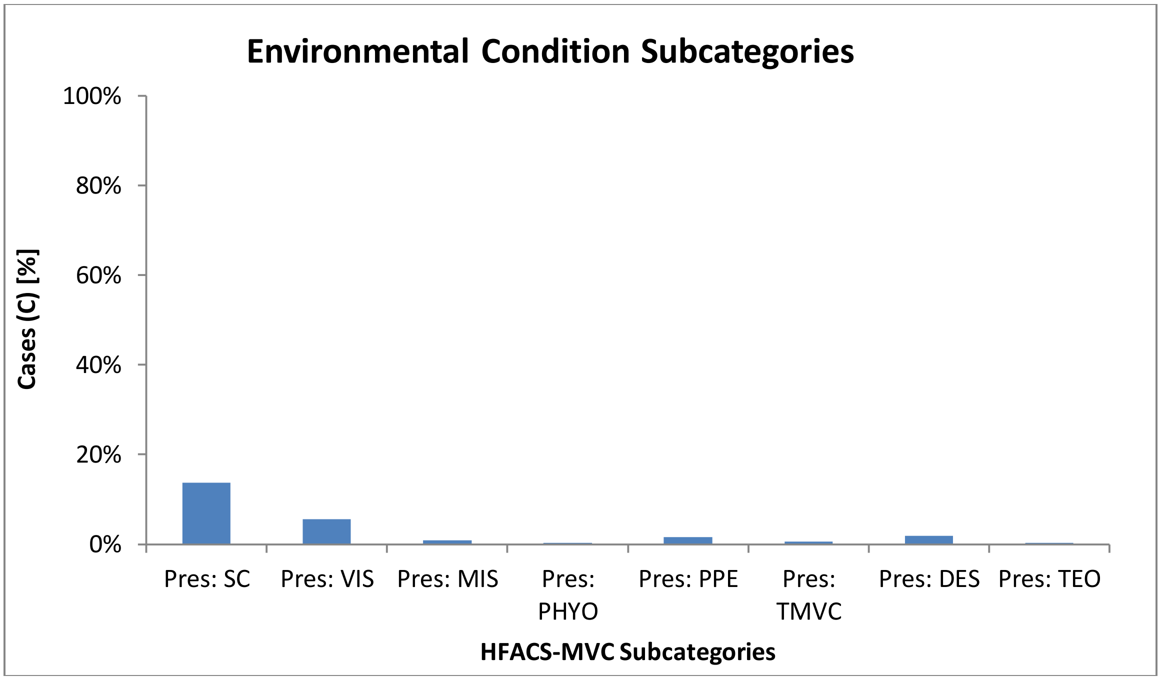

Figure 23: Environmental Condition Subcategories, percentage of total cases with at least one factor per subcategory (N=883)

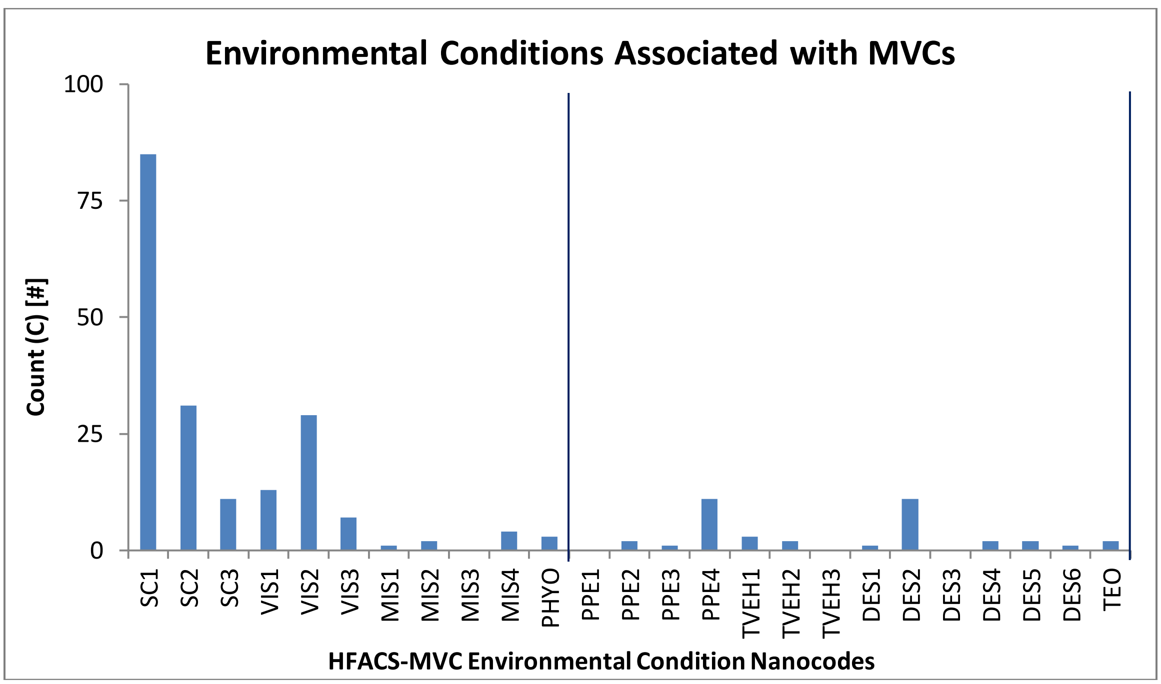

Figure 24: Environmental Condition Causal Factors, count of environmental condition nanocodes (N=224)

Environmental conditions include physical and technological environment causal categories. A large majority of the 224 environmental condition nanocodes were physical environment factors (n=186) rather than technological environment factors (n=38). The physical environment factors typically involved surface conditions (SC1-3) and visibility issues (VIS1-2). The technological environment factors typically involved road sign (PPE4) and road design (DES2) issues.

4.3.3 Operator Conditions

Operator conditions include adverse mental state, adverse physiological state, and and physical/mental limitation causal categories. Figure 25 shows the percentage of cases associated with each of the three operator condition causal categories. The leading operator condition causal categories associated with off-duty MVCs were adverse physiological state factors followed by adverse mental state factors. Of the 883 MVC cases in the dataset, one-third contained adverse physiological state factors, one-fifth contained adverse mental state factors, and one-tenth contained physical/mental limitation factors.

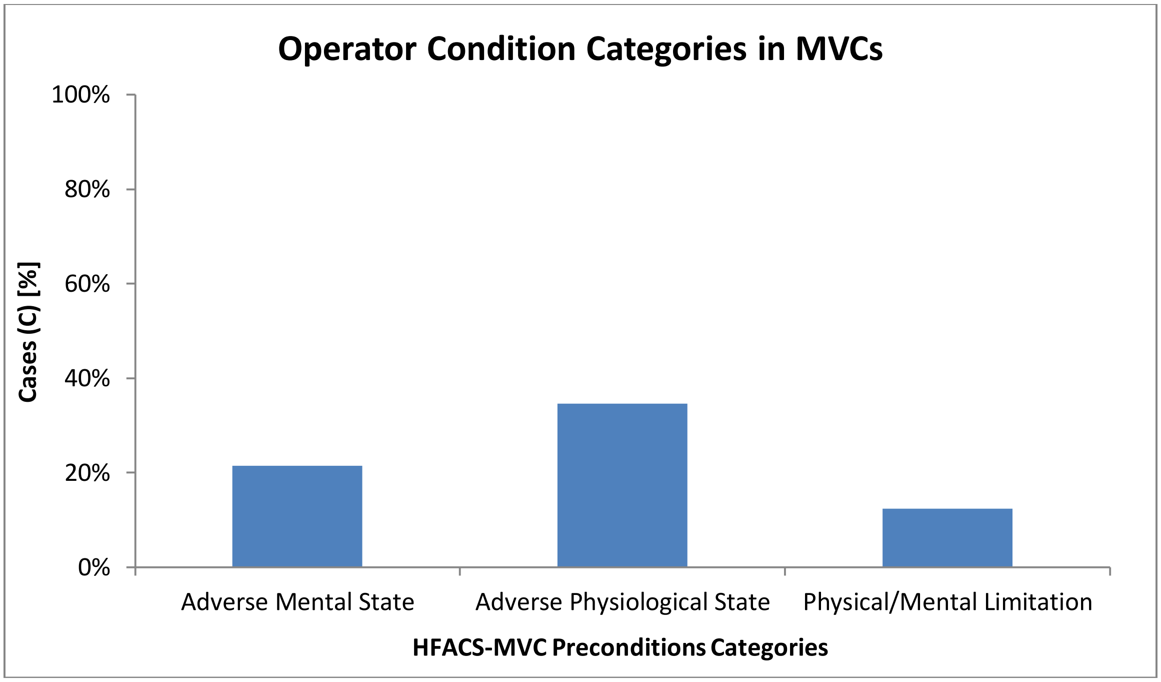

Figure 25: Operator Condition Categories, percentage of total cases with at least one factor per category (N=883)

The majority of cases contained at least one operator condition factor (n=492). These 492 cases contained one (n=363), two (n=94), three (n=26), or four (n=9) operator condition nanocodes per case. A total of 665 operator condition nanocodes were identified. Breakdowns of operator conditions associated with MVCs by subcategory and nanocode are presented in Figures 26 and 27.

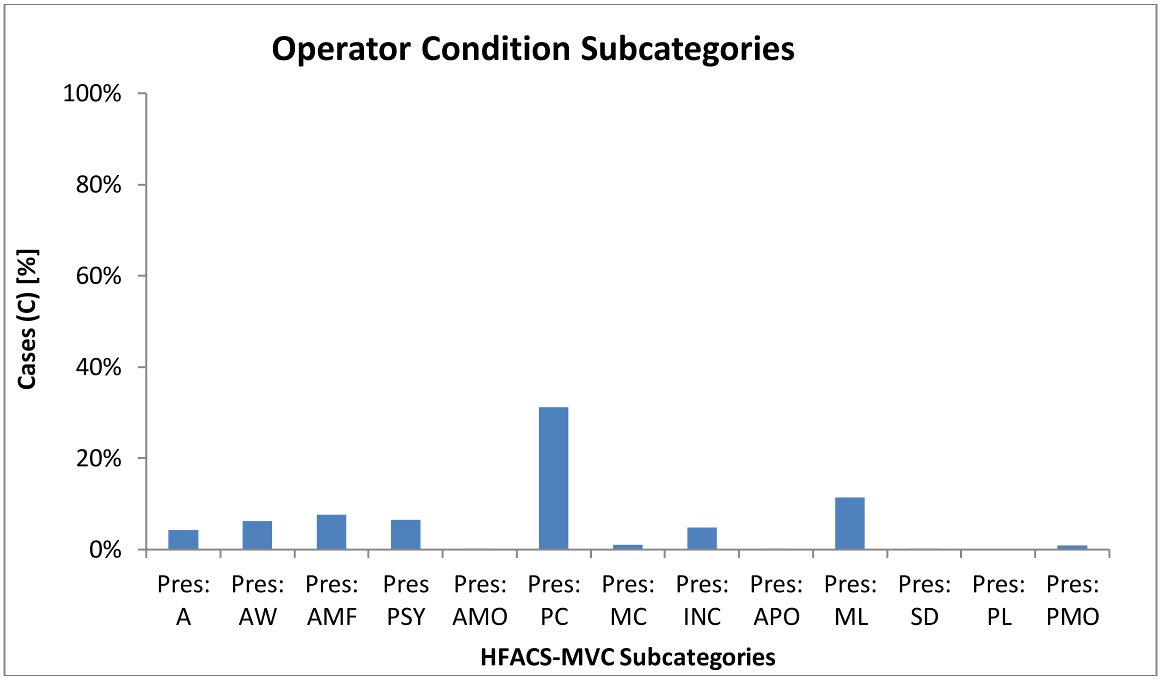

Figure 26: Operator Condition Subcategories, percentage of total cases with at least one factor per subcategory (N=883)

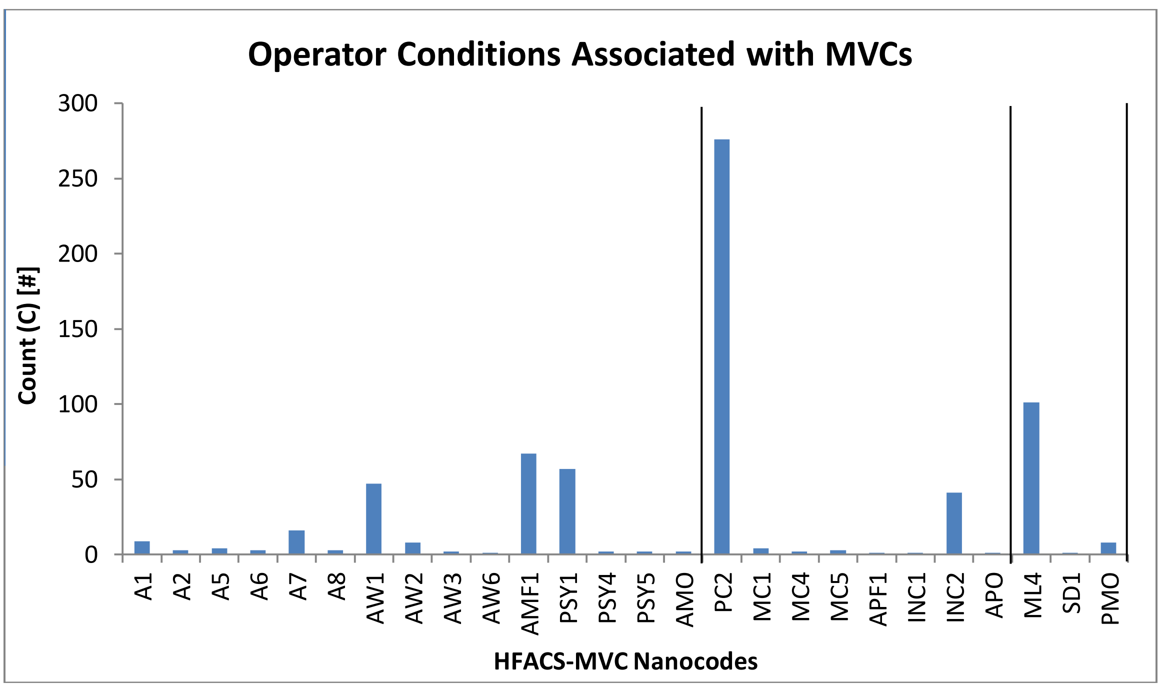

Figure 27: Operator Condition Causal Factors, count of operator condition nanocodes (N=665)

Most operator conditions captured were adverse mental conditions (n=226) and adverse physiological conditions (n=329) rather than physical/mental limitations (n=110).

The adverse mental condition factors were related to drowsiness (ML4), breakdowns in awareness (AW1), and the psychological makeup of operators (PSY1). The adverse physiological state factors were related to operator impairment due to drugs and/or alcohol (PC2). The physical/mental limitation factors were related to lack of experience or proficiency of service members with the vehicles they were operating or with the areas in which they were travelling (ML4).

4.3.4 Operator Factors

Operator factors include personal readiness and communication, coordination, and planning causal categories. Figure 28 shows the percentage of cases associated with each of the two operator factor categories. By far, the leading operator factor causal category was communication, coordination, and planning followed by personal readiness.

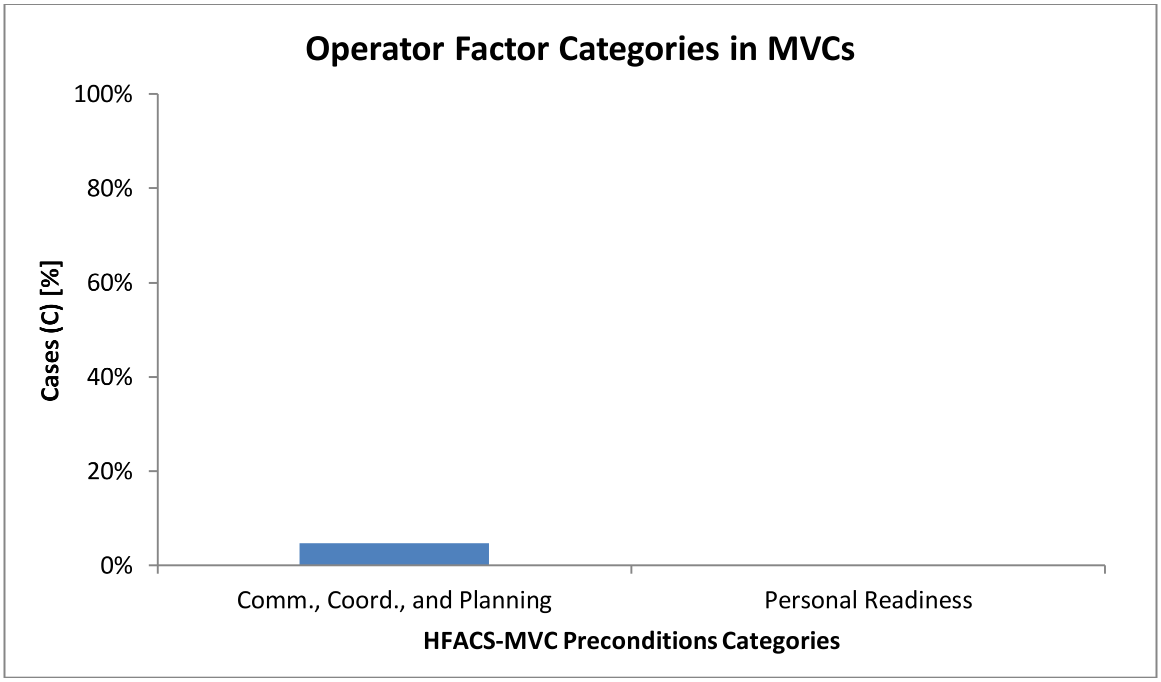

Figure 28: Operator Factor Categories, percentage of total cases with at least one factor per category (N=883)

Only 44 cases were associated with any operator factors. The 44 cases containing operator factors had one (n=41), two (n=2), or three (n=1) operator factors per case. A total of 48 operator factor nanocodes were identified. The overwhelming majority of the operator factors classified were communication, coordination, and planning factors (n=46) rather than personal readiness factors (n=2). Breakdowns of operator factors associated with MVCs by subcategory and nanocode are presented in Figures 29 and 30.

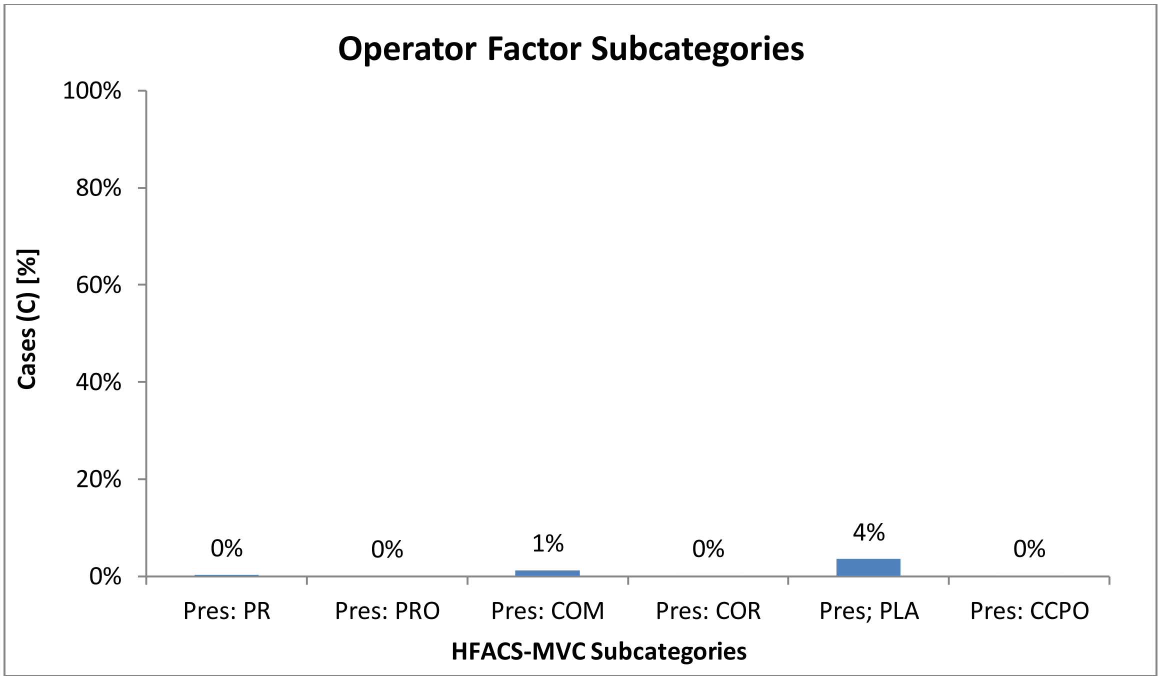

Figure 29: Operator Factor Causal Factor Subcategories, percentage of cases with at least one factor per subcategory (N=883)

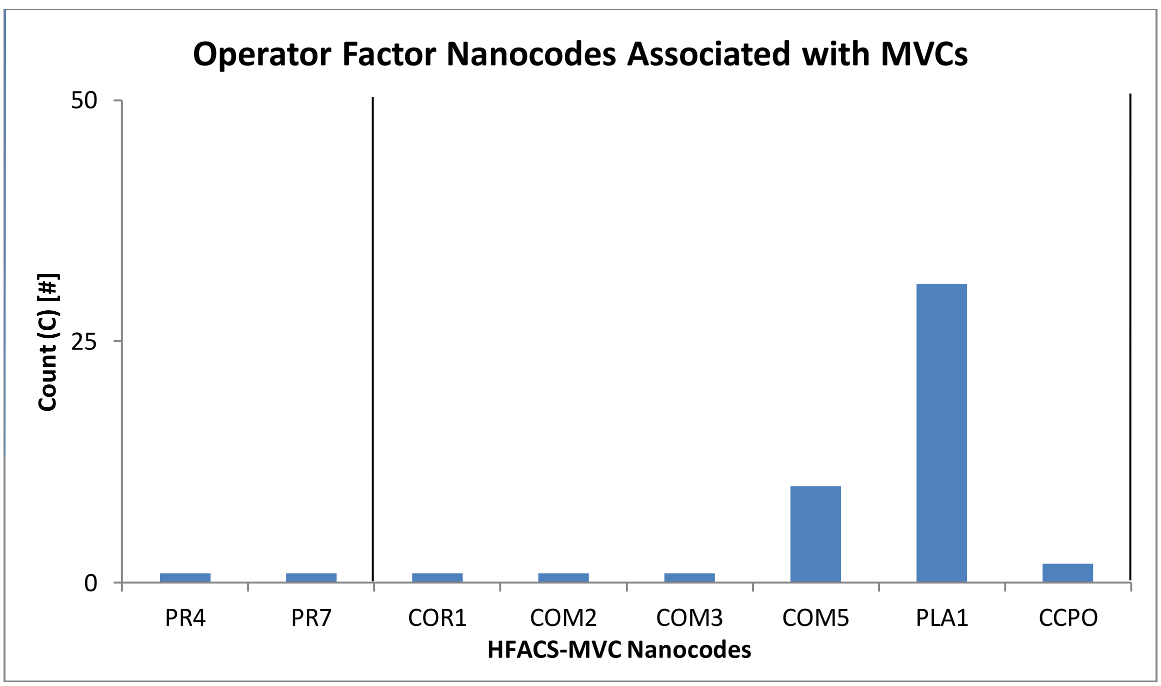

Figure 30: Operator Factor Causal Factors, count of operator factor nanocodes (N=48)

Common operator factor subcategories include communication and planning. In particular, these factors were related to inadequate travel planning by the operator prior to departure (PLA1) and communciation between an operator and other road users (COM5).

CHAPTER 5: RESULTS, COMPARISONS OF TRENDS

The following section presents the general trends associated with off-duty MVCs for each of the independent variables. Nonparametric statistical analyses were conducted to compare HFACS-MVC causal factor patterns for each independent variable. For statistically significant causal categories, odds ratios were calculated and causal factor (nanocode) comparisons were included. Insufficient cell counts prevented calculations of valid Pearson Chi-Squares for the perceptual error and personal readiness causal categories.

Again, the four independent variables of interest were military branch, vehicle type, paygrade, and age group. For each independent variable, contingency tables were created and presented alongside Pearson Chi-Square and Odds Ratio statistics for each HFACS-MVC unsafe act and precondition category (except Technical Environment and Personal Readiness which lacked sufficient cell counts). These can be found in Appendix F for military branch comparisons, in Appendix G for vehicle type comparisons, in Appendix H for paygrade comparisons, and in Appendix I for age group comparisons.

5.1 Military Branches: USAF, USN, USMC

The dataset contained about ten years of MVCs from both the USAF and USN. In contrast, the dataset contained only about three years of MVCs from the USMC. Similar percentages of cases were eliminated from all three services' datasets due to an absence of unsafe acts committed by the service member. Interestingly, a notably larger proportion of cases were eliminated from the USN dataset than from both the USAF and USMC datasets.

As such, the large majority of classified cases involved operators in the USAF (43%) and USN (42%) and a much smaller percentage involved operators in the USMC (15%). There were a total of 1,384 nanocodes, 942 nanocodes, and 316 nanocodes classified for cases in the USAF, USN, and USMC. As such, there were 3.7 factors per case for the USAF, 2.5 factors per case for the USN, and 2.4 factors per case for the USMC.

5.1.1 Temporal Trends

The number of cases in the final dataset from each branch by fiscal year is provided in Figure 31. Again, keep in mind that the dataset for FY2008 was limited and contained less than a full year of MVCs.

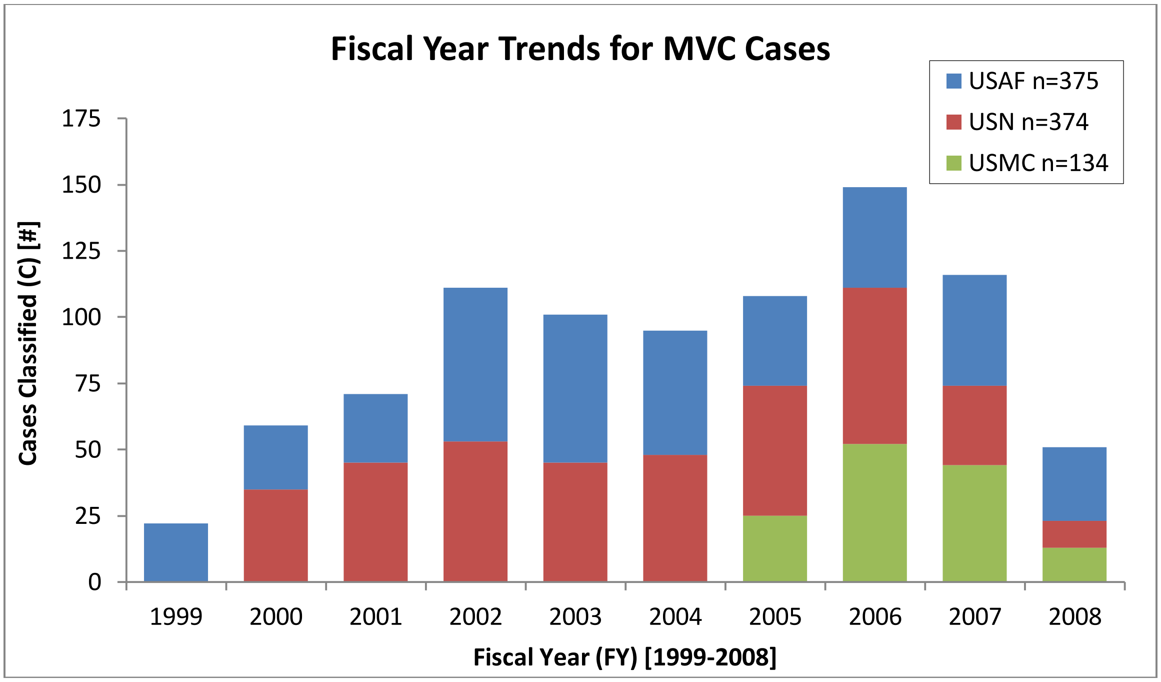

Figure 31: Temporal Trends of MVC Cases by Military Branch

5.1.2 Unsafe Act Trends

The unsafe act trends by military branch are shown in Figure 32. The leading unsafe act causal categories associated with off-duty MVCs for the USAF, USN, and USMC were skill based errors followed by violations and decision errors with few, if any, perceptual errors. Differences in unsafe act category trends between the three branches were significant for skill based errors (χ^2= 6.906, p<0.01) and violations (χ^2=30.997, p<0.01) but insignificant for decision errors (χ^2=0.264, ns).

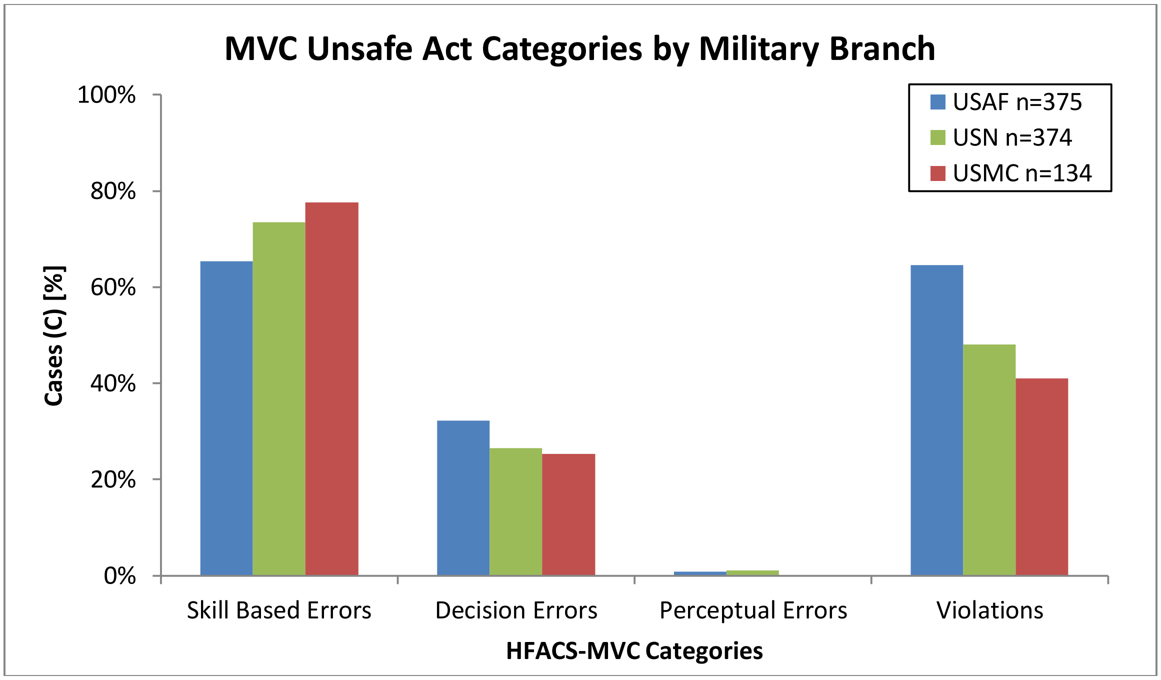

Figure 32: Unsafe Act Categories by Branch, percent of cases per branch with at least one factor per category

Approximately two-thirds of USAF cases and three-fourths of USN and USMC cases contained skill based errors. The difference between the percentages of USN and USMC cases associated with skill based errors was insignificant (χ^2=0.868, ns). However, the differences between the percentages of USN and USMC cases and the percentage of USAF cases associated with skill based errors were significant. Specifically, MVCs in the USAF were associated with significantly fewer skill based errors than MVCs in both the USN (χ^2=5.926, $p<0.05$) and the USMC (χ^2=6.906, $p<0.05$). The relative odds of a service member having a MVC involving one or more skill based errors was approximately 1.5 times greater in the USN (OR=1.47) and almost two times greater in the USMC (OR=1.84) than in the USAF.

The percentages of USAF, USN, and USMC cases associated with each of the skill based error subcategories are presented in Figure 33. Common skill based error subcategories for all three military branches were related to technique, attention, and control. The three main skill based error subcategories associated with cases for all three branches were related to technique, control, and attention. Technique errors were associated with the highest percentage of MVCs for service members in the USAF followed by service members in the USN and USMC. The opposite trend was identified for errors related to loss of control due to unknown reasons which were associated with the highest percentage of MVCs for service members in the USMC followed by service members in the USN and eventually those in the USAF. In fact, less than one-twentieth of the USAF cases were associated with loss of control for unknown reasons.

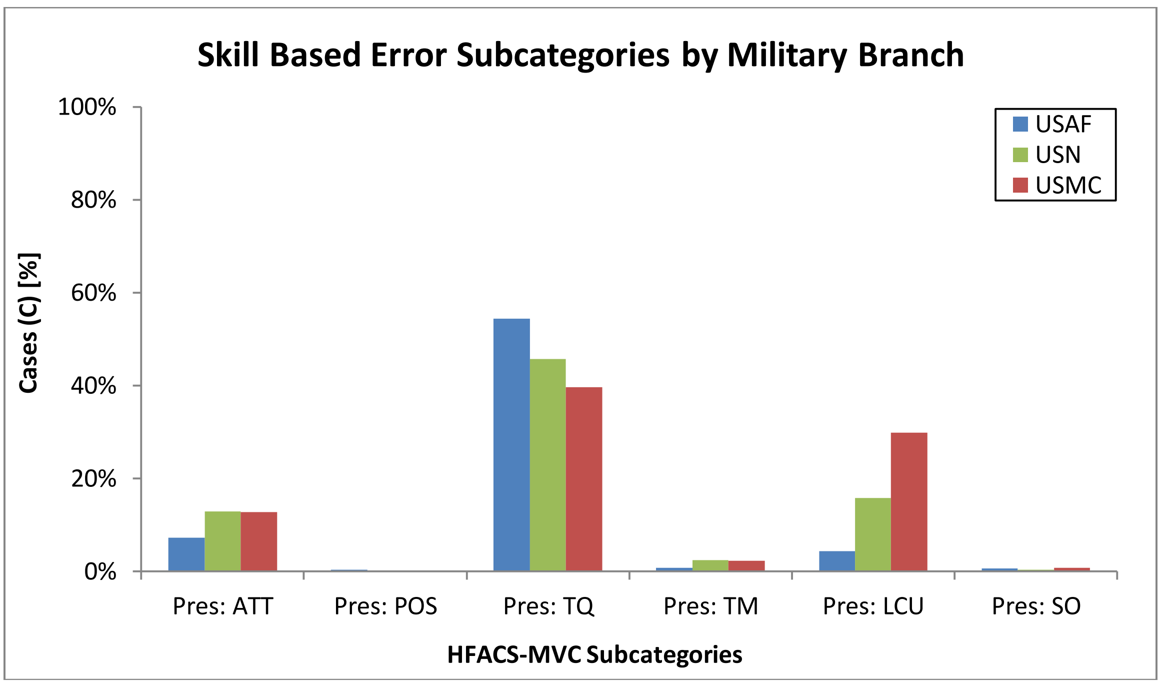

Figure 33: Skill Based Error Subcategories, percentage of cases per branch with at least one factor in subcategory

The USAF cases contained 281 skill based error nanocodes. The USN contained 297 skill based error nanocodes. The USMC cases contained 114 skill based error nanocodes. The skill based error nanocodes associated with each of the three military branches are presented in Figure 34.

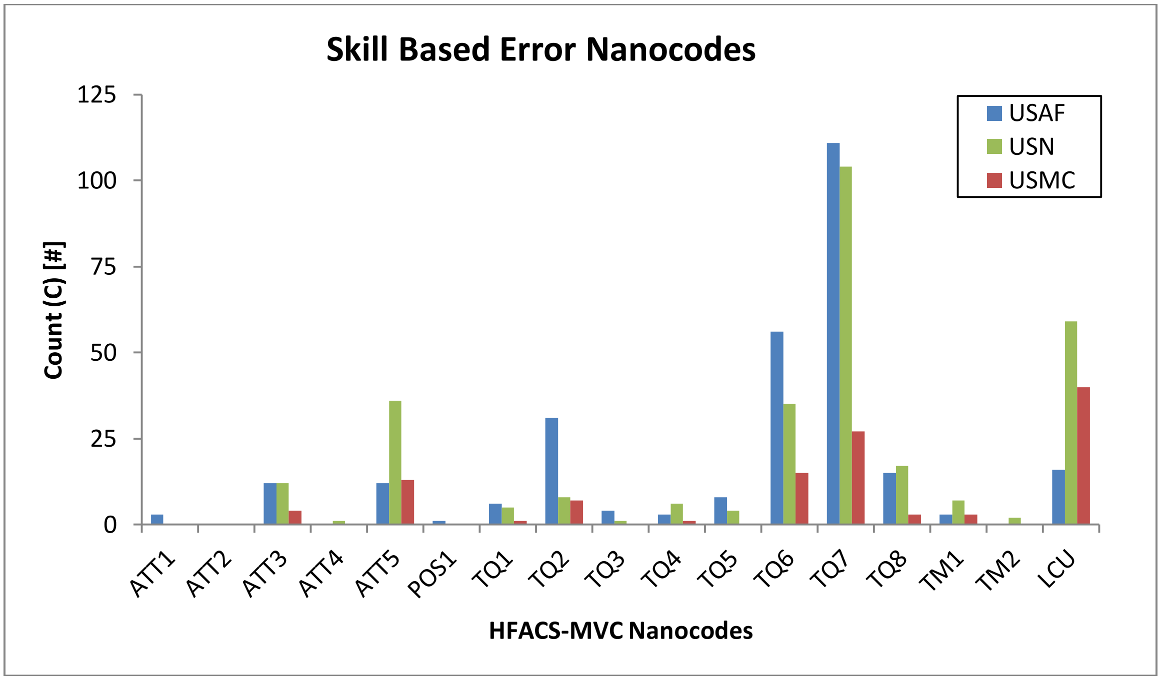

Figure 34: Skill Based Error Causal Factors, counts of nanocodes per branch

The three most common skill based errors associated with USAF MVCs were all related to technique (TQ7, TQ6, and TQ2). The most common skill based errors associated with USN MVCs were related to technique (TQ7, TQ6), control (LCU), and attention (ATT5). The most common skill based errors associated with USMC MVCs were related to technique (TQ6, TQ7) and control (LCU).

Approximately one-fourth of USN and USMC cases and one-third of USAF cases contained decision errors. Any differences amongst the branches in the percentages of cases containing decision errors were insignificant (χ^2=0.264, ns).

The percentages of USAF, USN, and USMC cases associated with each of the decision error subcategories are presented in Figure 35. The decision error subcategory trends for MVCs were similar across the military branches. The most common decision errors subcategories in MVCs for all three branches were related to situational assessment, procedures, and prioritization. However, MVCs in the USAF were associated with more prioritization errors than MVCs in either the USN or the USMC.

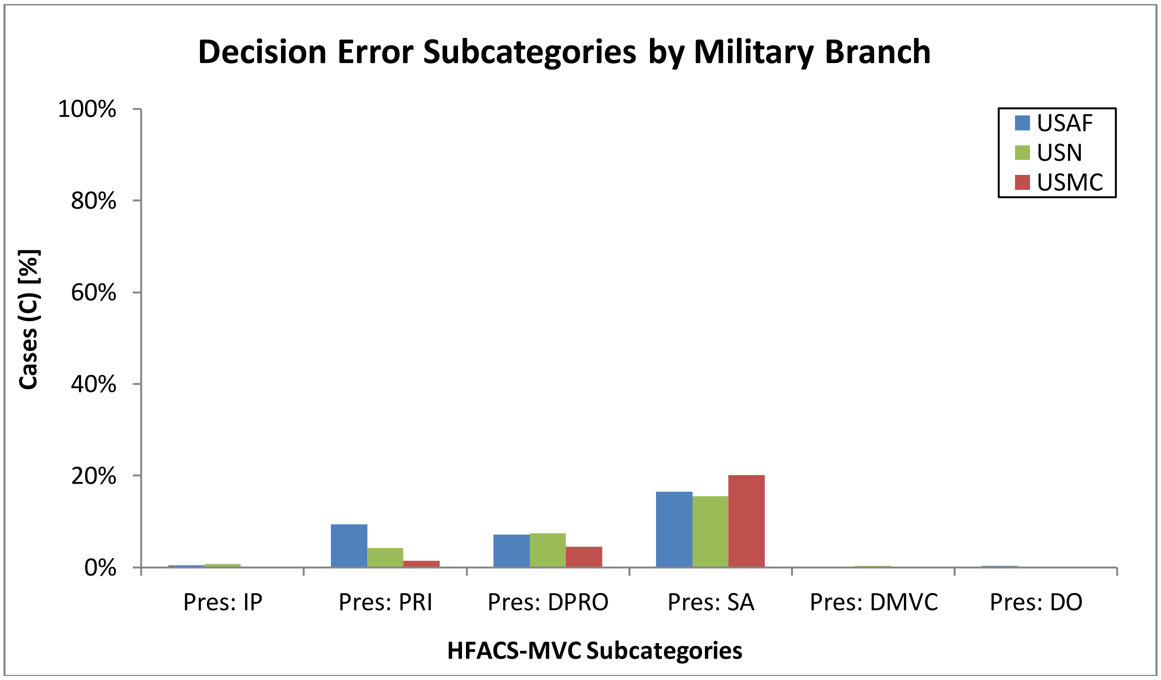

Figure 35: Decision Error Subcategories, percentage of cases per branch with at least one factor in subcategory

A little less than one-half of USN and USMC cases and two-thirds of USAF cases contained violations. Differences between the percentages of USN and USMC cases associated with violations were insignificant (χ^2=0.868, ns). In comparison, about and two-thirds of USAF cases contained violations. The percentage of cases associated with violations was significantly higher in the USAF than in both the USN (χ^2=34.607, $p<0.05$) and the USMC (χ^2=23.015, $p<0.05$). In fact, the relative odds of having a MVC involving one or more violations was over two times greater for a service member in the USAF than in the USN (OR=2.38) or the USMC (OR=2.63).

The percentages of USAF, USN, and USMC cases associated with each of the violation subcategories are presented in Figure 36. The main violation subcategories associated with cases for all three branches were all procedural in nature – speeding, drunk driving, and other. Around one-third of the USN and USMC cases but closer to one-half of the USAF cases were associated with speeding violations. Around one-fourth of the cases for all three branches were associated with drunk driving violations with the highest involvement seen for USAF cases and the least involvement seen for USMC cases. The USAF and USN contained similar percentages of cases associated with other procedural violations. A smaller percentage of USMC cases contained other procedural violations. Interestingly, the percentage of cases associated with knowledge-related violations for the USAF was approximately twice those for both the USN and USMC.

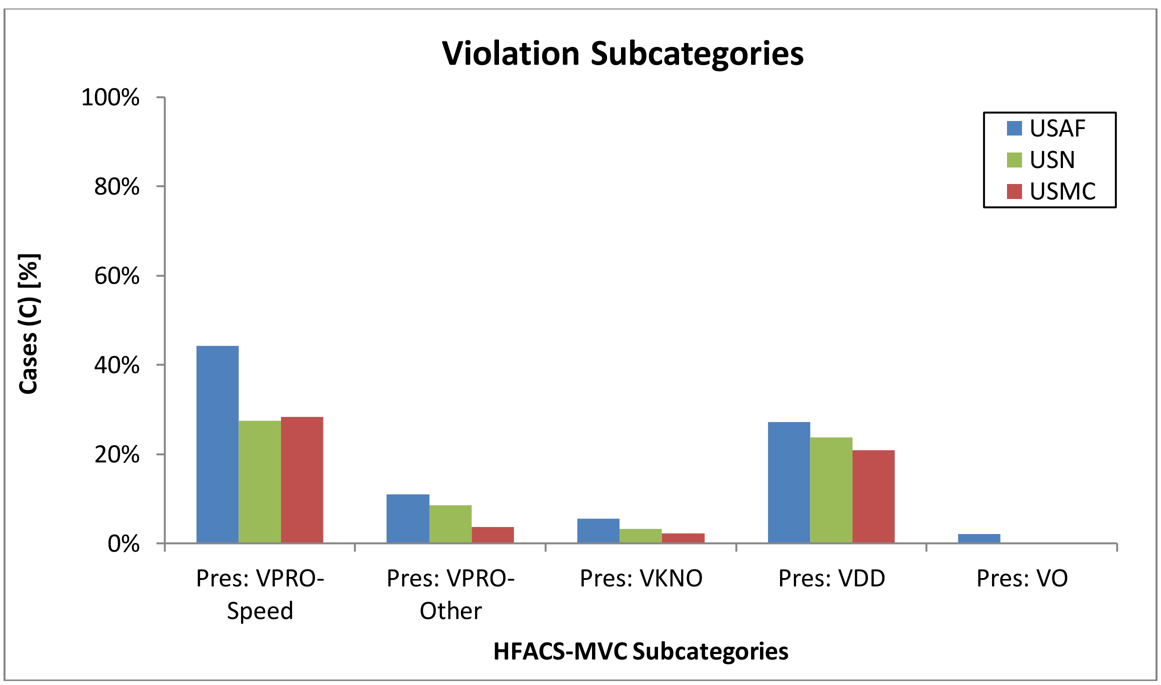

Figure 36: Violation Subcategories, percentage of cases per branch with at least one factor in subcategory

The USAF cases contained 340 violation nanocodes. The USN contained 236 violation nanocodes. The USMC cases contained 74 violation nanocodes. The violation nanocodes associated with each of the three military branches are presented in Figure 37.

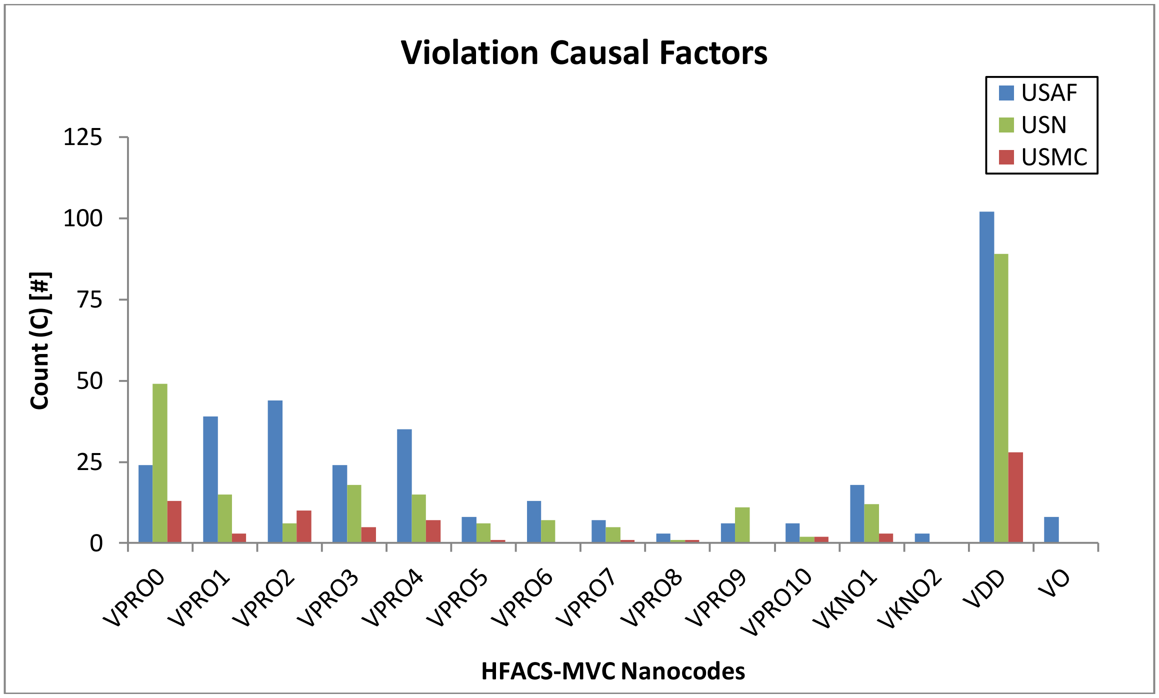

Figure 37: Violation Causal Factors, counts of nanocodes per branch

The violations associated with MVCs for the three military branches were similar. The most common violation associated with MVCs for all three branches was drunk driving (VDD). For the USAF, the top three violations were drunk driving (VDD) and travelling 10-29 mph over the speed limit (VPRO1, VPRO2). For the USN, the top three violations were drunk driving (VDD), travelling at an unknown speed in excess of the posted limit (VPRO0), and travelling 30-39 mph over the speed limit (VPRO3). For the USMC, the top three violations were drunk driving (VDD), travelling at an unknown speed in excess of the posted limit (VPRO0), and travelling 20-29 mph over the speed limit (VPRO2). The USAF cases contained a much smaller percentage of violation nanocodes classified with the nanocode VPRO0 which captures speeding at unknown speeds over the posted limit than cases for both the USN and USMC.

5.1.3 Precondition Trends

Overall, the MVC data for the three military branches exhibited similar trends at the preconditions level. Across the board, the USAF generally had the highest percentages of cases with at least one factor from each precondition causal category for six of the seven precondition causal categories with the only exception being personal readiness. The differences between the USAF as compared to the USN and USMC were most noticeable in their percentages of cases containing AMS and PML causal factors. The preconditions for unsafe act trends for the USAF, USN, and USMC are shown in Figure 38.

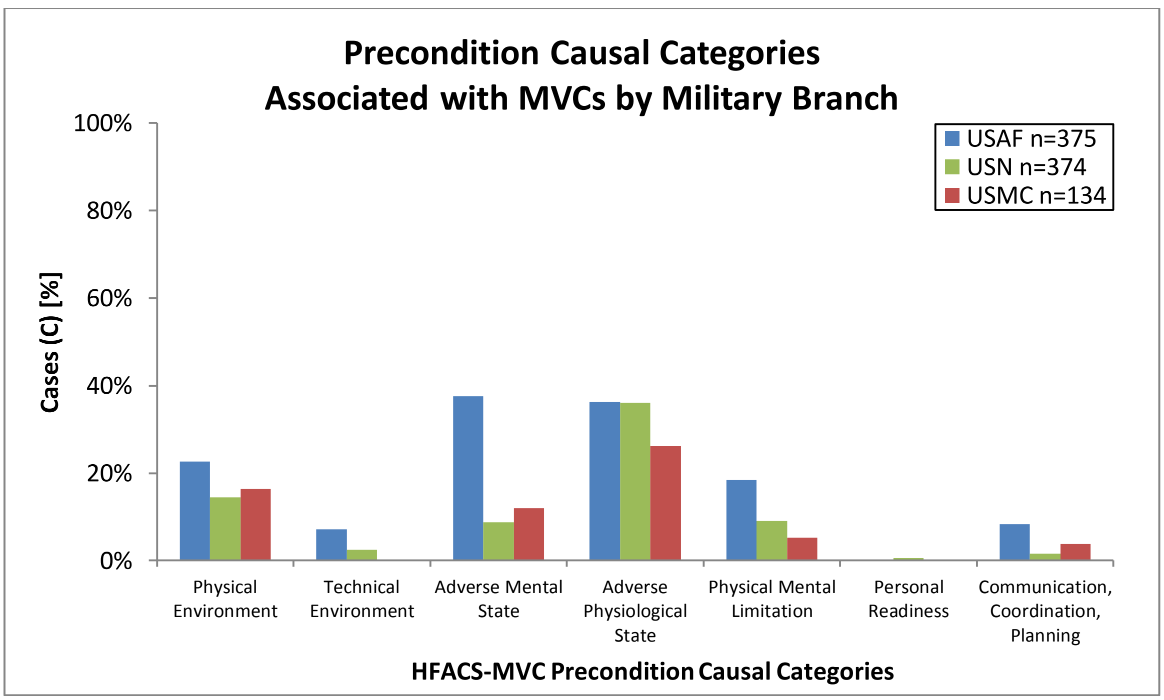

Figure 38: Preconditions Causal Categories, percentage of cases per branch with at least one factor in category

These trends suggest that there are differences in the preconditions associated with USAF, USN, and USMC MVCs. Looking at environmental conditions, significant differences were found between the branches for physical environment factors (χ^2=8.852, p<0.05) and technological environment factors (χ^2=17.716, p<0.01). Looking at operator conditions, significant differences were found between the branches for adverse mental state factors (χ^2=100.399, p<0.01) and physical/mental limitation factors (χ^2=22.459, p<0.01) but not for adverse physiological state factors (χ^2=5.084, ns). Looking at operator factors, significant differences were found between branches for communication, coordination, and planning factors (χ^2=18.713, p<0.01).

Physical environment factors were associated with approximately one-fourth of the USAF cases and between one-tenth and one-fifth of the USN and USMC cases. No significant differences were found for physical environment factors between the USMC and the USAF (χ^2=2.322, ns) or the USN (χ^2=0.304, ns). However, there was a significant difference for physical environment factors between the USAF and the USN (χ^2=8.388, p<0.05). In fact, the relative odds of a service member having a MVC associated with one or more physical environment factors was over 1.5 times greater in the USAF than in the USN (OR=1.72).

Similar percentages of USAF, USN, and USMC cases were associated with each of the four physical environment subcategories (Figure 39). The main physical environment subcategories for all three branches were related to surface conditions and visibility. Higher percentages of surface condition and visibility factors were found in cases for the USAF than for either of the other two military branches.

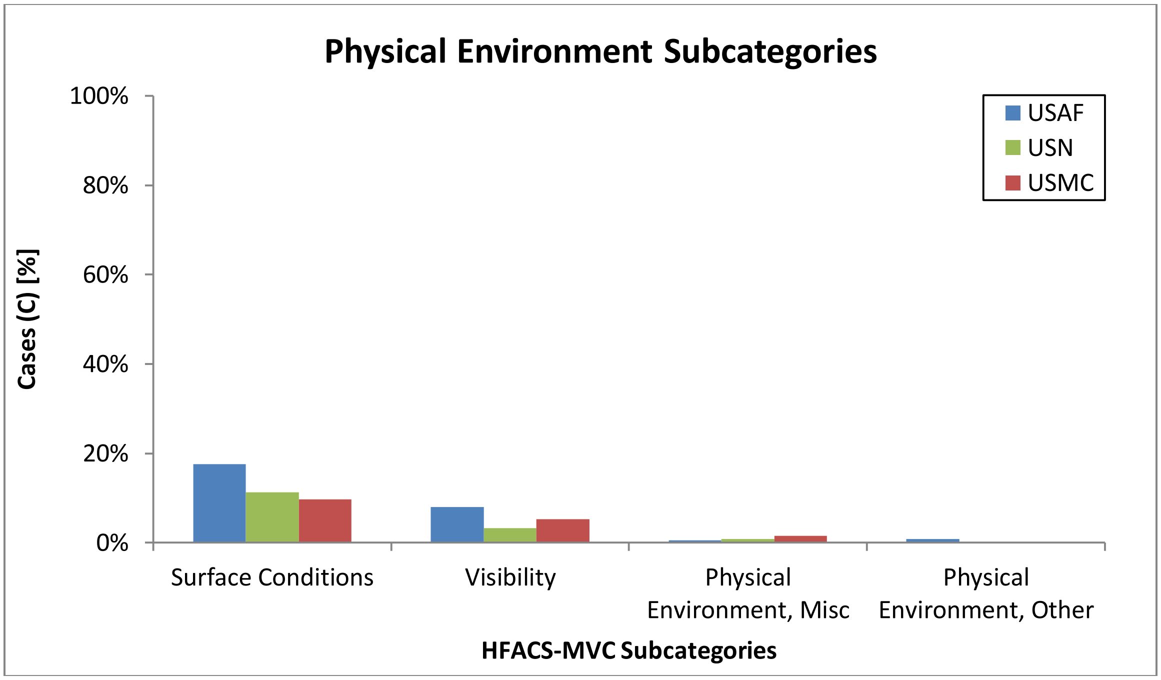

Figure 39: Physical Environment Subcategories, percentage of cases per branch with at least one factor in subcategory

The USAF cases contained 106 physical environment nanocodes. The USN contained 58 physical environment nanocodes. The USMC cases contained 22 physical environment nanocodes. The physical environment nanocodes by military branch are presented in Figure 40.

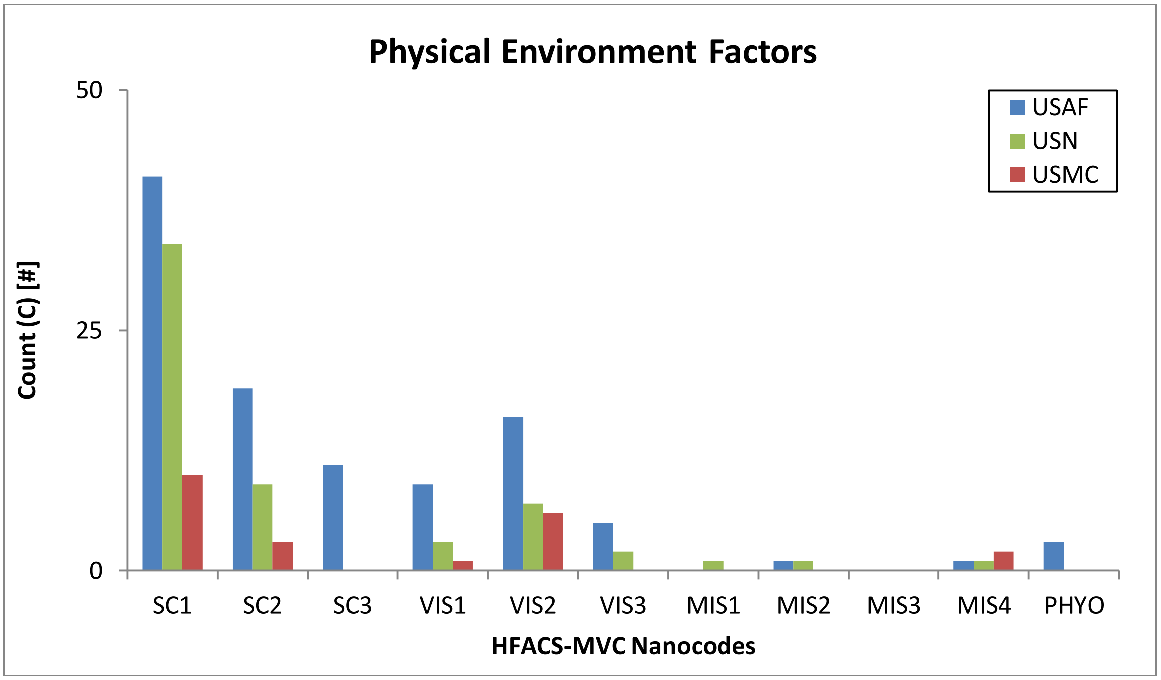

Figure 40: Physical Environment Causal Factors, count of nanocodes per branch

The physical environment conditions associated with MVCs were similar across the military branches. The most common physical environment conditions associated with MVCs in the USAF, USN, and USMC were related to surface conditions (SC1-2) and visibility (VIS2). Slippery road surface condition (SC1) was the leading physical environment factor associated with MVCs for all three military branches.

Technological environment factors were associated with less than one-tenth of the USAF cases, a miniscule percentage of the USN cases, and none of the USMC cases. No significant difference was found for technological environment factors between cases in the USN and USMC (χ^2=3.283, ns). However, the percentage of cases in the USAF associated with technological environment factors was significantly higher than the percentages of cases in both the USN (χ^2=9.404, $p<0.05$) and USMC (χ^2=10.188, $p<0.05$). The relative odds of a service member having a MVC containing one or more technological environment factors in the USAF were three times greater than in the USN (OR=3.125) and infinitely greater than in the USMC (OR=∞).

Few if any of the cases for all three branches were associated with any of the four technological environment subcategories (Figure 41). The main technological environment subcategories were related to the vehicle, protective devices on the road, and design of the road. Miniscule percentages of cases for the USN contained factors from any of the technological environment subcategories. Higher percentages of cases for the USAF contained road design and protective devices technological environment subcategories.

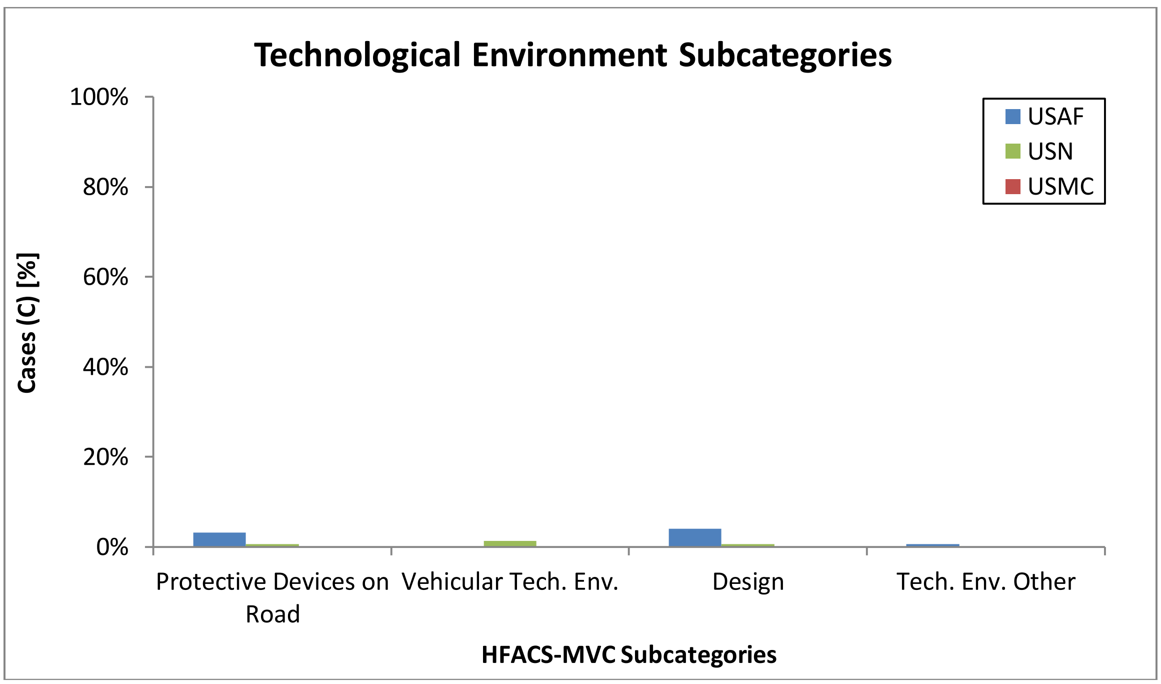

Figure 41: Technological Environment Subcategories, percentage of cases per branch with at least one factor in subcategory

The USAF cases contained 29 technological environment nanocodes. The USN contained 9 technological environment nanocodes. The USMC cases did not contain any technological environment nanocodes. The technological environment nanocodes associated with each of the three military branches are presented in Figure 42.

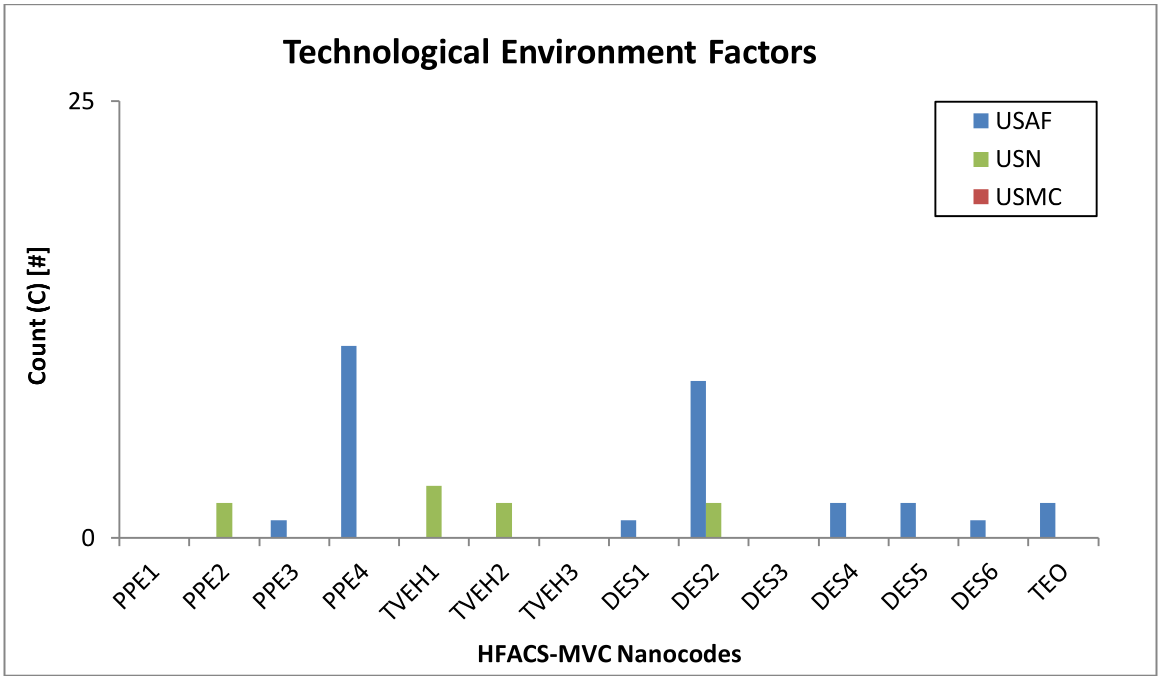

Figure 42: Technological Environment Causal Factors, count of nanocodes per branch

Technological environment conditions associated with USAF cases all related to the road environment. The top technological environment factors for the USAF captured inadequate signs (PPE4) and inadequate road design (DES2). Technological environment conditions associated with USN cases were related to the road environment and vehicle environment. The top technological environment nanocodes for the USN captured deficiencies associated with the vehicle (TVEH1), vehicular equipment (TVEH2), guardrails (PPE2), and road design (DES2).

Over one-third of USAF cases contained adverse mental state factors. In comparison, around one-tenth of USN and USMC cases contained adverse mental state factors. MVCs in the USN and USMC contained similar percentages of adverse mental state factors (χ^2=1.100, ns). However, the percentage of MVCs in the USAF associated with adverse mental state factors was significantly different from the percentages of MVCs in both the USN (χ^2=86.945, p<0.05) and USMC (χ^2=30.473, p<0.05). The odds of a service member having a MVC involving one or more adverse mental state factors in the USAF was over four times greater than in the USMC (OR=4.17) and over six times greater than in the USN (OR=6.25).

The percentages of USAF, USN, and USMC cases for all three branches associated with each of the adverse mental state subcategories are presented in Figure 43. The main adverse mental state subcategories for all three branches were related to mental fatigue/drowsiness, awareness, and attitude. However, the USAF had higher percentages of its cases associated with all five of the adverse mental state subcategories compared to both the USN and the USMC. This discrepancy was especially true for adverse mental state factors related to psychology and awareness.

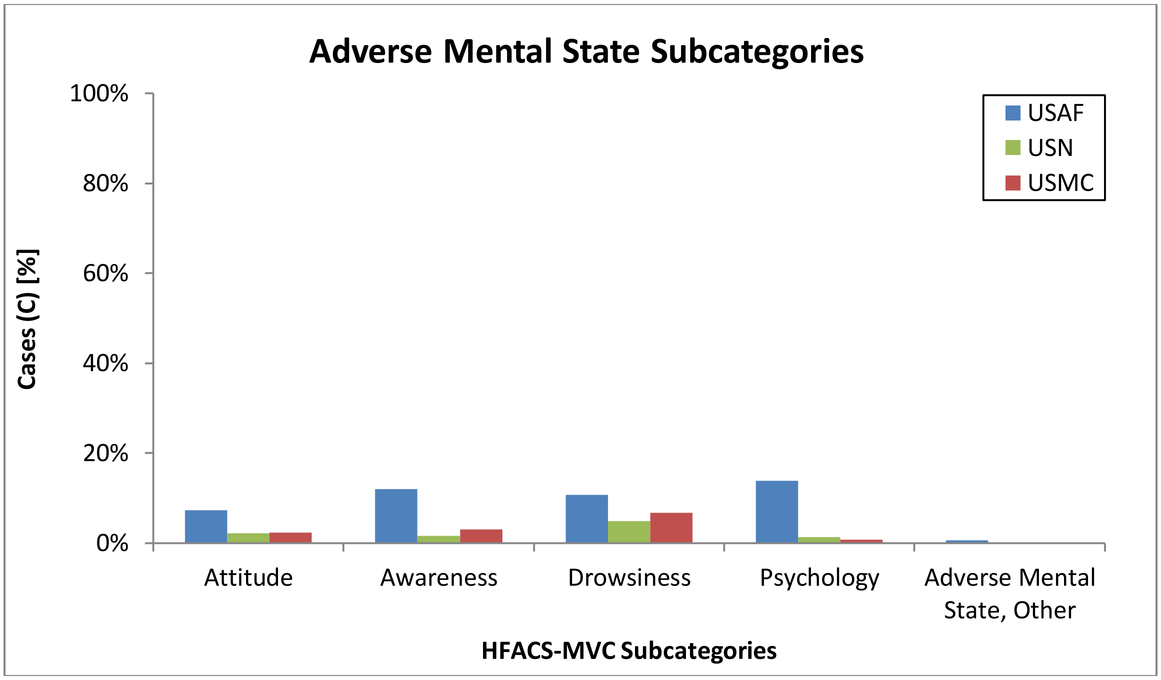

Figure 43: Adverse Mental State Subcategories, percentage of cases per branch with at least one factor in subcategory

The USAF cases contained 172 adverse mental state nanocodes. The USN contained 37 adverse mental state nanocodes. The USMC cases contained 17 adverse mental state nanocodes. The adverse mental state nanocodes associated with each of the three military branches are presented in Figure 44.

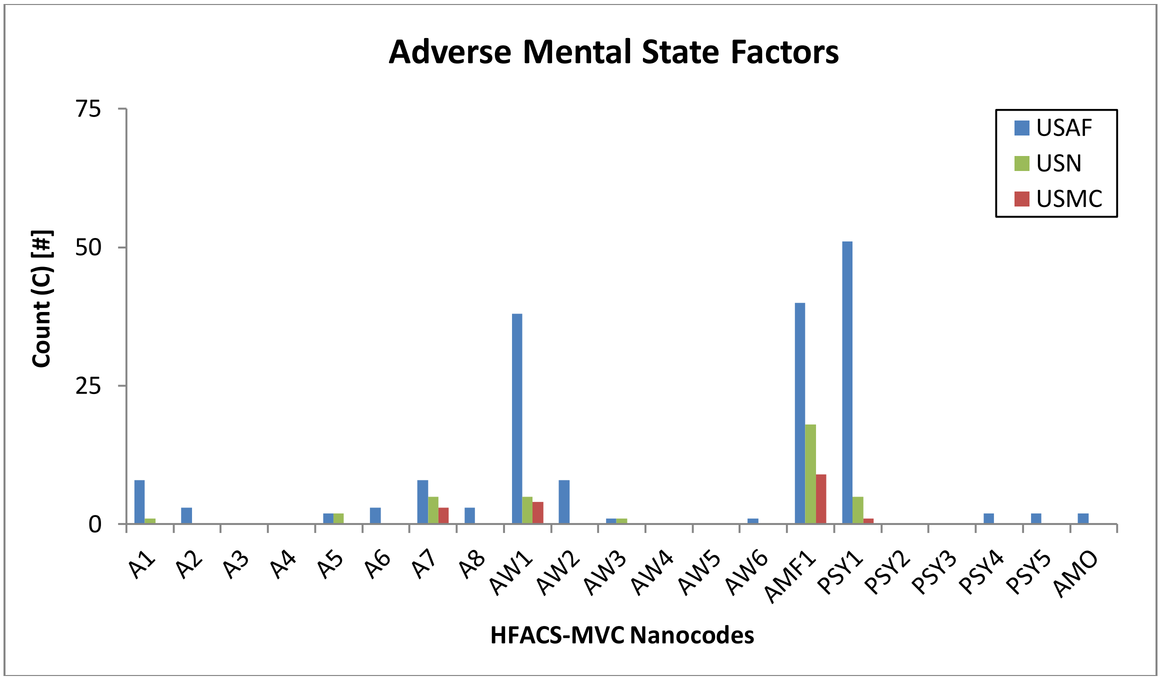

Figure 44: Adverse Mental State Causal Factors, count of nanocodes per branch

Though there were similar numbers of MVCs classified for the USAF and USN, USAF cases contained over four times as many adverse mental state factors as USN cases. For the USAF, the top adverse mental state factors were personality style (PSY1) followed by drowsiness (AMF1) and inattention/distraction (AW1). The top adverse mental state factor for both the USN and USMC was drowsiness (AMF1). Other adverse mental state factors associated with both the USN and USMC were inattention/distraction (AW1) and stress (A7).

Over one-third of USAF and USN cases and one-fourth of USMC cases contained adverse physiological state factors. Any differences between the percentages of MVCs associated with adverse physiological state factors in the USAF, USN, and USMC were insignificant (χ^2=5.084, ns). The percentages of MVCs associated with the adverse physiological state subcategories for each military branch is presented in Figure 45.

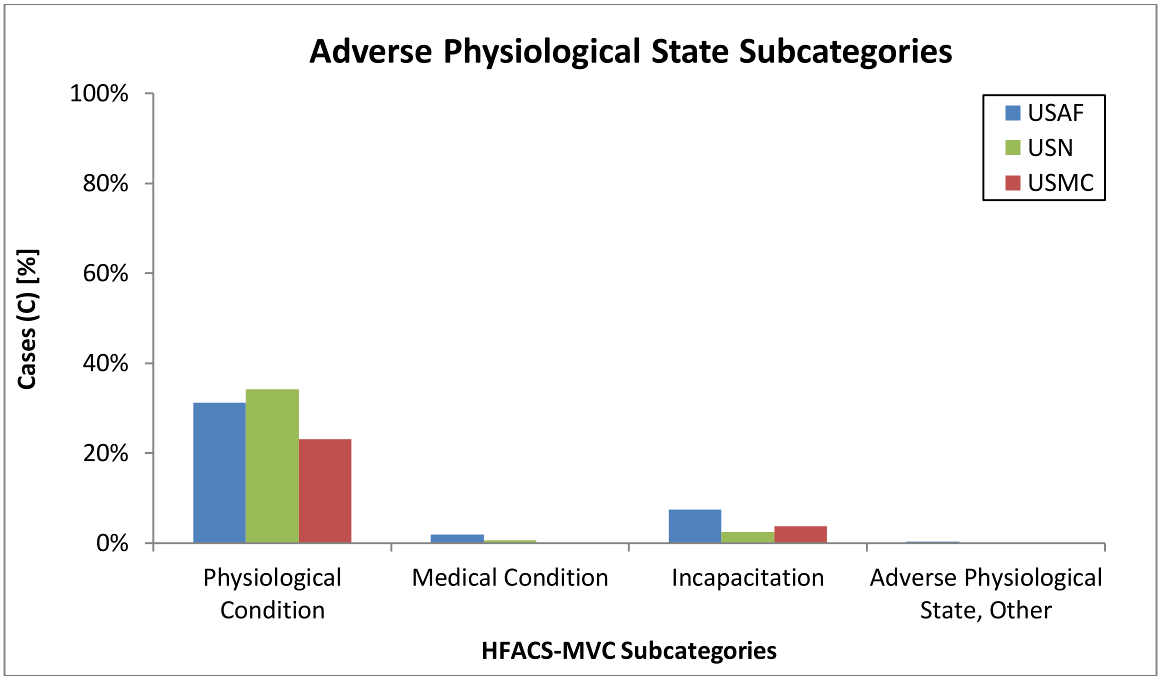

Figure 45: Adverse Mental State Subcategories, percentage of cases per branch with at least one factor in subcategory

The top physical/mental limitation subcategories associated with cases for all three branches captured physical condition followed by mental limitation and incapacitation factors. Larger percentages of USAF and USN cases were associated with physiological conditions than USMC cases with physiological condition factors identified in one-third of the USAF and USN cases and one-fourth of the USMC cases. Higher percentages of cases were associated with mental limitations, medical conditions, and incapacitation in the USAF than in the USN and USMC. The percentage of USAF cases associated with mental limitation factors was approximately double and over triple the percentages of cases associated with mental limitation factors in the USN and USMC respectively. The percentage of USAF cases associated with incapacitation factors was approximately double and over triple the percentages of cases associated with mental limitation factors in the USMC and USN respectively.

Approximately one-fifth of USAF cases contained physical/mental limitation factors. In comparison, less than one-tenth of USN and USMC cases contained physical/mental limitation factors. No significant difference in percentages of cases containing physical/mental limitation factors was found between the USN and the USMC (χ^2=1.988, ns). However, the percentage of USAF MVCs associated with physical/mental limitation factors was significantly different from the percentages of MVCs in both the USN (χ^2=13.681, $p<0.05$) and USMC (χ^2=13.494, $p<0.05$). The relative odds of a service member having a MVC involving one or more physical/mental limitation factors in the USAF was over two times greater than in the USN (OR=2.27) and over four times greater than in the USMC (OR=4.17).

The percentages of USAF, USN, and USMC cases associated with each of the physical/mental limitation subcategories are shown in Figure 46. For all three branches, the most common physical/mental limitation subcategory for MVCs captured mental limitation factors. A higher percentage of cases were associated with mental limitations for the USAF than the USN or USMC.

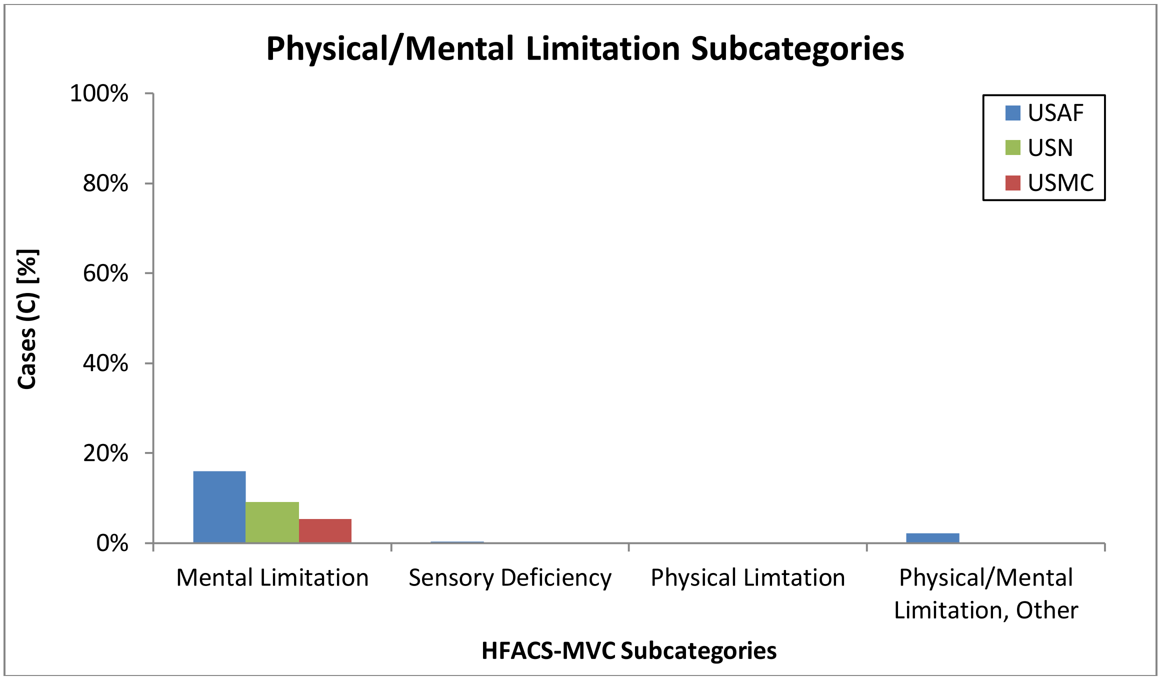

Figure 46: Physical/Mental Limitation Subcategories, percentage of cases per branch with at least one factor in subcategory

The USAF cases contained 61 physical/mental limitation nanocodes. The USN contained 34 physical/mental limitation nanocodes. The USMC cases contained only 7 adverse mental state nanocodes. The physical/mental limitation nanocodes associated with each of the three military branches are presented in Figure 47.

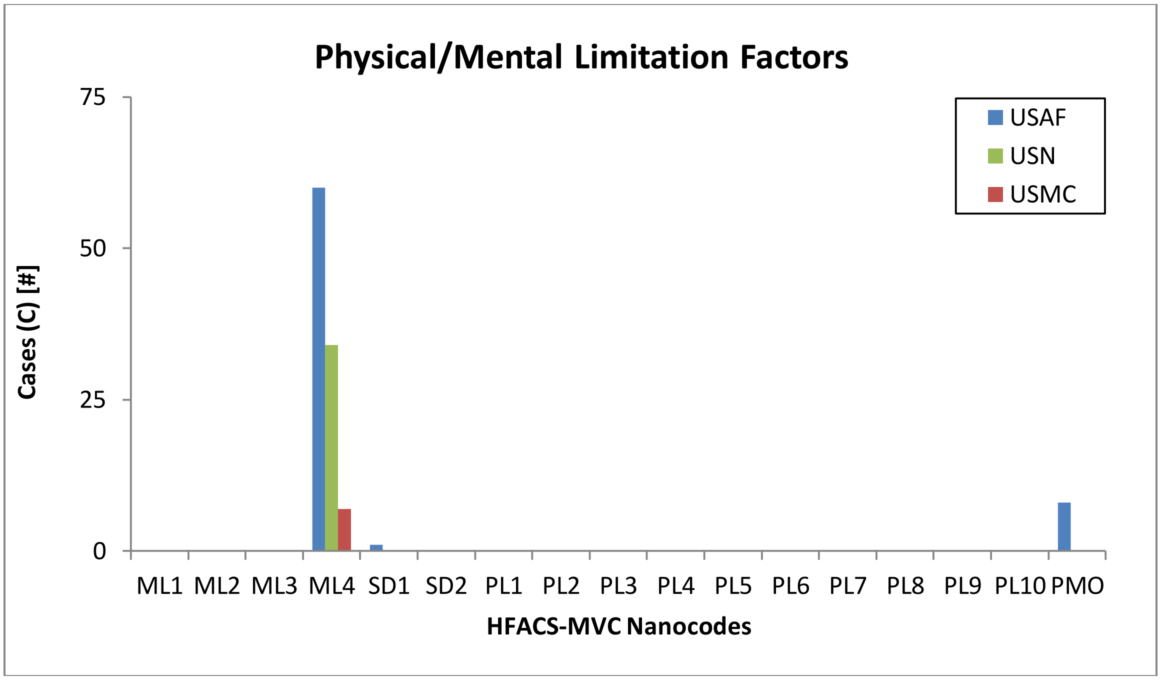

Figure 47: Physical/Mental Limitation Causal Factors, count of nanocodes per branch

The top physical/mental limitation factor associated with cases for all three branches involved limited experience or proficiency (ML4). In fact, limited experience or proficiency was the primary physical/mental limitation factor classified for the USAF and the sole physical/mental limitation factor classified for the USN and the USMC.

Factors from the category of communication, coordination, and planning were present in less than one-tenth and one-twentieth of cases in the USAF and USN respectively. Insignificant differences in the percentages of cases associated with communication, coordination, and planning factors were found between the USMC and both the USN (χ^2=2.107, ns) and the USAF (χ^2=3.090, ns). However, a significant difference was found between the percentages of cases associated with communication, coordination, and planning factors for the USN and USAF (χ^2=17.000, p<0.05). The relative odds of a service member having a MVC associated with one or more communication, coordination, and planning factors was over five times greater in the USAF than in the USN (OR=5.56).

Small percentages of cases for all three branches were associated with each of the four communication, coordination, and planning subcategories (Figure 48). The leading communication, coordination, and planning subcategory for all three branches captured planning factors. The USAF contained higher percentages of cases associated with all four communications, coordination, and planning subcategories.

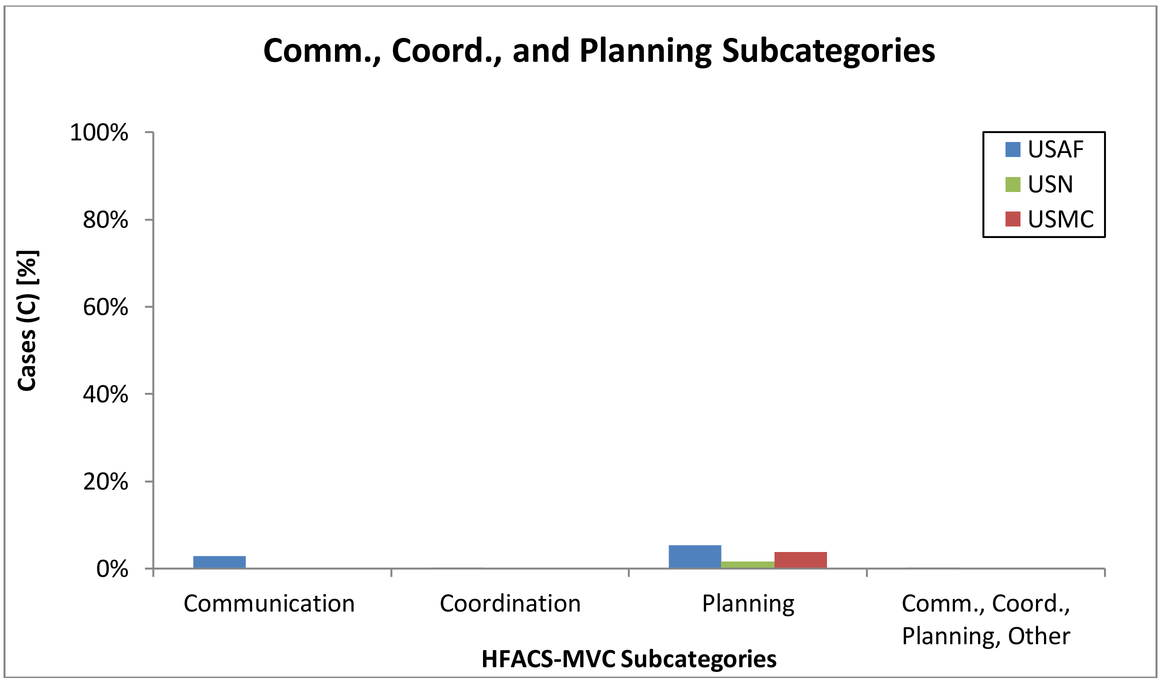

Figure 48: Comm., Coord., and Planning Subcategories, percentage of cases per branch with at least one factor in subcategory

The USAF cases contained 35 communication, coordination, and planning nanocodes. The USN cases contained 5 communication, coordination, and planning nanocodes. The USMC cases contained 6 communication, coordination, and planning nanocodes. The communication, coordination, and planning nanocodes associated with each of the three military branches are presented in Figure 49.

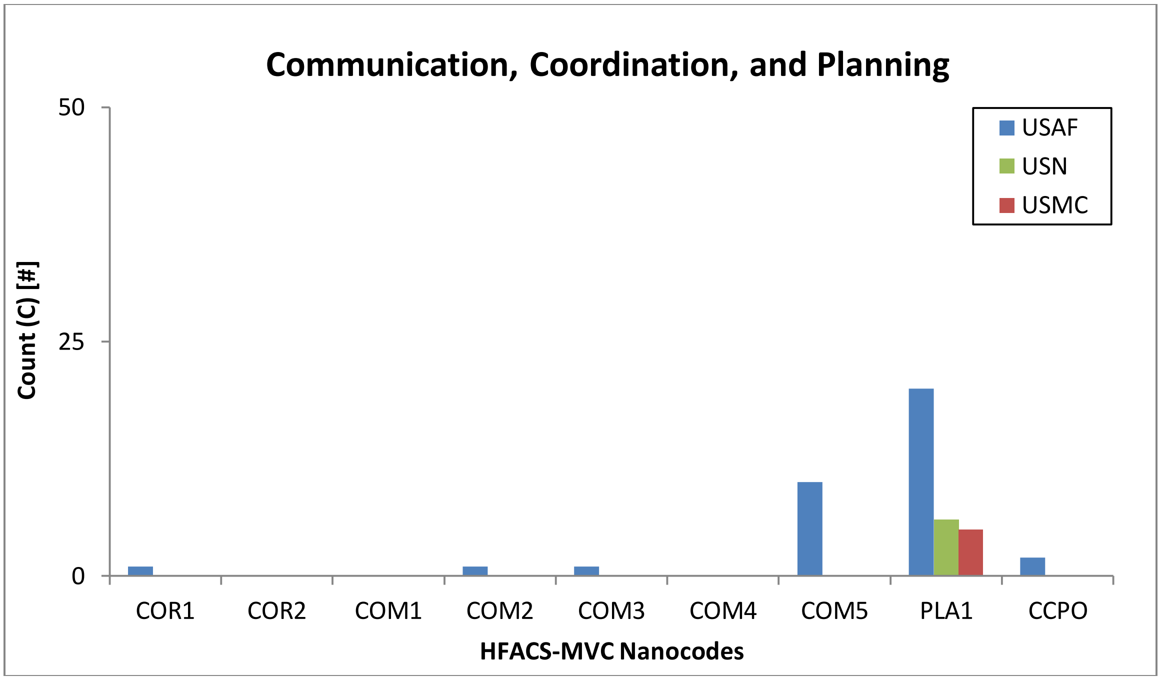

Figure 49: Comm., Coord., and Planning Causal Factors, count of nanocodes per branch

For all three branches, the leading communication, coordination, and planning factor associated with MVCs was related to poor travel planning (PLA1). In fact, poor travel planning was the primary communication, coordination, and planning factor classified for the USAF and the sole communication, coordination, and planning factor classified for the USN and the USMC. Following poor travel planning, the next most common communication, coordination, and planning factor classified for the USAF was related to inadequate transfer of knowledge between road users (COM5).

5.2 VEHICLE TYPES: 2W, 4W

The final dataset contained cases involving operators of both 2W and 4W vehicles. Though more cases involved 4W vehicles (n=548), a sizeable portion of the cases involved 2W vehicles (n=335). There were a total of 978 and 1,664 nanocodes classified for cases involving 2W and 4W vehicles respectively. As such, there were 2.9 factors per case for 2W MVCs and 3.0 factors per case for the 4W MVCs.

5.2.1 Temporal Trends

The temporal trends comparing MVCs by vehicle type are shown in Figure 50. This comparison used the percentages of MVCs that involved 2W and 4W vehicles each fiscal year. This was done to account for any differences in the number of services providing MVC data each fiscal year.

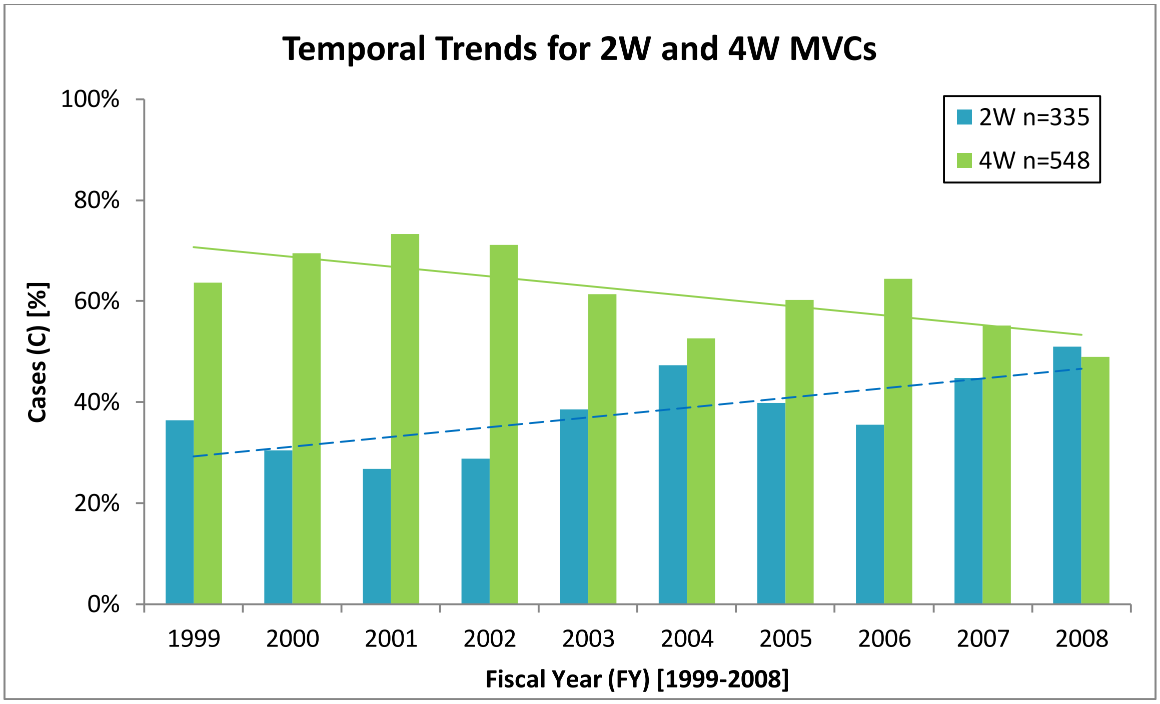

Figure 50: Temporal Trends of MVC Cases by Vehicle Type

Earlier in the decade between FY1999 and FY2008, 2W vehicles were involved in approximately one third of the total MVCs each year. Over time, however, there was an upward trend in the involvement of 2W vehicles relative to 4W vehicles involved in MVCs each fiscal year. The data suggest that the contributing percentages of 2W and 4W MVCs are trending towards a 50/50 split where half of the MVCs involve 2W vehicles and half of the MVCs involve 4W vehicles each year.

5.2.2 Unsafe Act Trends

The unsafe act trends for 2W and 4W MVCs are shown in Figure 51. The percentages of cases associated with the four categories of unsafe acts were practically identical for 2W and 4W MVCs. No significant differences were found between 2W and

4W MVCs for skill based errors (χ^2=0.642, ns), decision errors (χ^2=0.745, ns), or violations (χ^2=0.490, ns).

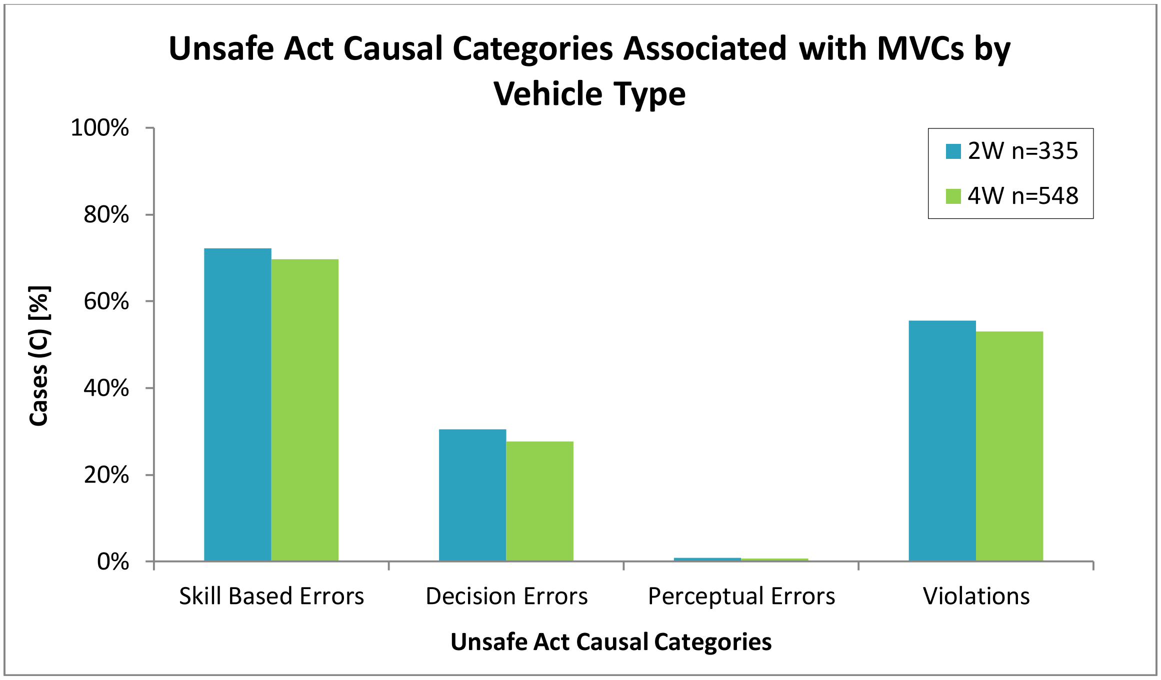

Figure 51: Unsafe Acts for 2W and 4W MVCs, percentages of cases containing at least one factor in category

Even though no significant differences were identified at the causal category level, the causal subcategories associated with MVCs for each vehicle type were identified. The percentages of 2W and 4W cases associated with skill based error causal factor subcategories are presented in Figure 52. The main skill based error subcategories were similar for 2W and 4W MVCs. Common skill based error subcategories for both vehicle types were related to technique, attention, and control. However, 2W MVCs were associated with more technique errors while 4W MVCs were associated with more attention errors and control errors.

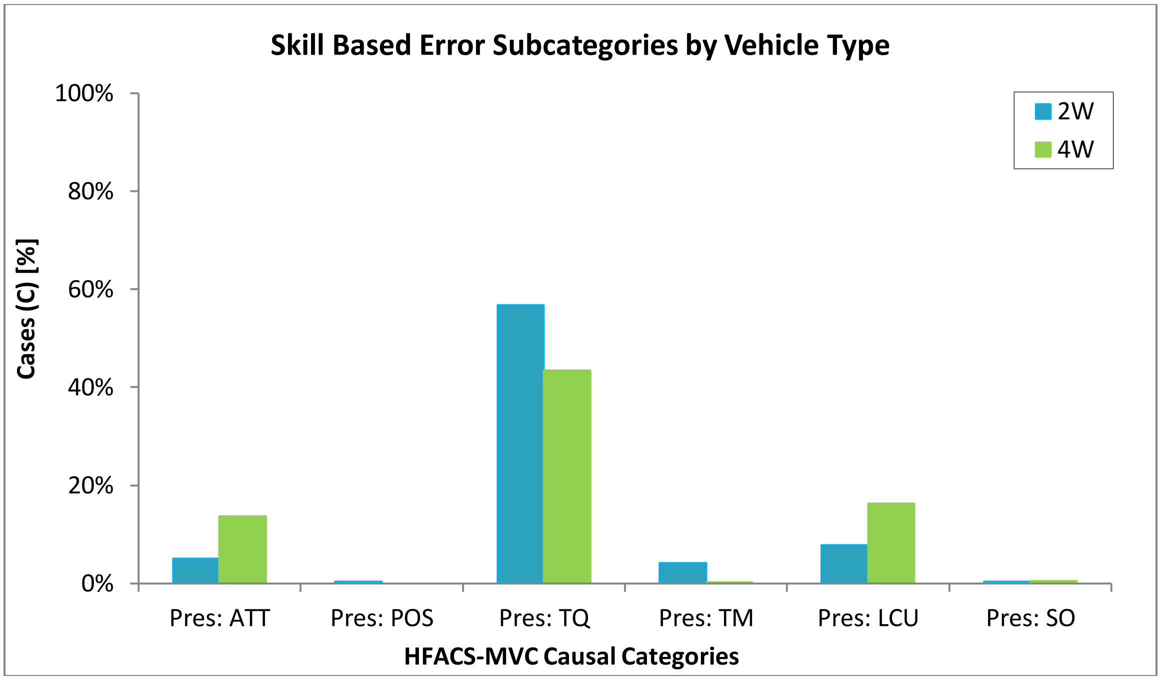

Figure 52: Skill Based Error Subcategories, percentage of cases per vehicle type with at least one factor in subcategory

The percentages of 2W and 4W cases associated with decision error causal factor subcategories are presented in Figure 53. The decision error subcategory trends for MVCs were almost identical for the two vehicle types. The most common decision errors subcategories for both 2W and 4W MVCs were related to situational assessment, procedures, and prioritization.

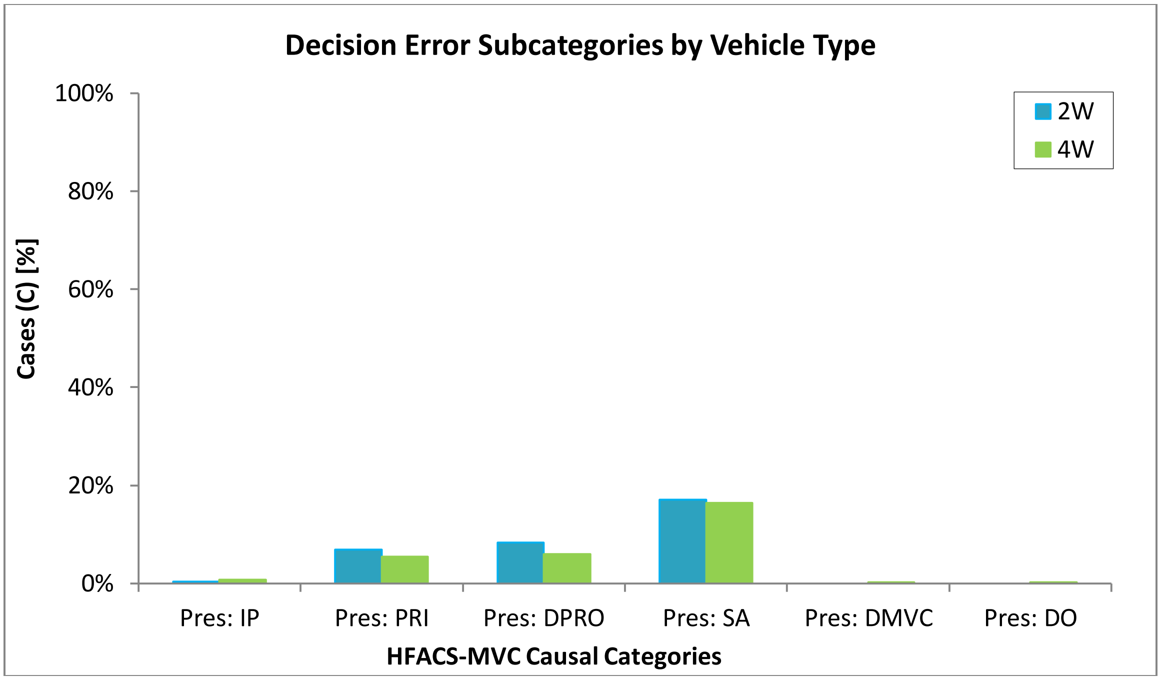

Figure 53: Decision Error Subcategories, percentage of cases per vehicle type with at least one factor in subcategory

The percentages of 2W and 4W cases associated with violation causal factor subcategories are presented in Figure 54. The main violation subcategories were similar for 2W and 4W MVCs. Common violation subcategories for both vehicle types related to speeding and drunk driving. However, 2W MVCs were associated with more speeding and knowledge violations while 4W MVCs were associated with more drunk driving violations.

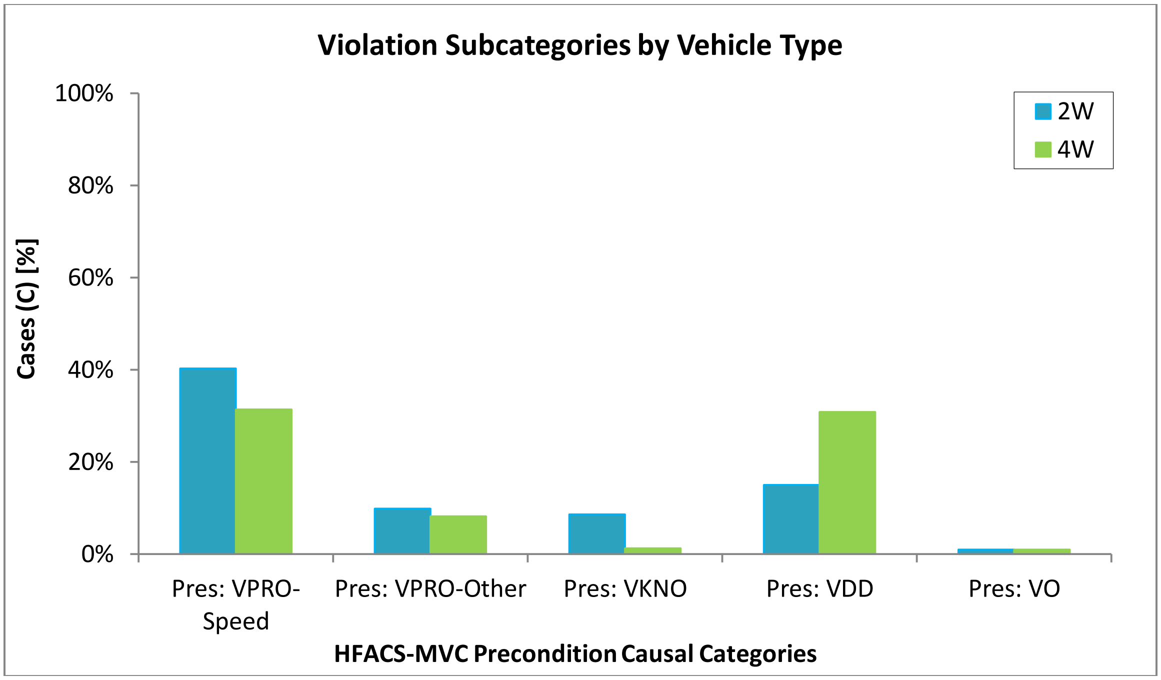

Figure 54: Violation Subcategories, percentage of cases per vehicle type with at least one factor in subcategory

5.2.3 Precondition Trends

The precondition trends for 2W and 4W MVCs are shown in Figure 59. These trends suggest that differences exist in the preconditions associated with 2W and 4W MVCs. Several of the causal pattern trends for preconditions were found to be significantly different for MVCs involving 2W and 4W vehicles.

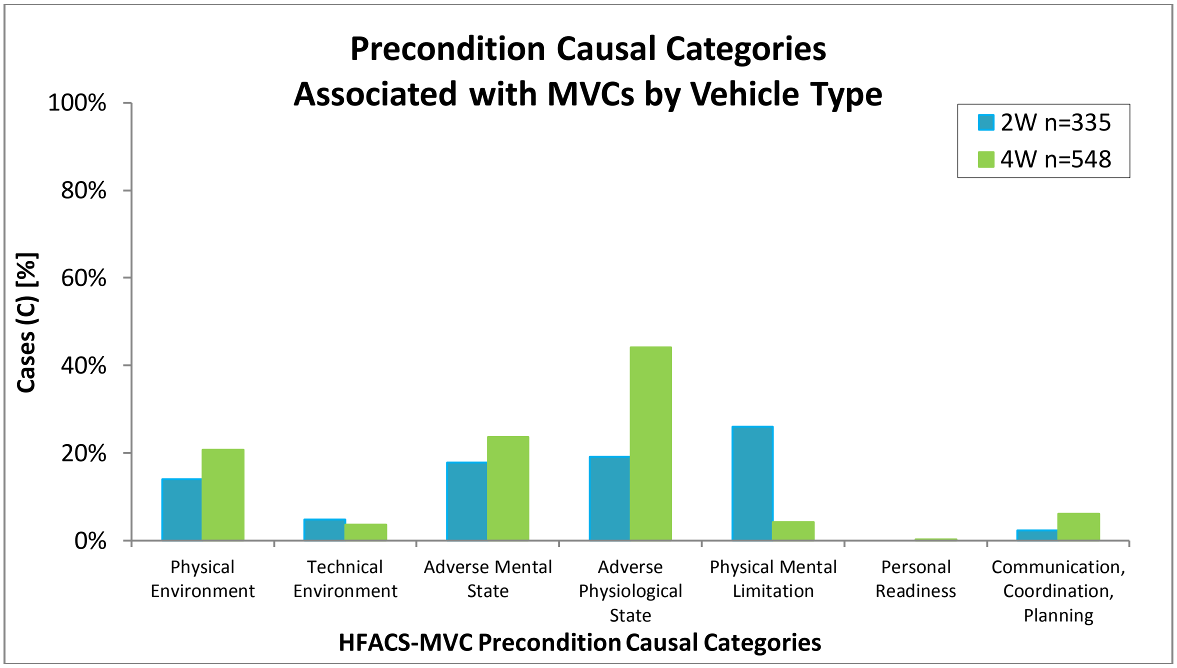

Figure 55: Preconditions by Vehicle Type, percentage of cases per vehicle type with at least one factor in category

Looking at environmental conditions, the difference between 2W and 4W MVCs was significant for physical environment factors (χ^2=6.397, p<0.05) but not for technological environment factors (χ^2=0.675, ns). Approximately one-tenth of the 2W cases and one-fifth of the 4W cases were associated with physical environment factors. The relative odds of a service member having a MVC associated with one or more physical environment factors was over 1.5 times greater in a 4W vehicle than on a 2W vehicle (OR=1.61). About one-twentieth of the cases for both 2W and 4W vehicles were associated with technological environment factors.

The percentages of 2W and 4W cases associated with each of the physical environment subcategories are presented in Figure 56. The leading physical environment subcategories for both vehicle types were surface conditions followed by visibility.

Higher percentages of cases were associated with surface condition and visibility physical environment factors for 4W vehicles compared to 2W vehicles.

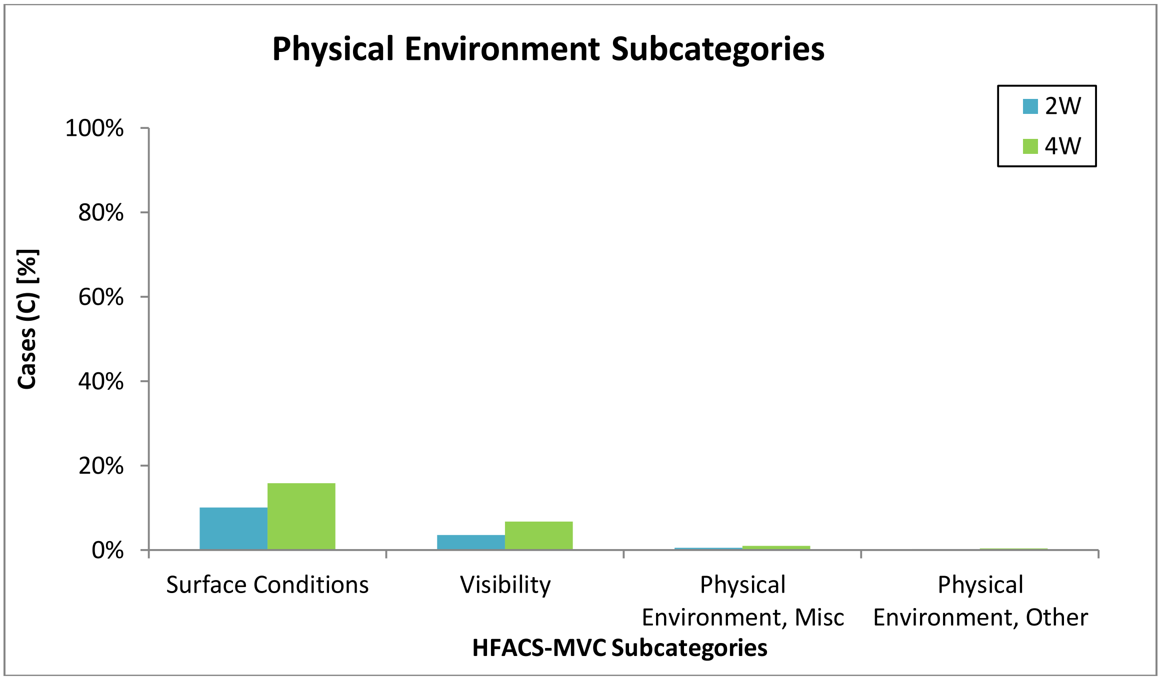

Figure 56: Physical Environment Subcategories, percentage of cases per vehicle type with at least one factor in subcategory

The 2W vehicle cases contained 51 physical environment nanocodes. The 4W vehicle cases contained 135 physical environment nanocodes. The physical environment nanocodes associated with the two vehicle types are presented in Figure 57.

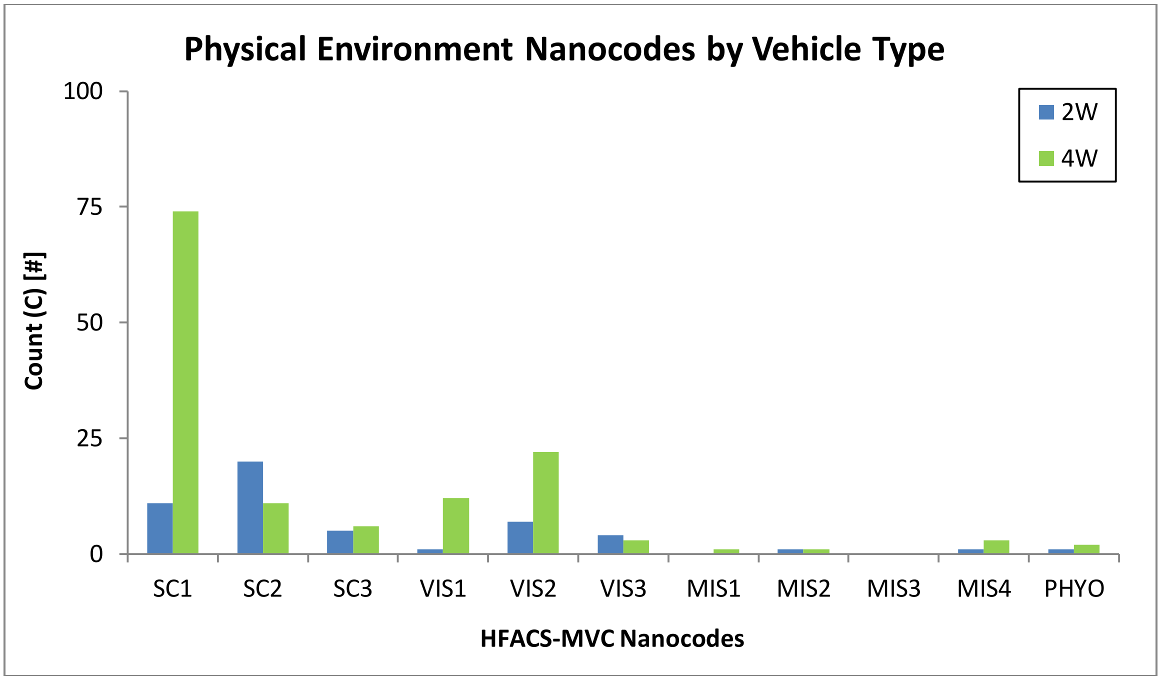

Figure 57: Physical Environment Causal Factors, count of nanocodes by vehicle type

The leading physical environment causal factors for both 2W and 4W MVCs were related to road surface conditions followed by visibility issues. For 4W MVCs, the most common physical environment factors were slippery road conditions (SC1) followed by inadequate visibility issues stemming from insufficient lighting (VIS2) and ambient weather conditions (VIS1). For 2W MVCs, the most common physical environment factors were road surface debris (SC2) followed by slippery road conditions (SC1) and inadequate visibility due to insufficient lighting (VIS2). Fewer 4W MVCs were associated with road surface debris (SC2) and obscured view of traffic due to interaction of vehicle and environment (VIS3) compared to 2W MVCs. Fewer 2W MVCs were associated with slippery road surface (SC1) and inadequate visibility due to weather conditions like sun glare, fog, rain, or snow (VIS1) compared to 4W MVCs.

Looking at operator conditions, significant differences were found between 2W and 4W MVCs for all causal categories – adverse mental state factors, adverse physiological state factors, and physical/mental limitation factors. Cases for 4W vehicles contained more adverse mental and physiological state factors. Cases for 2W vehicles contained more physical/mental limitation factors.

Approximately one-fifth of 2W cases and one-fourth of 4W cases contained adverse mental state factors. Cases for 2W vehicles were associated with significantly fewer adverse mental state factors compared to cases for 4W vehicles (χ^2=4.159, $p<0.05$). The relative odds of a service member having a MVC associated with one or more adverse mental state factors was almost 1.5 times greater in a 4W vehicle than on a 2W vehicle (OR=1.43).

The percentages of 2W and 4W cases associated with adverse mental state subcategories are presented in Figure 58. Similar percentages of 2W and 4W cases were associated with attitude and awareness adverse mental state subcategories. The leading adverse mental state subcategories for 2W and 4W cases were drowsiness and psychology respectively. The top adverse mental state subcategory for 2W cases was psychology. One-tenth of the 2W cases but less than one-twentieth of the 4W cases were associated with psychology factors. The top adverse mental state subcategory for 4W cases was drowsiness. Around one-tenth of the 4W cases but less than one-fortieth of the 2W cases were associated with drowsiness factors.

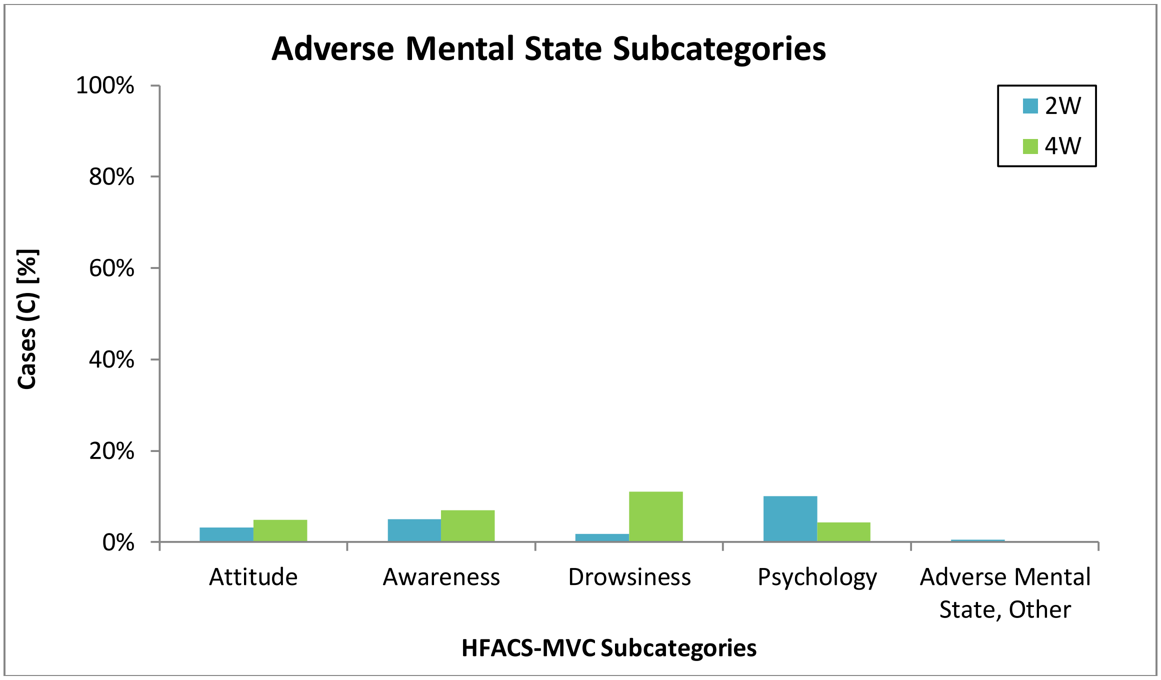

Figure 58: Adverse Mental State Subcategories, percentage of cases per vehicle type with at least one factor in subcategory

The 2W vehicle cases contained 73 adverse mental state nanocodes. The 4W vehicle cases contained 153 adverse mental state nanocodes. The adverse mental state nanocodes associated with the two vehicle types are presented in Figure 59.

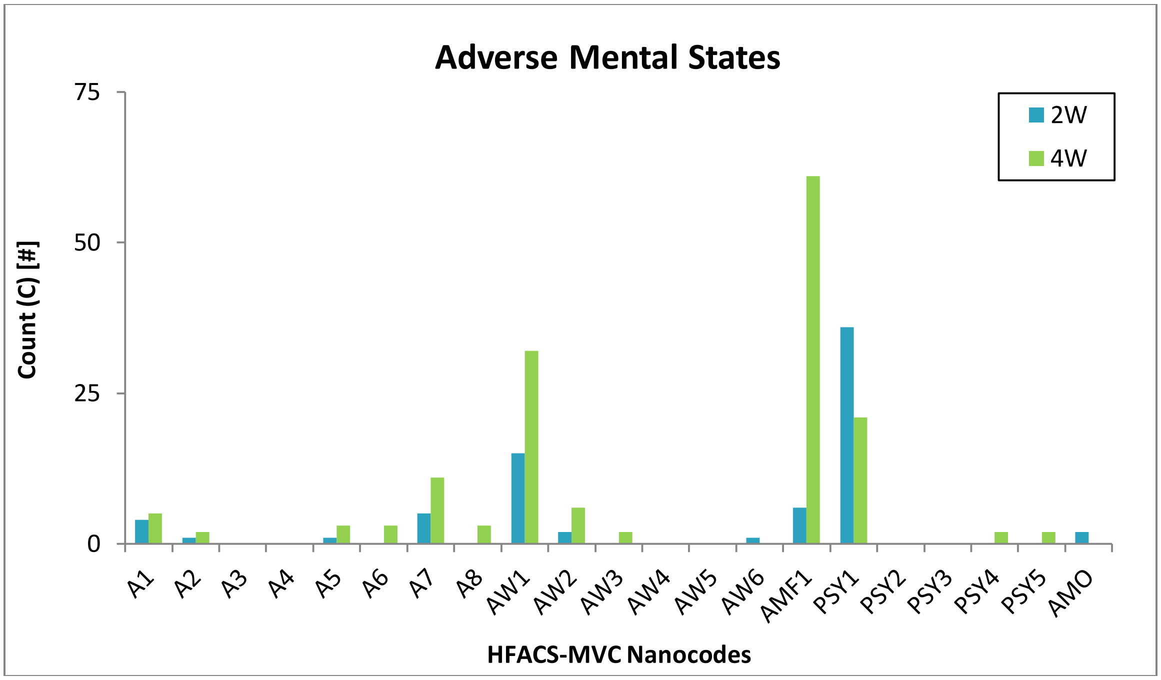

Figure 59: Adverse Mental State Factors, counts of adverse mental state nanocodes per vehicle type

The leading adverse mental state causal factors associated with both 2W and 4W MVCs were drowsiness (AMF1), personality style (PSY1), and inattention/distraction (AW1). However, 2W and 4W MVCs contained different proportions of these adverse mental state factors. More 2W MVCs were associated with personality style (PSY1) than 4W MVCs. More 4W MVCs were associated with drowsiness (AMF1) than 2W MVCs. For 2W MVCs, the most common adverse mental state factors are personality style (PSY1) followed by inattention/distraction (AW1) then drowsiness (AMF1). For 4W MVCs, the most common adverse mental state factors are drowsiness (AMF1) followed by inattention/distraction (AW1) then personality style (PSY1).

Slightly less than one-fifth of 2W cases contained adverse physiological state factors. In comparison, almost one-half of 4W cases contained adverse physiological state factors. Cases for 2W vehicles were associated with significantly fewer adverse physiological state factors than cases for 4W vehicles (χ^2=57.639, p<0.01). The relative odds of a service member having a MVC associated with one or more adverse physiological state factors was almost 3.5 times greater in a 4W vehicle than on a 2W vehicle (OR=3.35).

The percentages of 2W and 4W cases associated with adverse physiological state subcategories are presented in Figure 60. The top adverse physiological state subcategory for both 2W and 4W cases captured physiological conditions. However, the percentages of the cases associated with physiological conditions were different for each of these vehicle types. Two-fifths of the 4W cases compared to one-fifth of the 2W cases contained at least one physiological condition causal factor. The percentages of cases involving incapacitation also differed by vehicle type. Almost one-tenth of the 4W cases but none of the 2W cases contained incapacitation causal factors.

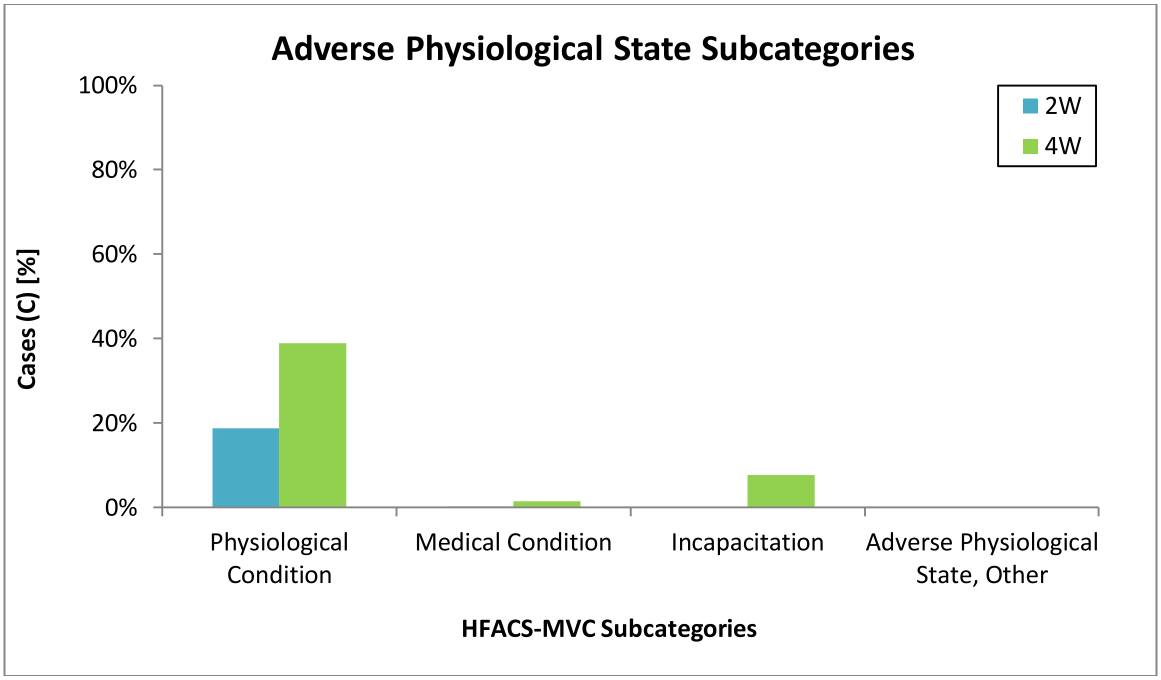

Figure 60: Adverse Physiological State Subcategories, percentage of cases per vehicle type with at least one factor in subcategory

The 2W vehicle cases contained 64 adverse physiological state nanocodes. The 4W vehicle cases contained 265 adverse physiological state nanocodes. The adverse physiological state nanocodes associated with the two vehicle types are presented in Figure 61.

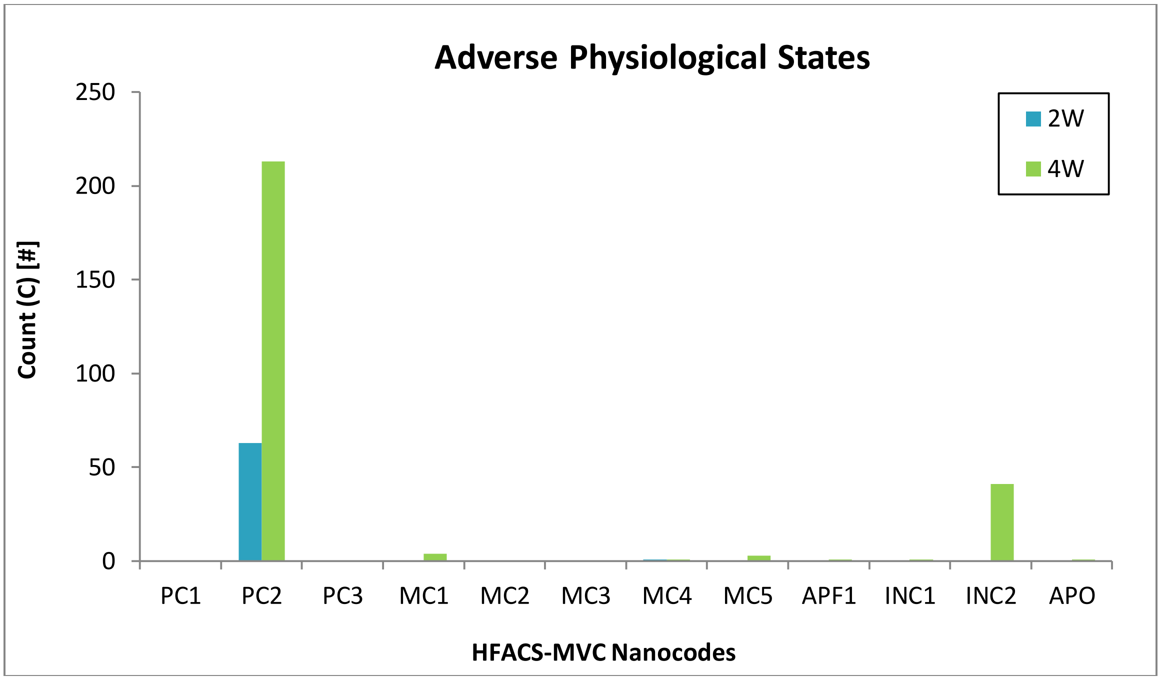

Figure 61: Adverse Mental State Causal Factors, count of nanocodes per vehicle type

The leading adverse physiological state factor associated with both 2W and 4W MVCs was impairment due to drugs or alcohol (PC2). In fact, impairment was the primary adverse physiological state factor classified for 4W MVCs and the sole adverse physiological state factor classified for 2W MVCs. Following impairment, the next most common adverse physiological state factor classified for 4W MVCs was incapacitation due to falling asleep (INC2). None of the 2W MVCs contained incapacitation factors related to falling asleep or otherwise.

In contrast to adverse mental and physiological state factors, physical/mental limitation factors are associated with significantly more MVCs for 2W vehicles than 4W vehicles (χ^2=90.376, p<0.01). Less than one-twentieth of 2W cases contained physical/mental limitation factors compared to over one-fourth of 4W cases. The relative odds of a service member having a MVC associated with one or more physical/mental limitation factors was over eight times greater on a 2W vehicle than in a 4W vehicle (OR=8.33).

The percentages of 2W and 4W cases associated with each of the physical/mental limitation subcategories are presented in Figure 62. The leading physical environment subcategory for both vehicle types captured mental limitation factors. However, the percentage of cases with mental limitation factors was eight times higher for 2W vehicles than for 4W vehicles. In fact, one-fourth of all 2W cases contained at least one mental limitation causal factor compared to one-thirtieth of the 4W cases.

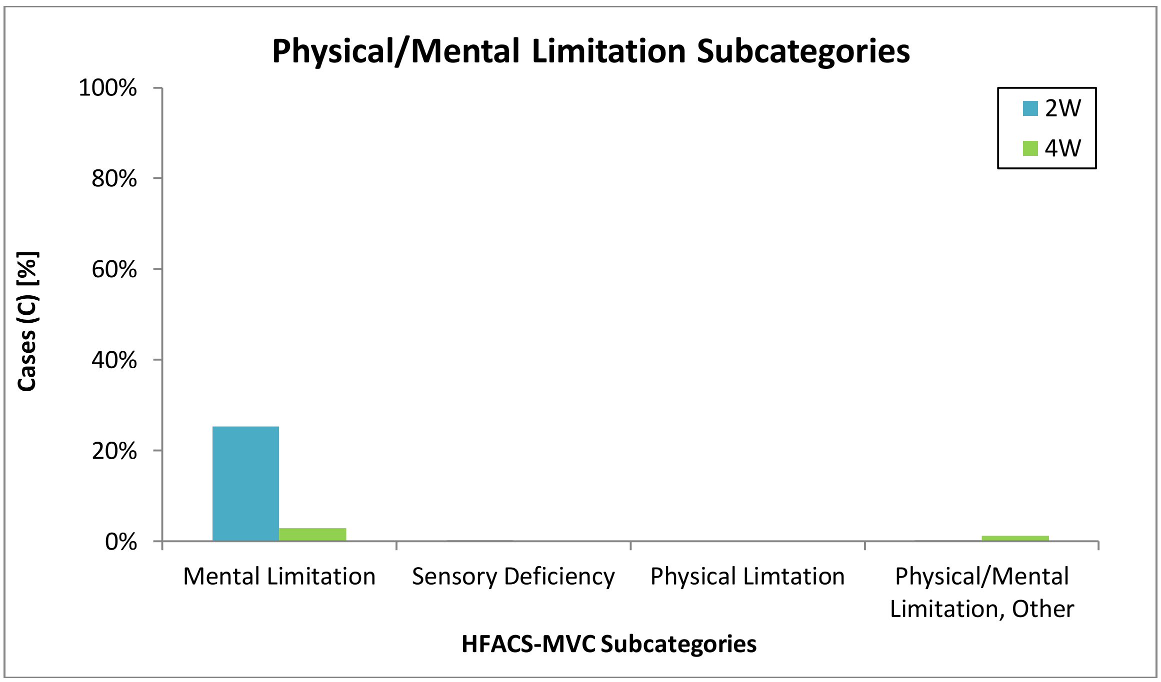

Figure 62: Physical/Mental Limitation Subcategories, percentage of cases per vehicle type with at least one factor in subcategory

The 2W vehicle cases contained 87 physical/mental limitation nanocodes. The 4W vehicle cases contained 23 physical/mental limitation nanocodes. The physical/mental limitation nanocodes associated with the two vehicle types are presented in Figure 63.

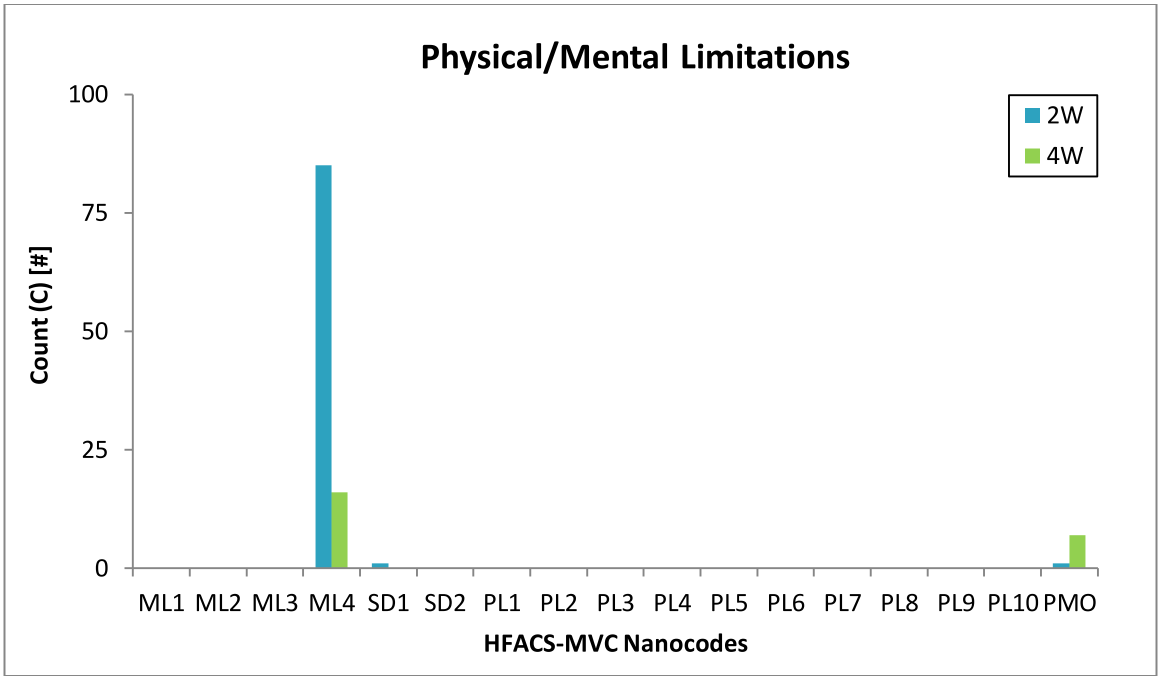

Figure 63: Physical/Mental Limitation Causal Factors, counts of nanocodes per vehicle type

The leading physical/mental limitation factor associated with both 2W and 4W MVCs captured inadequacies in proficiency or experience. In fact, limited experience/proficiency (ML4) was the primary physical/mental limitation factor classified for 4W MVCs and the sole physical/mental limitation factor classified for 2W MVCs.

Looking at operator factors, few cases for either vehicle type – two percent of 2W MVCs and six percent of 4W MVCs – contained communication, coordination, and planning factors. The difference between the percentages of 2W and 4W MVCs associated with communication, coordination, and planning factors was found to be significant (χ^2=6.684, p<0.05). The relative odds of a service member having a MVC associated with one or more communication, coordination, and planning factors was over 2.5 times greater on a 4W vehicle than in a 2W vehicle (OR=2.70).

The percentages of 2W and 4W cases associated with each of the communication, coordination, and planning subcategories are presented in Figure 64. The leading communication, coordination, and planning subcategories for both vehicle types were planning followed by communication. The percentage of cases associated with planning causal factors was higher for 4W vehicles than for 2W vehicles.

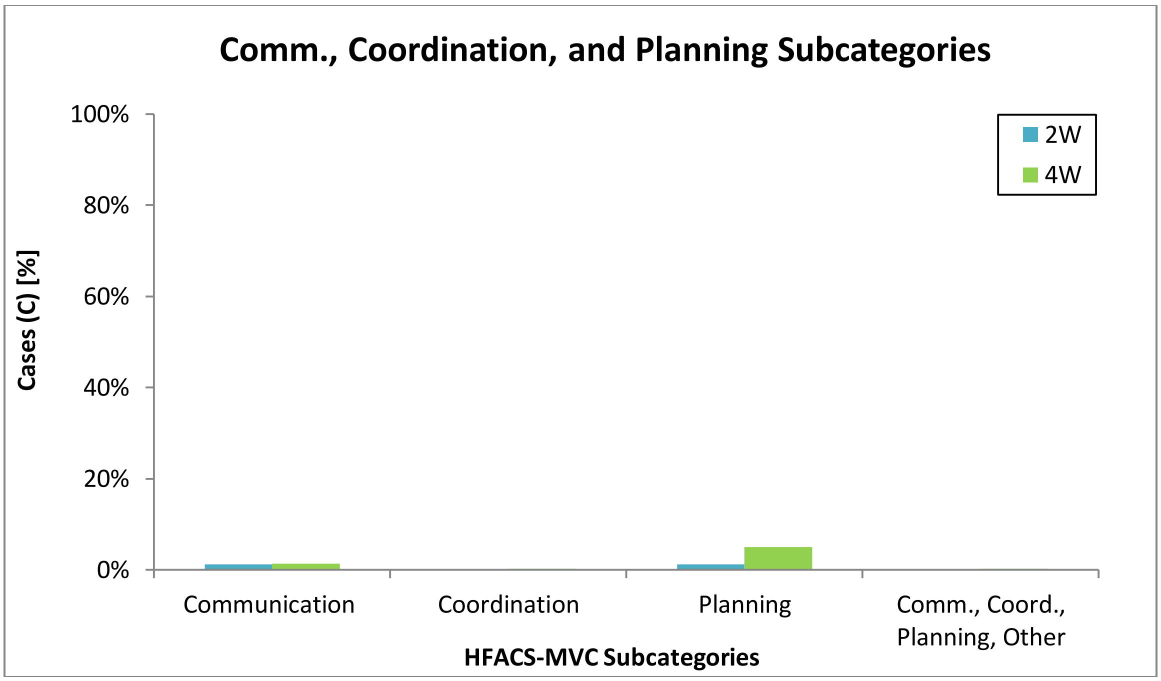

Figure 64: Comm., Coord., and Planning Subcategories, percentage of cases per vehicle type with at least one factor in subcategory

The 2W vehicle cases contained 9 communication, coordination, and planning nanocodes. The 4W vehicle cases contained 37 communication, coordination, and planning nanocodes. The communication, coordination, and planning nanocodes associated with the two vehicle types are presented in Figure 65.

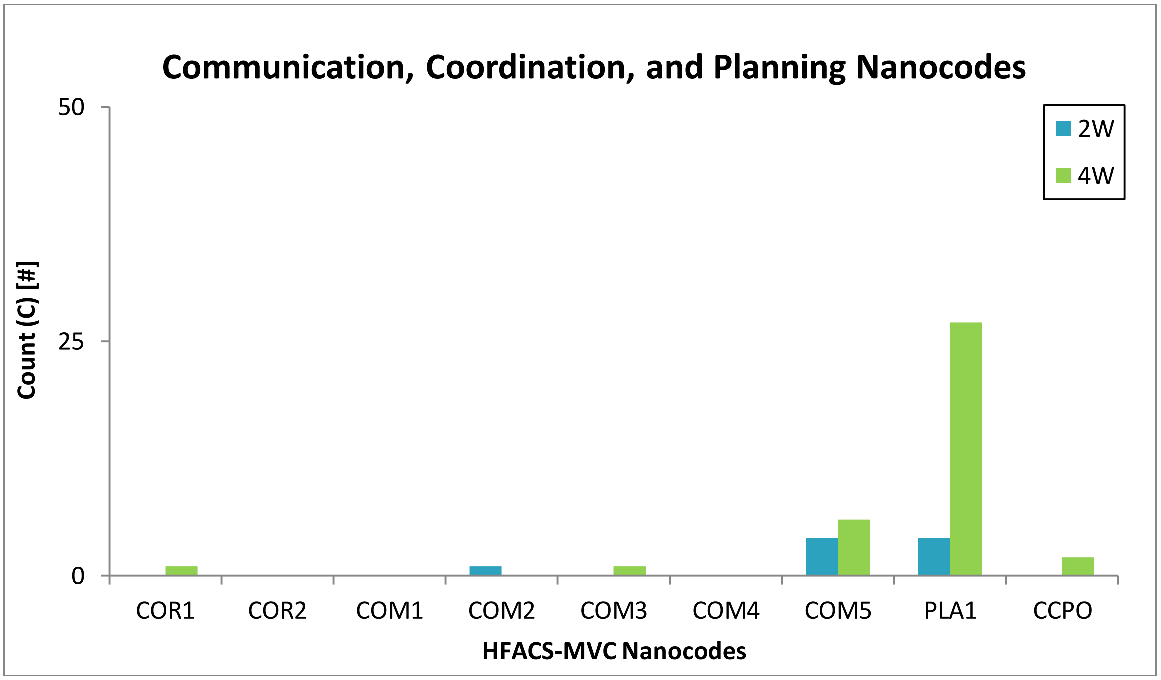

Figure 65: Comm., Coord., and Planning Causal Factors, counts of nanocodes per vehicle type

The top communication, coordination, and planning causal factors associated with both 2W and 4W MVCs were poor travel planning (PLA1) and inadequate knowledge transfer (COM5). Similar proportions of cases for 2W MVCs were associated with poor travel planning and inadequate knowledge transfer. In comparison, a larger proportion of cases for 4W MVCs were associated with poor travel planning than with inadequate knowledge transfer.

5.3 Paygrades: Enlisted, Officer

Paygrade data were provided for cases from the USAF and USN but not for cases from the USMC. The overwhelming majority of cases involved enlisted service members. A much smaller percentage of cases involved officers with only one warrant officer in the entire dataset. Due to the uniqueness of the warrant officer population and its singular representation in the dataset, the warrant officer case was excluded. A small fraction of the cases (n=10) involved operators with unknown paygrades which were excluded from the dataset.

The final paygrade dataset contained 739 cases involving enlisted (n=689) and officer (n=49) service members in the USAF and USN (Figure 66). There were a total of 2,167 and 131 nanocodes classified for cases involving enlisted and officer paygrades respectively. As such, there were 3.2 factors per case for enlisted paygrades and 2.7 factors per case for officer paygrades.

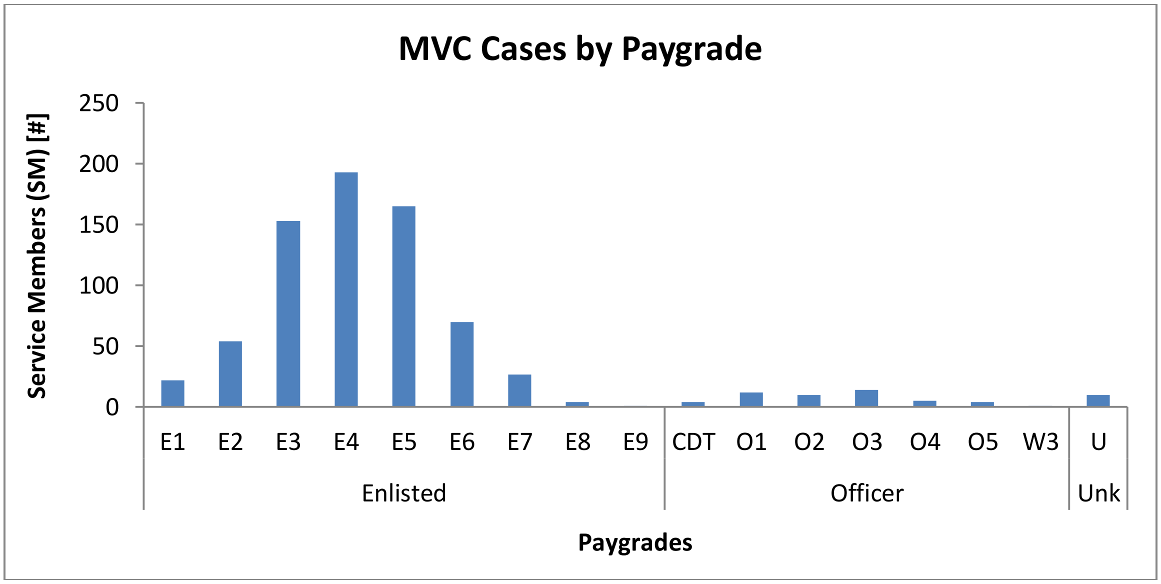

Figure 66: Enlisted, Officer, and Warrant Service Members Involved in MVCs (USAF and USN; excluding USMC)

5.3.1 Temporal Trends

The temporal trends for MVCs by paygrade are shown in Figure 67. These trends used the percentages of MVCs that involved officer and enlisted paygrades each fiscal year. This was done to account for any differences in the number of services providing MVC data each fiscal year.

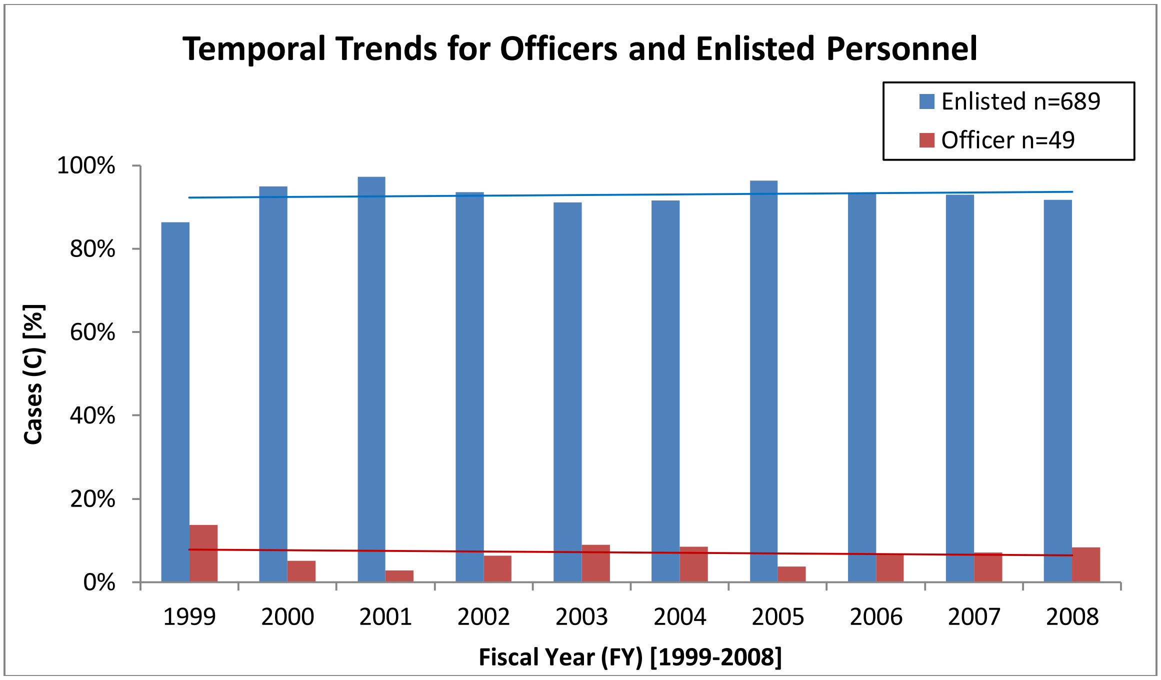

Figure 67: Temporal Trends of MVC Cases by Paygrade

A comparison of the relative contributions of officer and enlisted paygrades indicate stable trends over time. Enlisted personnel were consistently involved in over 90% of MVCs each year.

5.3.2 Unsafe Act Trends

The unsafe act trends for MVCs by paygrade are shown in Figure 68. Overall, trends for unsafe act causal categories were similar for MVCs involving enlisted and officer paygrades. No significant differences between enlisted and officer MVCs were found for skill based or decision errors. However, a significant difference was found between enlisted and officer MVCs for violations.

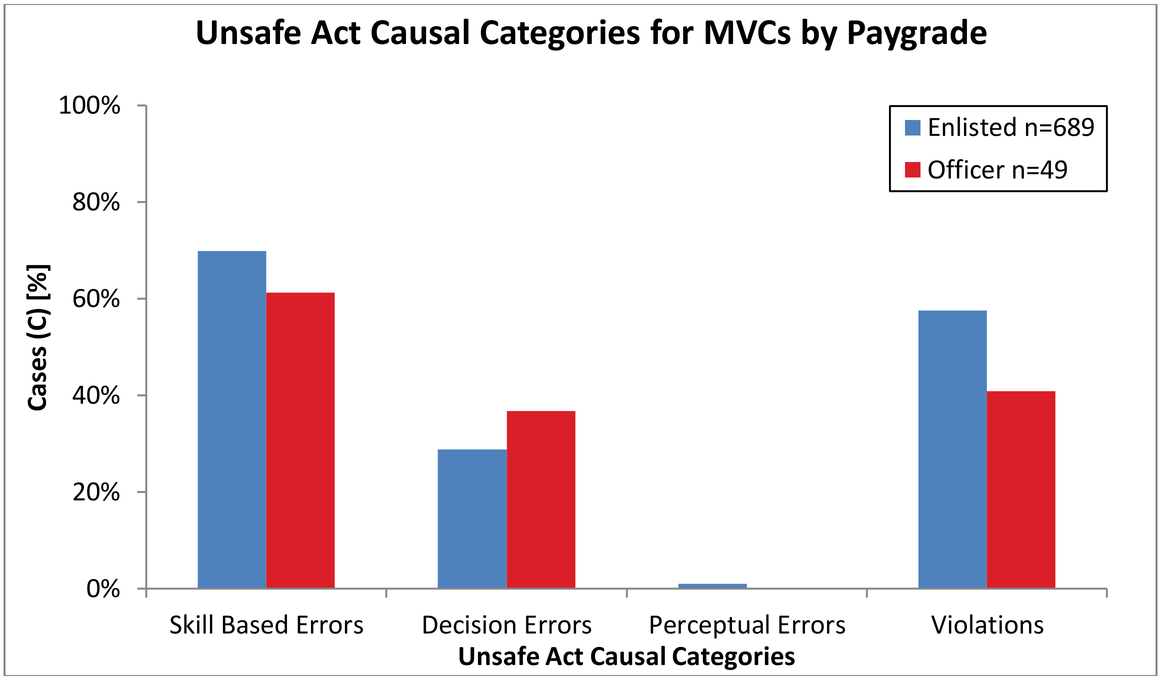

Figure 68: Unsafe Acts for Officers and Enlisted Personnel, percentage of cases containing at least one factor per category

Around two-thirds of the cases for both paygrades contained skill based errors. A slightly higher percentage of cases for enlisted paygrades contained skill based errors than cases for officer paygrades. The difference between the percentages of cases associated with skill based errors for enlisted and officer paygrades was found to be insignificant (χ^2=1.584, ns).

The skill based error subcategories associated with MVCs by military paygrade are presented in Figure 69. The skill based error subcategory trends for MVCs involving enlisted and officer paygrades were generally similar. Common skill based error subcategories for MVCs for both paygrades were related to technique and control. However, MVCs involving enlisted service members were associated with more attention errors than MVCs involving officers.

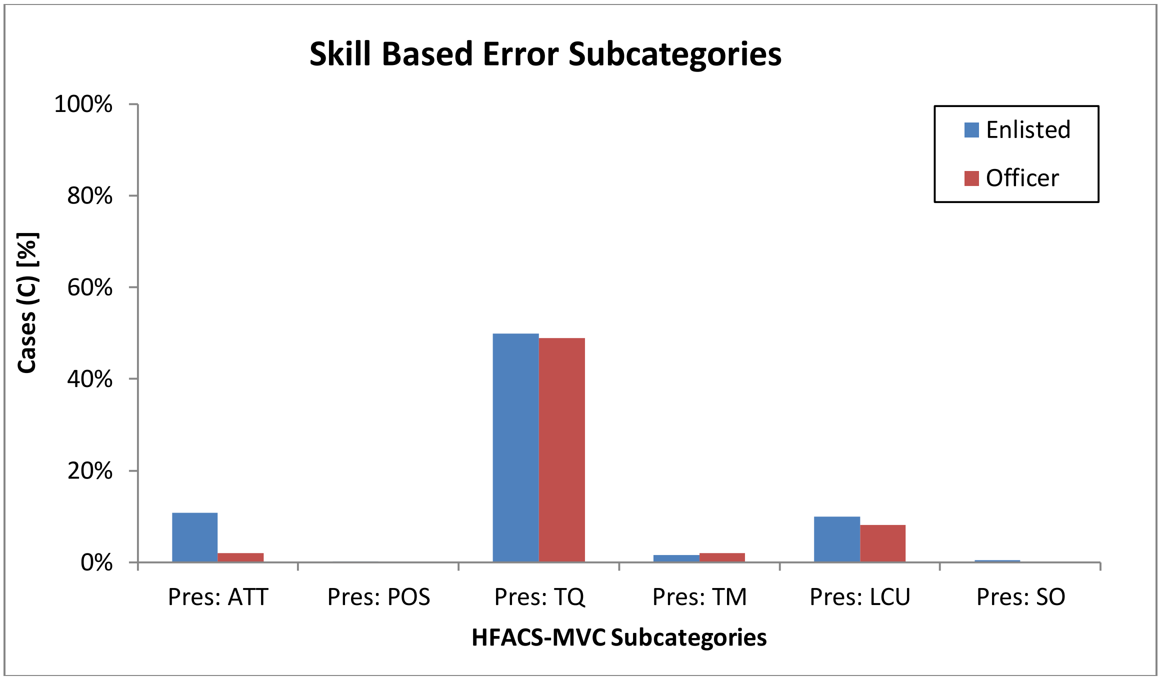

Figure 69: Skill Based Error Subcategories, percentages of cases per paygrade containing at least one factor per subcategory

Around one-third of the cases for both paygrades contained decision errors. A slightly higher percentage of cases for officer paygrades contained decision errors than cases for enlisted paygrades. The difference between the percentages of cases associated with decision errors for enlisted and officer paygrades was found to be insignificant (χ^2=1.413, ns).

The decision error subcategories associated with MVCs by military paygrade are presented in Figure 70. The decision error subcategory trends were similar for MVCs involving enlisted and officer paygrades. The most common decision errors subcategories for MVCs for both paygrades were related to situational assessment, procedures, and prioritization. However, MVCs involving officers were associated with more prioritization errors than MVCs involving enlisted personnel.

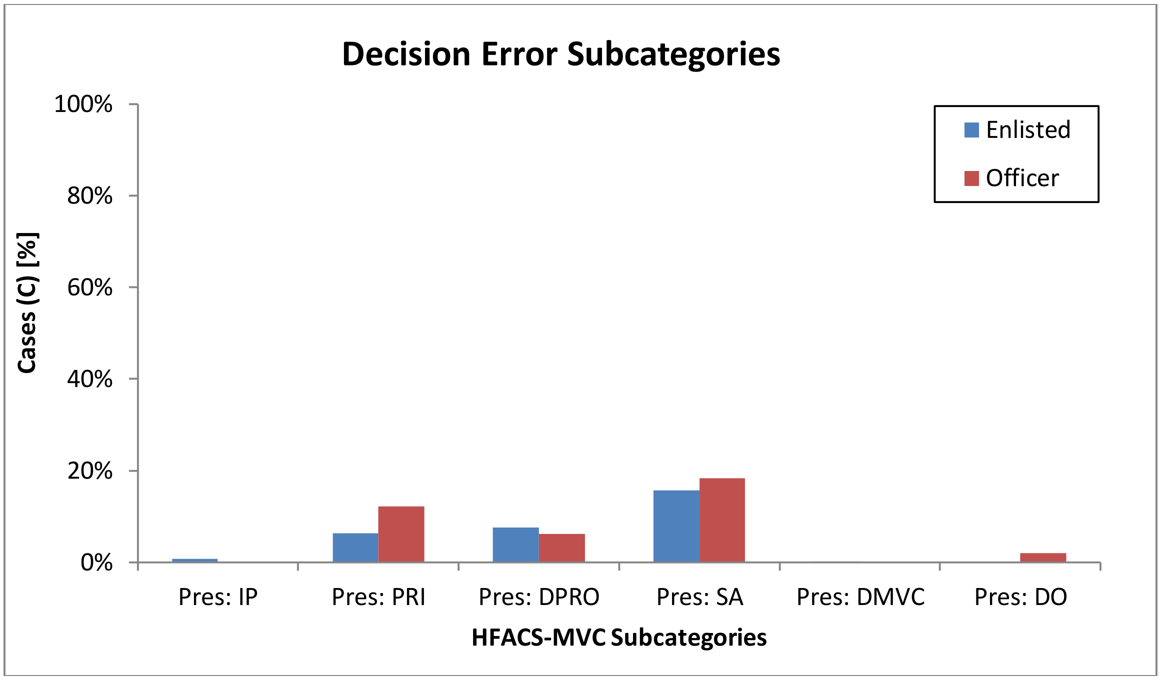

Figure 70: Decision Error Subcategories, percentages of cases per paygrade containing at least one factor per subcategory

Around three-fifths of the cases for enlisted paygrades and two-fifths of the cases for officer paygrades contained violations. The difference between the percentages of cases associated with violations for enlisted and officer paygrades was found to be significant (χ^2=5.162, p<0.05). The relative odds of a service member having a MVC associated with one or more violations was two times greater with an enlisted paygrade than an officer paygrade (OR=1.96).

The percentages of enlisted and officer cases associated with each of the violation subcategories are presented in Figure 71. The main violation subcategories associated with cases for both paygrades were procedural in nature – speeding, drunk driving, and other. Higher percentages of cases were associated with virtually all of the violation subcategories for enlisted than for officer paygrades, especially for the top two violation subcategories. Looking at the leading violation subcategory, over one-third of enlisted cases compared to one-fourth of the officer cases were associated with speeding violations. The next most common violation subcategory, drunk driving, was associated with over one-fourth of the enlisted cases less than one-fifth of the officer cases.

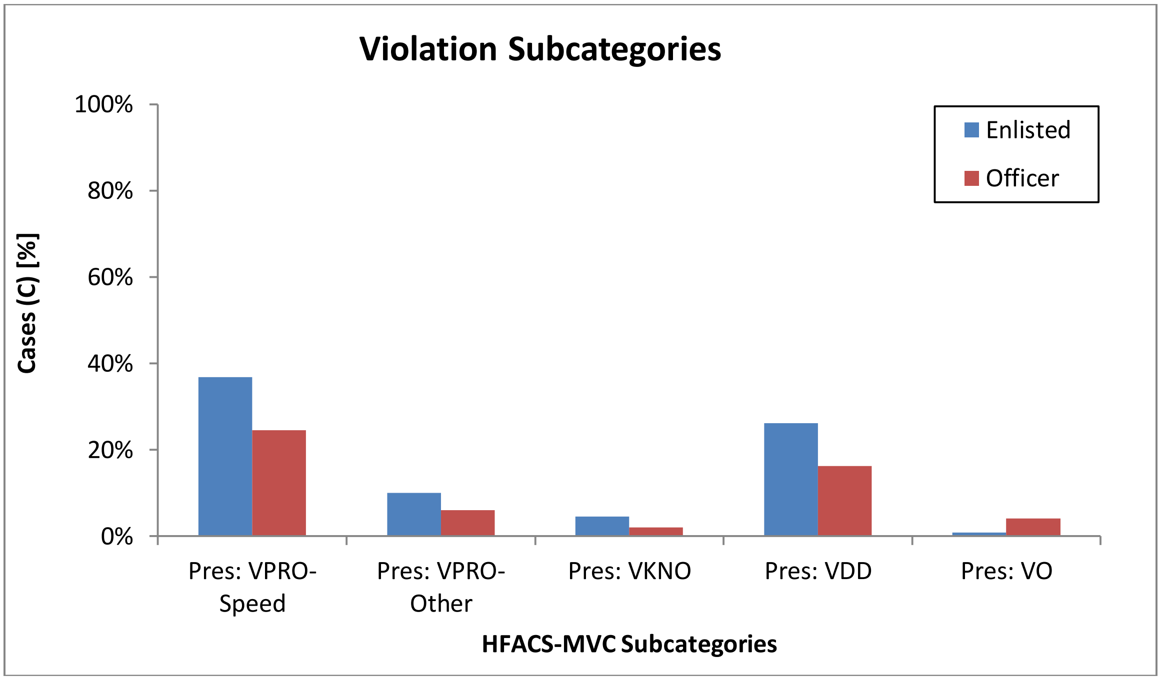

Figure 71: Violation Subcategories, percentage of cases per paygrade with at least one factor in subcategory

Cases for enlisted paygrades contained 543 violation nanocodes. Cases for officer paygrades contained 26 violation nanocodes. The violation nanocodes associated with each of the two paygrades are presented in Figure 72.

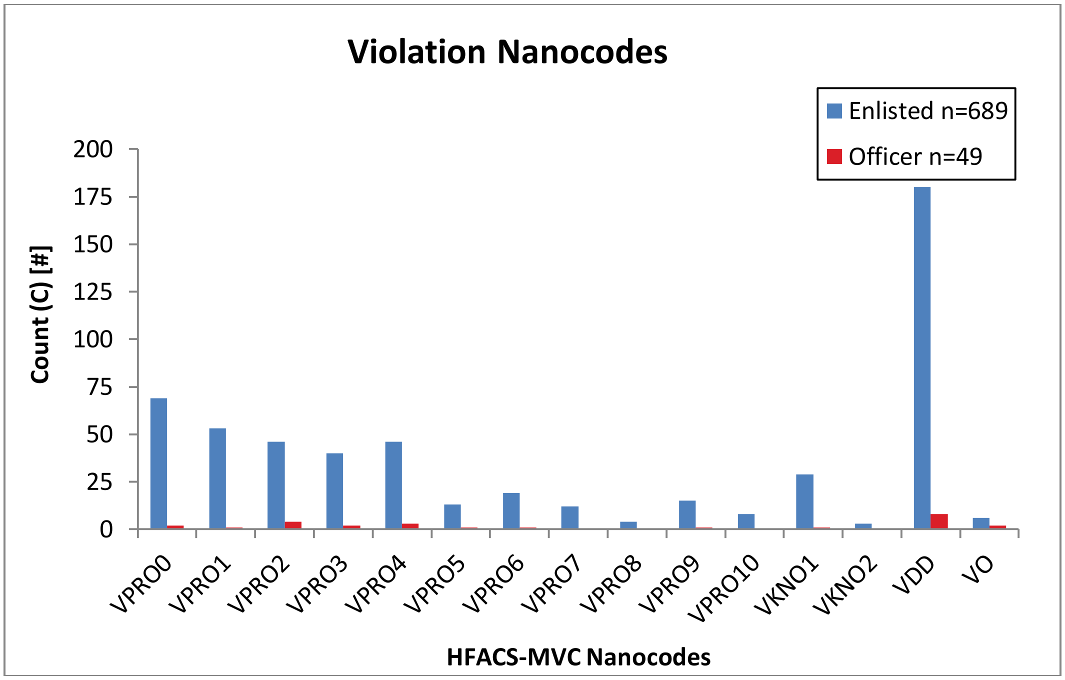

Figure 72: Violation Causal Factors, counts of nanocodes per paygrade

The violations associated with MVCs for the two paygrades were similar. The most common violation associated with MVCs for both paygrades was drunk driving (VDD). For enlisted paygrades, the top violations were drunk driving (VDD), travelling at an unknown speed in excess of the posted limit (VPRO0), and travelling 10-19 mph over the speed limit (VPRO1). For officer paygrades, the top violations were drunk driving (VDD), travelling 20-29 mph over the speed limit (VPRO2), and travelling 40 mph or more over the speed limit (VPRO4).

5.3.3 Precondition Trends

The precondition trends for cases involving enlisted and officer paygrades are shown in Figure 73. The trends for the two paygrades appear to be fairly similar for environmental conditions, operator conditions, and operator factors.

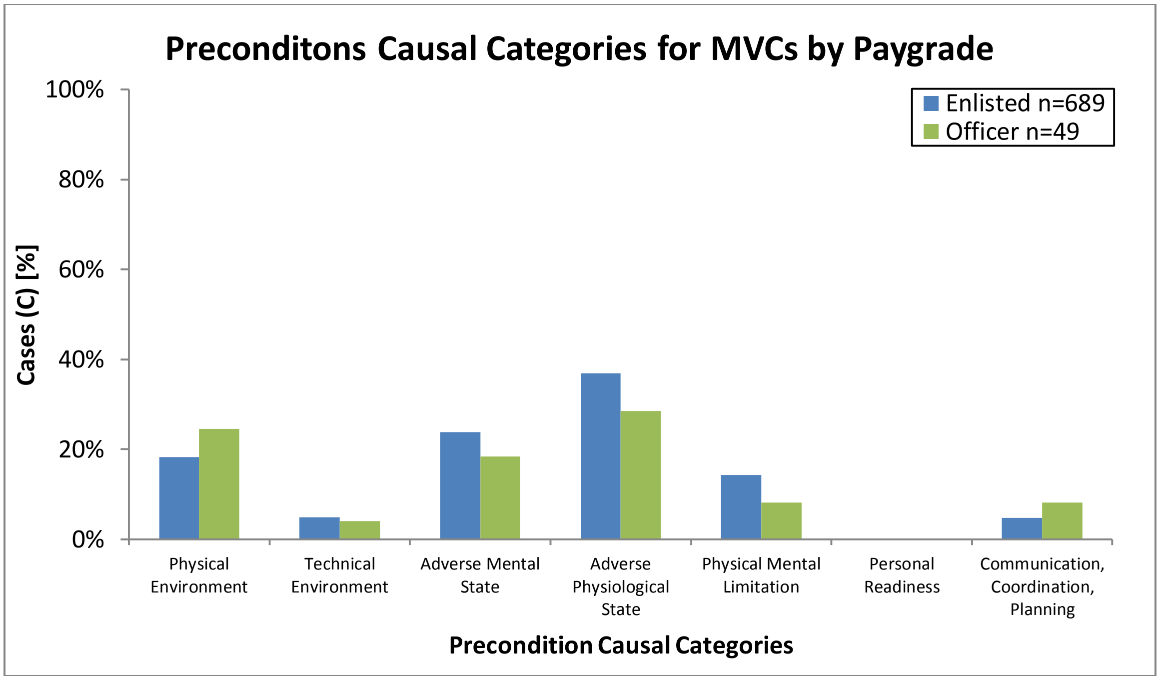

Figure 73: Preconditions for MVCs by Paygrade, percentages of cases containing at least one factor per category

There were minor differences between the precondition categories associated with MVCs for enlisted and officer paygrades but these were found to be insignificant. Specifically, no significant differences were found between MVCs for enlisted and officer paygrades for physical environment (χ^2=1.158, ns), technological environment (χ^2=0.072, ns), adverse mental state (χ^2=0.753, ns), adverse physiological state (χ^2=1.361, ns), physical/mental limitation (χ^2=1.467, ns) or communication, coordination, and planning (χ^2=1.093, ns) causal categories.

The percentage of cases associated with precondition subcategories are presented in Figure 74. The trends were generally similar for preconditions subcategories associated with enlisted and officer MVCs. However, a much higher percentage of physiological condition factors were associated with enlisted MVCs than with officer MVCs.

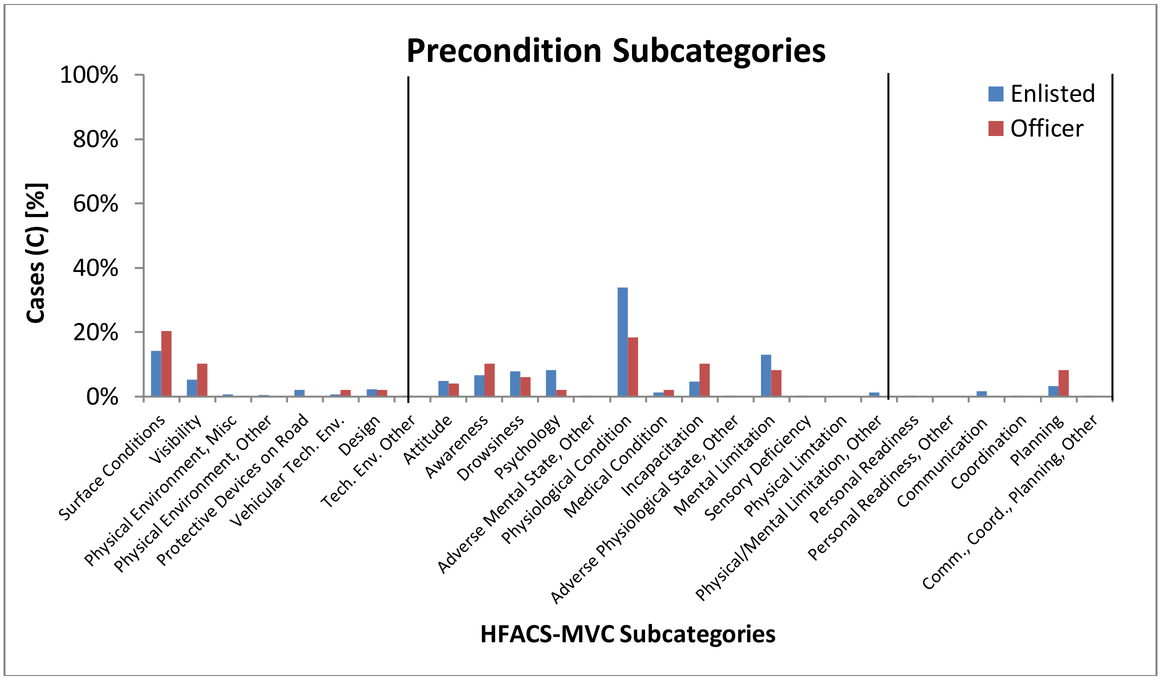

Figure 74: Precondition Subcategories by Paygrade,

5.4 AGE GROUPS: 17-20, 21-25, 26-30, 31-35, 36-40, >40

Age data were provided for cases from the USAF and USN cases but not for cases from the USMC. The breakdown of cases by age group is presented in Figure 75. As expected, involved service members were quite young. The most common age of involved service members was 21 years. The large majority of involved service members were under the age of 30 (78.1%) with close to half (48.7%) between the ages of 19 and 23. Only a fraction of cases involved service members under the age of 20 (1.4%) or over the age of 39 (4.3%).

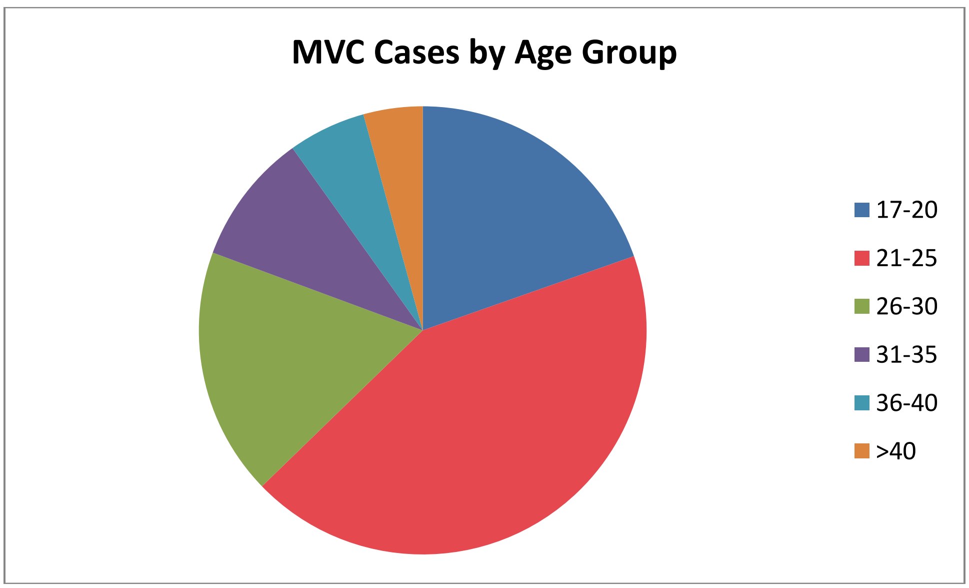

Figure 75: MVC Cases by Age of Service Member Operating Vehicle (USAF and USN; excluding USMC)

There were a total of 450, 1,081, 385, 193, 134, and 83 nanocodes classified for cases involving 17-20, 21-25, 26-30, 32-35, 36-40, and >40 year old service members respectively. As such, the average number of factors per case was similar across age groups. Cases involving 17-20, 21-25, and 36-40 year old service members contained slightly more than 3 factors per case and MVCs involving 26-30, 31-35, and over 40 year old service members contained slightly fewer than 3 factors per case.

5.4.1 Temporal Trends

Temporal trends for cases by age group are shown in Figure 76. The percentages of cases for all six age groups remained stable between FY1999 and FY2009. MVCs consistently involved young service members, particularly those under the age of 26. The trends indicate that approximately 30% and 40% of MVCs each fiscal year involved service members between the ages of 17-20 and 21-25 respectively.

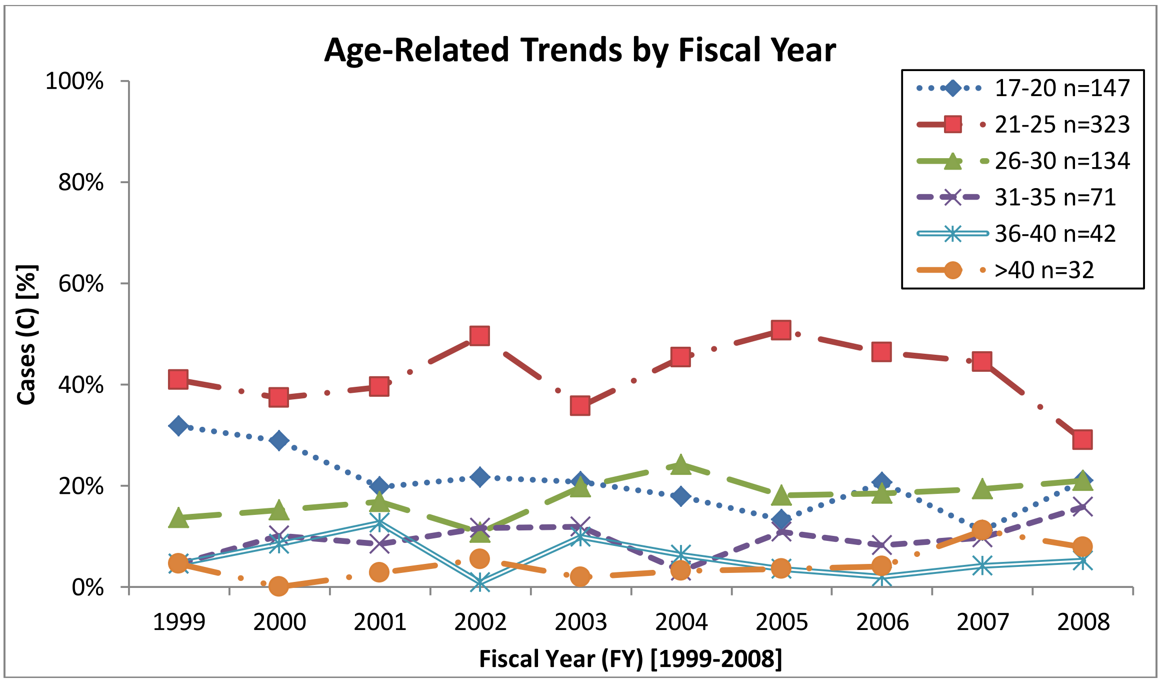

Figure 76: Temporal Trends for MVCs by Paygrade, percentages of cases containing at least one factor per category

5.4.2 Unsafe Act Trends

The unsafe act trends by age group are shown in Figure 77. The unsafe act category trends were generally similar across age groups. The leading unsafe act causal categories associated with MVCs for all age groups were skill based errors followed by violations and then decision errors for all age groups except the oldest (>40). Differences in MVC causal category trends by age group were insignificant for both skill based errors

(χ^2=4.286, ns) and decision errors (χ^2= 3.570, ns). However, the MVC causal category trends by age group were significantly different for violations (χ^2=20.453, p<0.01).

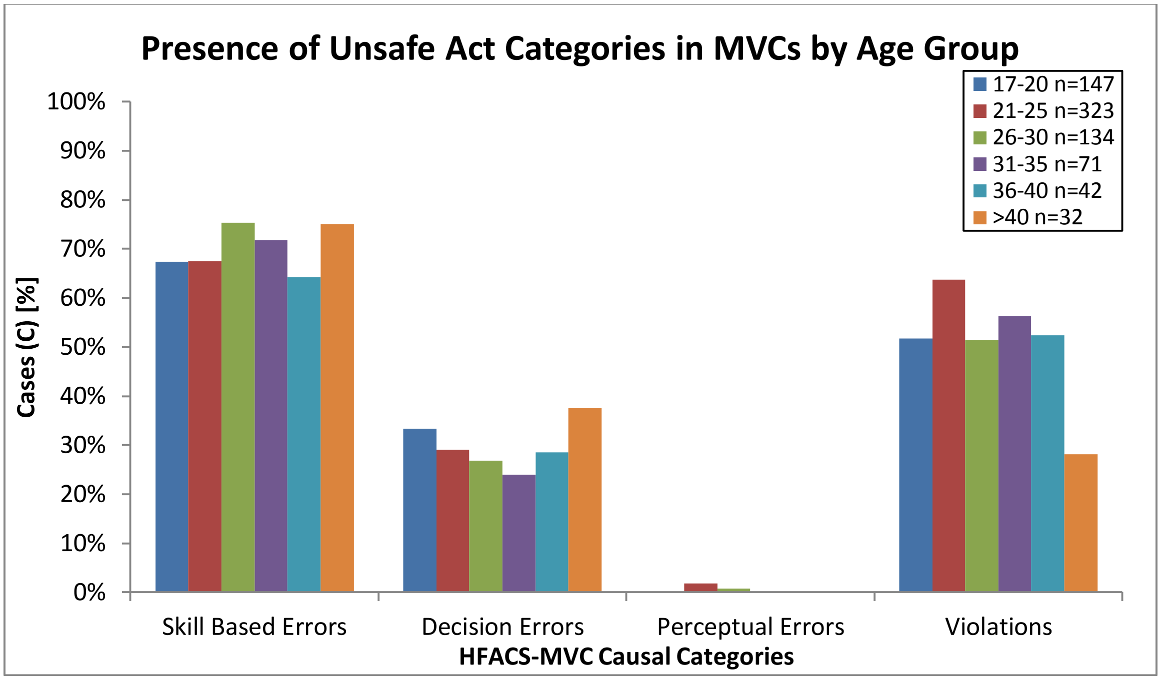

Figure 77: Unsafe Acts by Age Group, percentages of cases with at least one factor per category (USAF, USN)

The percentage of cases associated with violations was highest for the second youngest age group (21-25). In fact, almost two-thirds of the cases for 21-25 year old service members contained violations. The percentage of cases with violations for 21-25 year old service members was not significantly higher than the percentages of cases with violations for 31-35 year old (χ^2= 1.373, ns) or 36-40 year old (χ^2= 2.059, ns) service members. However, the percentage of cases with violations for 21-25 year old service members was significantly higher than the percentages of cases with violations for 17-20 year old service members (χ^2=6.139, p<0.05), 26-30 year old service members (χ^2=5.964, p<0.05), and service members over the age of 40 (χ^2=15.495, p<0.01). The relative odds of a 21-25 year old service member having a MVC involving one or more violations was over 1.5 times greater than a 17-20 year old (OR=1.64) or 26-30 year old (OR=1.66) service member and 4.5 times greater than a service member over the age of 40 (OR=4.50).

The percentage of cases associated with violations was lowest for the oldest group of service members (>40). Less than one-third of the cases for service members over the age of 40 contained violations. The percentage of cases with violations for service members over the age of 40 was significantly lower than the percentages of cases with violations for 17-20 year old (χ^2= 5.857, $p<0.05$), 21-25 year old (see above), 26-30 year old (χ^2= 5.663, $p<0.05$), 31-35 year old (χ^2= 7.040, $p<0.01$), and 36-40 year old (χ^2=4.390, $p<0.05$) service members. The odds of a service member over the age of 40 having a MVC involving one or more violations was at least 2.5 times less than a service member in any other age group. Specifically, the relative odds of a service member over the age of 40 having a MVC involving one or more violations was over 2.5 times less than 17-20 year old (OR=0.36), 21-25 year old (see above), 26-30 year old (OR=0.37), 31-35 year old (OR=0.30), and 36-40 year old (OR=0.36) service members.

One-fourth to two-thirds of MVCs for all age groups contained violations. The percentages of cases associated with each of the violation subcategories for the six age groups are presented in Figure 78. The leading violation subcategories associated with cases for all six age groups were speeding and drunk driving. For the younger age groups (17-35), the top violation subcategory associated with MVCs was speeding. The highest percentages of cases associated with speeding violations were found for service members aged 17-20 (37%) and 21-25 (41%). For older age groups (36+), the top violation subcategory associated with MVCs was drunk driving. The highest percentages of cases associated with drunk driving violations were found for service members aged 31-35 (30%) and 36-40 (40%).

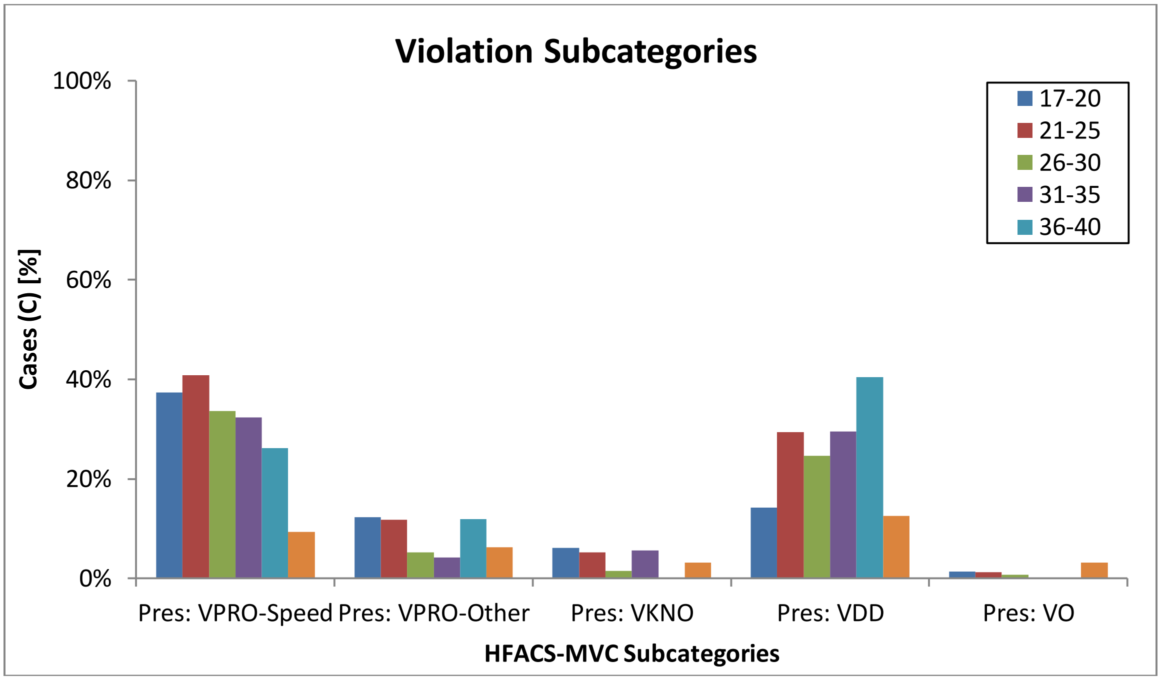

Figure 78: Violation Subcategories, percentage of cases per age group with at least one factor in subcategory

There were 106, 287, 88, 51, 33, and 11 violation nanocodes identified for cases involving 17-20, 21-25, 26-30, 31-35, 36-40, and >40 year old service members respectively. The violation nanocodes associated with the six age groups are presented in Figure 79.

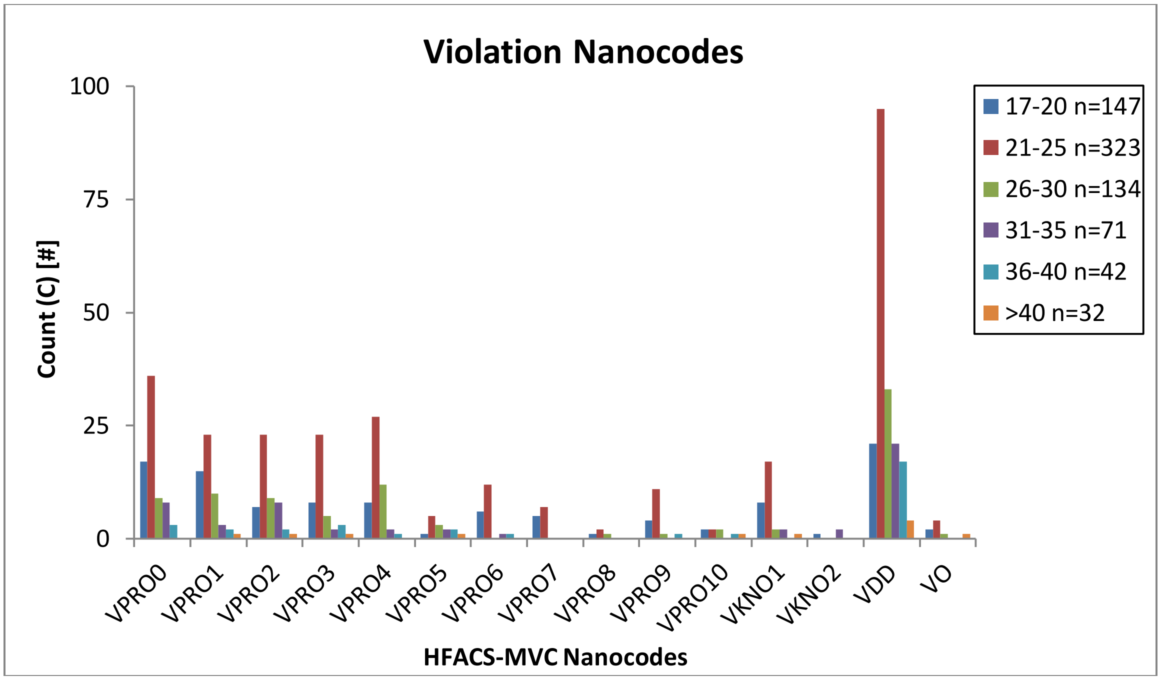

Figure 79: Violation Causal Factors, counts of nanocodes per age group

The most common violations for all six age groups were procedural violations related to drunk driving and speeding. The most common violation for all six age groups was drunk driving (VDD). The most common speeding violations for 21-25 year old service members were travelling at an unknown but unsafe speed (VPRO0) and travelling 40+ mph over the speed limit. The most common speeding violations for 26-30 year old service members were travelling 40+ mph over the speed limit (VPRO4) and travelling 10-19 mph over the speed limit (VPRO1). The most common speeding violations for 31-35 year old service members were travelling at an unknown illegal speed (VPRO0) and travelling 20-29 mph over the speed limit (VPRO2). The most common speeding violations for 17-20 year old and 36-40 year old service members were travelling at an unknown illegal speed (VPRO0) and travelling 10-19 mph over the speed limit (VPRO1).

While two-thirds to three-fourths of MVCs for all age groups contained skill based errors, no significant differences were found between age groups at the causal category level (χ^2=4.286, ns). The percentages of cases associated with skill based error causal factor subcategories by age group are presented in Figure 80. The main skill based error subcategories were similar for MVCs involving service members of all ages. Common skill based error subcategories for both vehicle types were related to technique, attention, and control. However, technique errors were associated with fewer MVCs for 36-40 and >40 year old service members, control errors were associated with fewer MVCs for 36-40 year old service members, and attention errors were associated with fewer MVCs for 21-25 year old service members compared to other age groups.

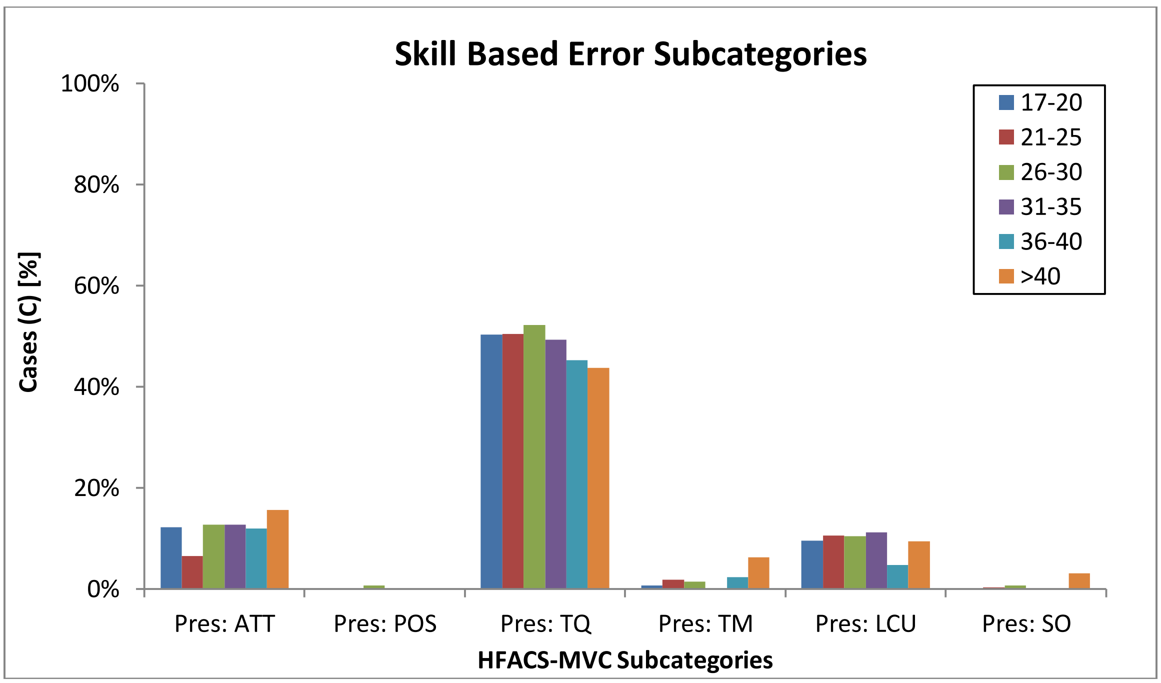

Figure 80: Skill Based Error Subcategories, percentages of cases per age group with at least one factor per subcategory (USAF, USN)

One-fourth to two-fifths of MVCs for all age groups contained decision errors (χ^2= 3.570, ns). The percentages of cases associated with decision error causal factor subcategories by age group are presented in Figure 81. Overall, the main decision error subcategory trends for MVCs were fairly similar across all age groups. Common decision error subcategories for both vehicle types were related to situation assessment, procedures, and prioritization. Compared to other age groups, MVCs were associated with fewer situational assessment errors for 36-40 year old service members, fewer control errors for service members over the age of 40, and fewer prioritization errors for 21-25 year old service members. Interestingly, MVCs for older service members (aged 36-40 and over the age of 40) were associated with more prioritization errors than compared to other age groups.

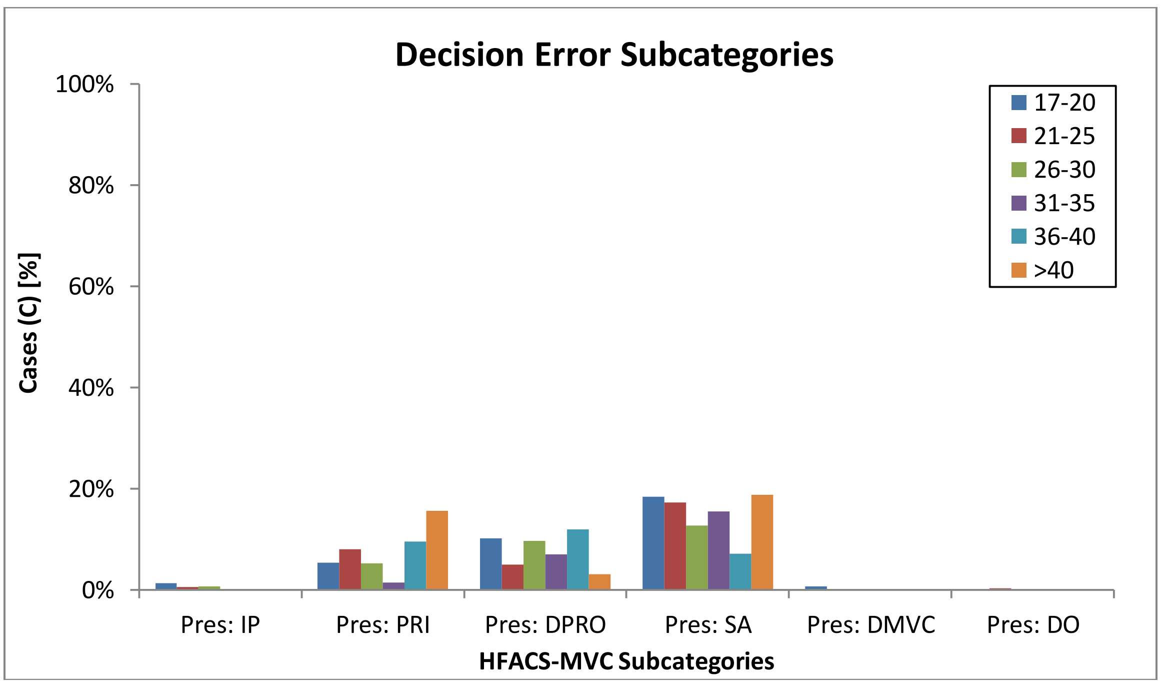

Figure 81: Decision Error Subcategories, percentages of cases per age group with at least one factor per subcategory (USAF, USN)

5.4.3 Precondition Trends

The precondition trends by age group are shown in Figure 82. The leading precondition causal categories associated with off-duty MVCs for all age groups was adverse physiological state followed by adverse mental state, physical environment, and physical/mental limitation. There were minor differences between precondition categories associated with MVCs for the six age groups. Most of these differences were insignificant, specifically those between age groups for physical environment (χ^2=7.266, ns), technological environment (χ^2=3.395, ns), adverse mental state (χ^2=4.189, ns), physical/mental limitation (χ^2=5.035, ns) and communication, coordination, and planning (χ^2=10.432, ns) factors. However, the difference between age groups was found to be significant for adverse physiological state factors (χ^2=14.162, p<0.05).

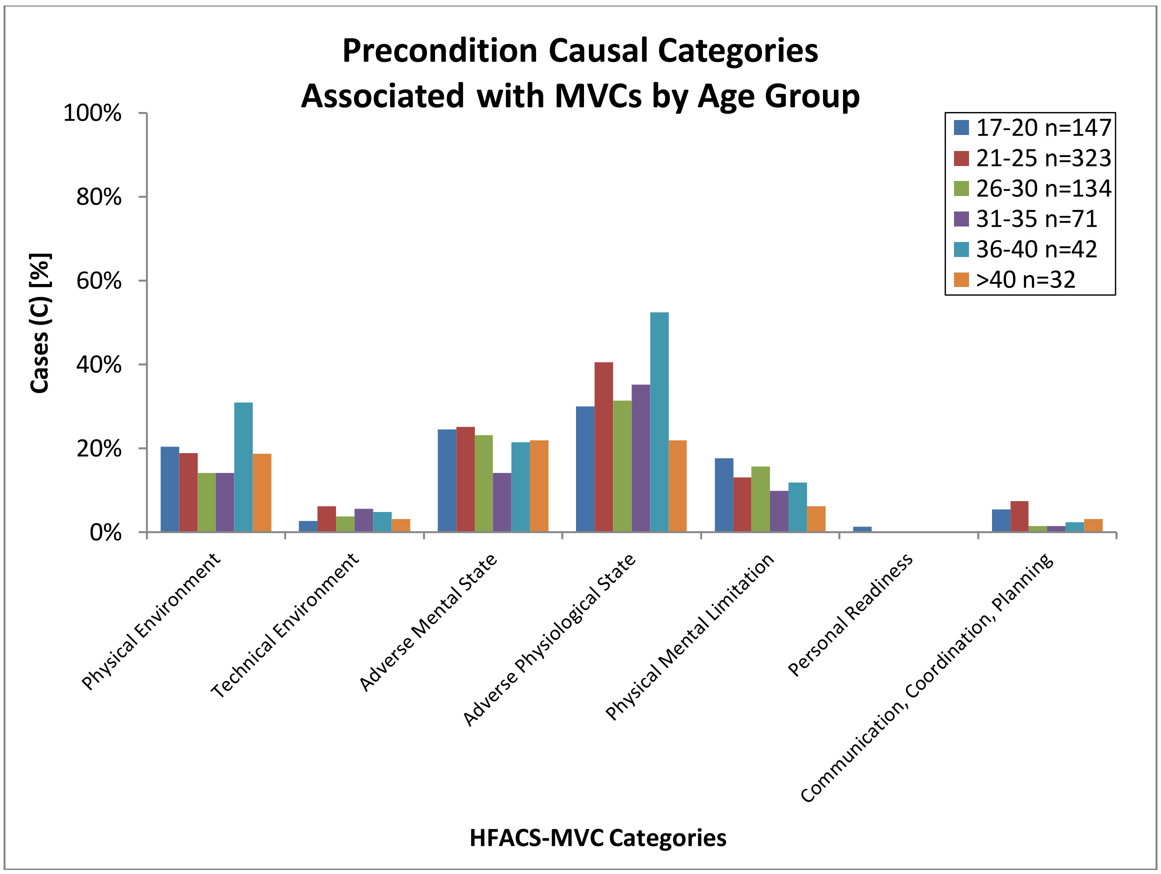

Figure 82: Preconditions for Unsafe Acts: Presence of Causal Categories

The percentage of cases associated with adverse physiological state factors was highest for the second oldest group of service members (36-40) followed by the second youngest group of service members (21-25) and lowest for the oldest group of service members (>40). Approximately one-half or more of the cases for 21-25 year old and 35-40 year old service members contained adverse physiological state factors. Comparatively, the other age groups were not nearly as likely to contain adverse physiological state factors with approximately one-third or less of their cases associated with adverse physiological state factors. Only one-fifth of cases involving service members over the age of 40 contained adverse physiological adverse physiological state factors.

The percentage of cases with adverse physiological states for 36-40 year olds was significantly higher than the percentages of cases for service members ages 17-20 (χ^2=7.244, p<0.01), 26-30 (χ^2=6.116, p<0.05), and over 40 (χ^2=7.092, p<0.01). The odds of a service member between the ages of 36 and 40 having a MVC involving at least one adverse physiological state factor was approximately 4 times greater than a service member over the age of 40 (OR=3.93) and 2.5 times greater than a 17-20 year old (OR=2.58) or 26-30 year old (OR=2.41) service member.

The percentage of cases with adverse physiological states for 21-25 year olds was significantly higher than the percentages for 17-20 year olds (χ^2=4.880, p<0.05) and >40 year olds (χ^2=4.277, p<0.05). The odds of a 21-25 year old service member having a MVC involving at least one adverse physiological state factor was over 1.5 times greater than a 17-20 year old service member (OR=1.60) and almost 2.5 times greater than a service member over the age of 40 (OR=2.44).

The percentages of cases associated with adverse physiological state subcategories by age group are presented in Figure 83. Subcategory trends were similar across age groups with the exception of 36-40 year old and over 40 year old service members with higher and lower percentages of MVCs with physiological conditions respectively.

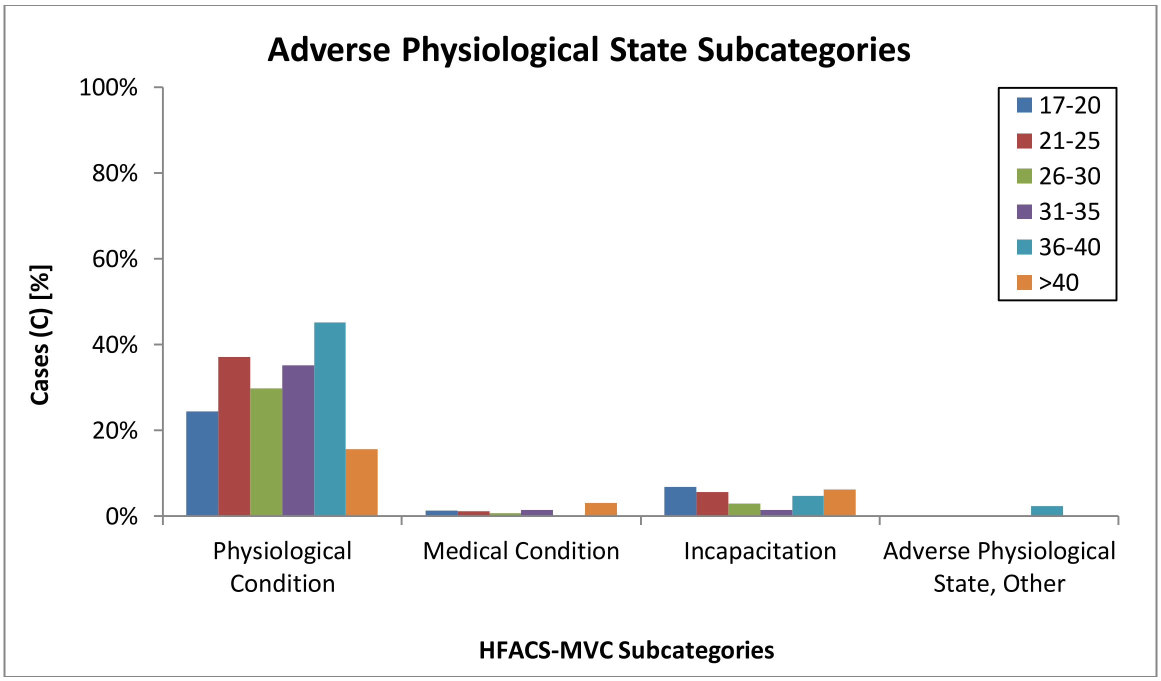

Figure 83: Adverse Physiological State Subcategories, percentage of cases per age group with at least one factor in subcategory

There were 49, 142, 45, 27, 22, and 8 adverse physiological state nanocodes identified for cases involving 17-20 year old, 21-25 year old, 26-30 year old, 31-35 year old, 36-40 year old, and over 40 year old service members respectively. The adverse physiological state nanocodes associated with the six age groups are presented in Figure 84.

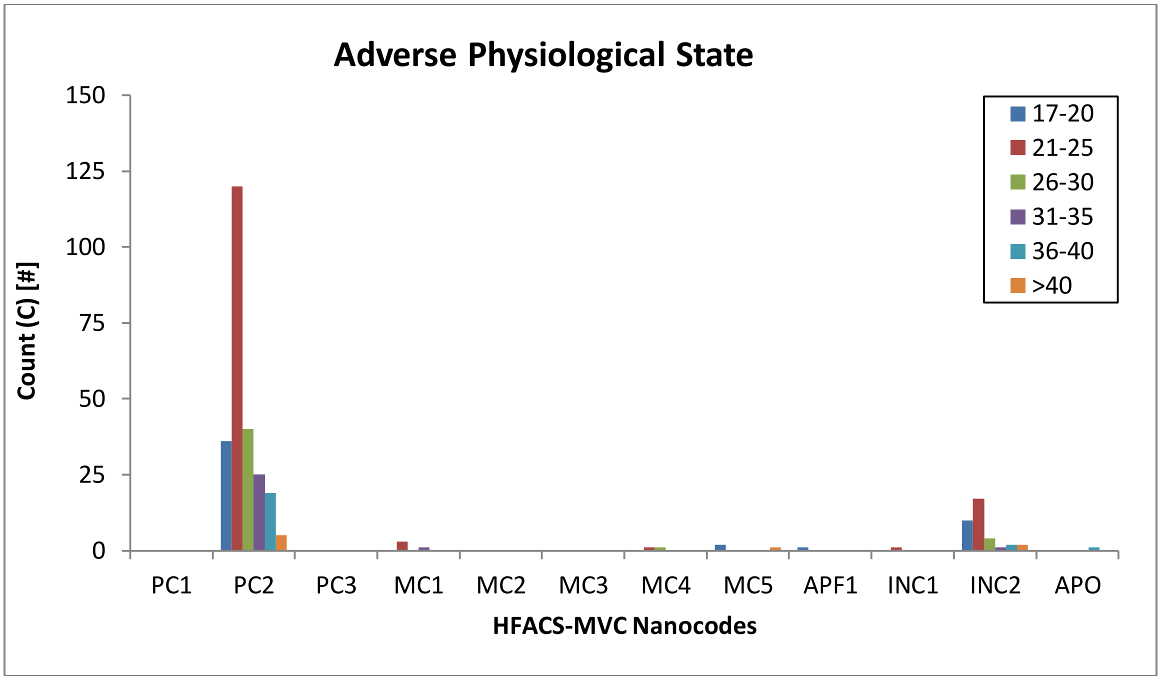

Figure 84: Adverse Physiological State Causal Factors, counts of nanocodes per age group

The majority of the adverse physiological state factors associated with all six age groups captured impairment due to drugs or alcohol (PC2). The other common adverse physiological state factor associated with all six age groups captured incapacitation due to falling asleep (INC2).

Though HFACS-MVC preconditions were insignificant across age groups for environmental condition categories, the subcategory trends were presented for MVCs involving the different age groups in Figure 85. Similar trends were found for environmental condition subcategories across age groups except visibility which were associated with a higher percentage of MVCs for 36-40 year old service members.

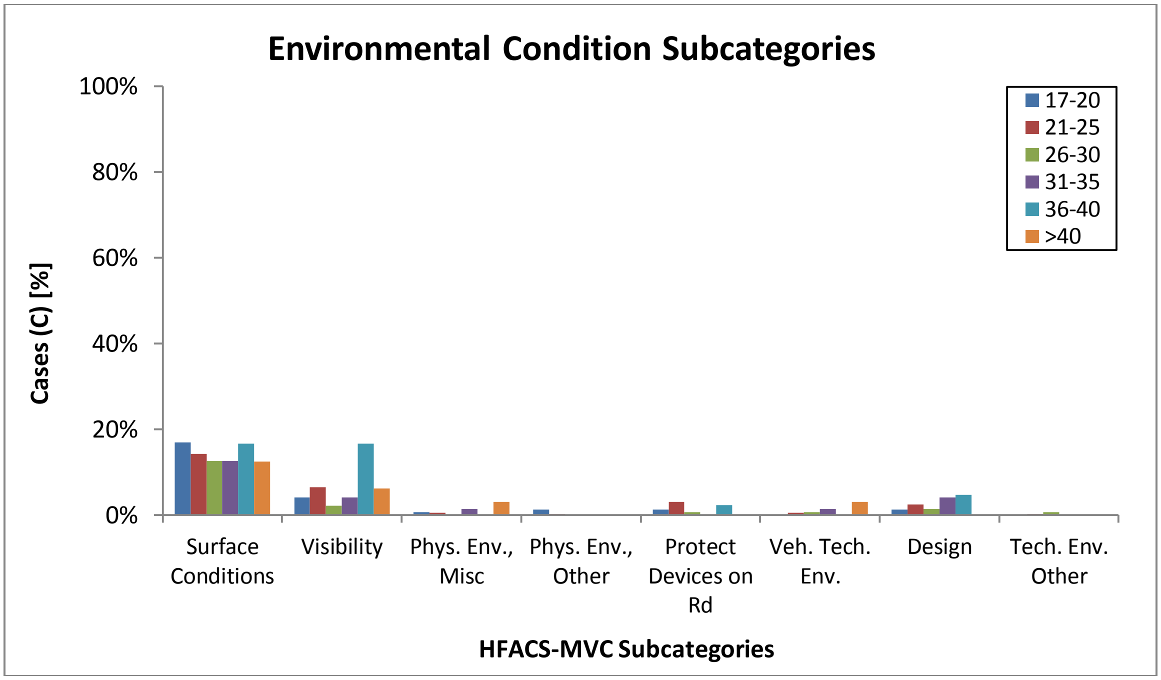

Figure 85: Environmental Condition Subcategories, percentage of cases per age group with at least one factor per subcategory

Though HFACS-MVC preconditions were insignificant across age groups for operator condition categories other than adverse physiological state, these subcategory trends were presented for MVCs involving the different age groups in Figure 86. Fairly similar trends were found for operator condition subcategories across age groups. Slight differences were observed for awareness which was associated with a higher percentage of MVCs for service members over age 40 and a lower percentage of MVCs for 31-35 year old service members and mental limitations which were associated with higher percentages of MVCs for younger service member age groups.

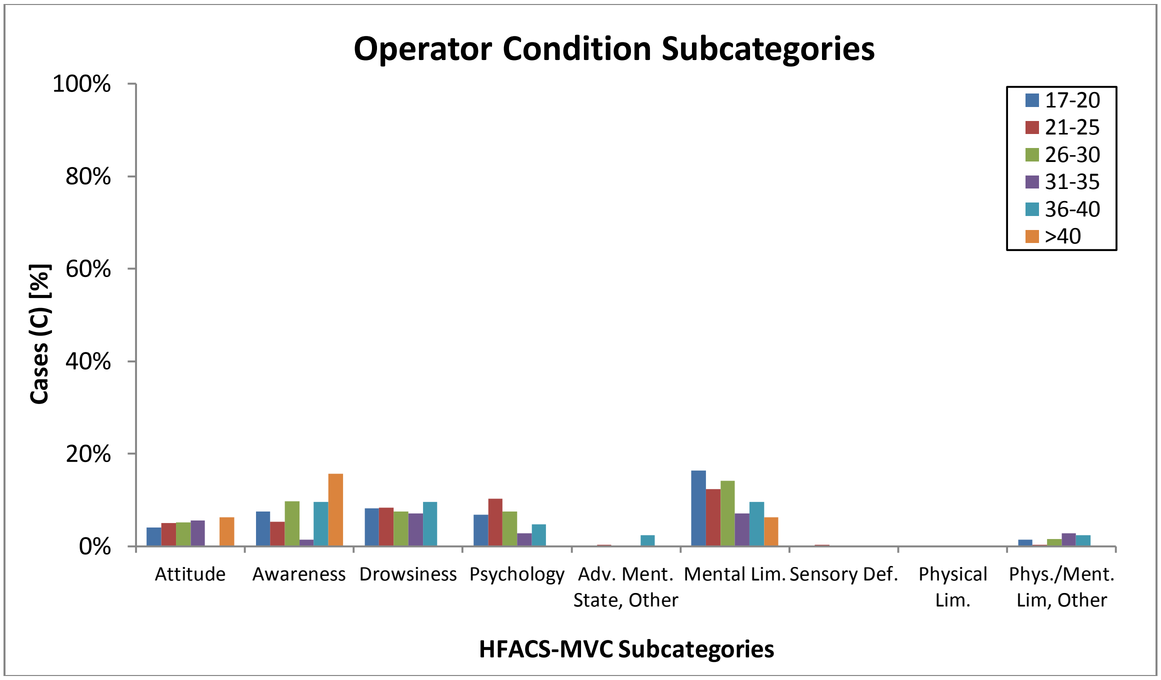

Figure 86: Operator Condition Subcategories (excl. APS), percentage of cases per age group with at least one factor per subcategory

Though HFACS-MVC preconditions were insignificant across age groups for operator factor categories, the subcategory trends were presented for MVCs involving the different age groups in Figure 87. Similar trends were found for operator factor subcategories across age groups.

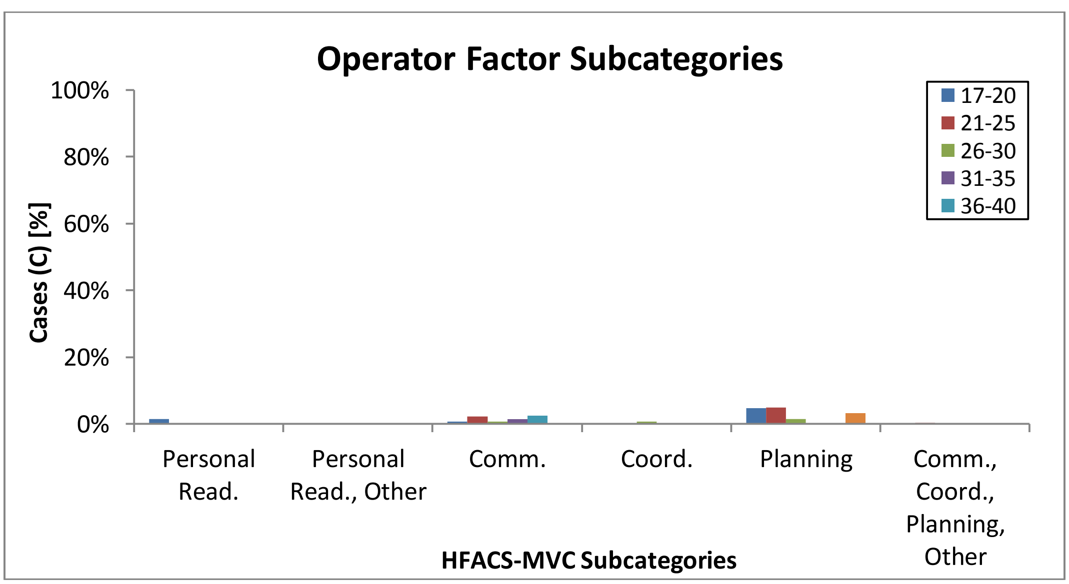

Figure 87: Operator Factor Subcategories, percentage of cases per age group with at least one factor per subcategory

CHAPTER 6: DISCUSSION, DATA AND OVERALL TRENDS

Prior studies have identified several demographic and behavioral characteristics associated with MVCs in the US for both the general and military populations. However no studies to date have comprehensively and systematically identified the human factors causes associated with MVCs in the military. The present study demonstrated that it is possible to modify and apply an established human error framework to classify the underlying human factors causes associated with MVCs in a comprehensive and systematic manner. Furthermore, this classification provided the opportunity to identify the main human factors trends associated with severe off-duty MVCs.

This chapter presents a discussion of the key findings from the present study. The main human factors trends associated with off-duty MVCs in the present study are reviewed. These trends are compared to those from existing literature for MVCs in the military, MVCs in the general population, and accidents in other industries. To account for variations in the overall quality and level of detail applied when identifying contributing factors at all four of the HFACS framework tiers, comparisons to other industries used the HFACS benchmarking standards from a non-filtered dataset containing accidents from a range of sources (Berry, 2010). The implications of these trends and their comparisons are discussed.

6.1 UNSAFE ACT TRENDS

The temporal trends for the unsafe acts affecting military personnel involved in serious off-duty MVCs remained stable between FY1999 and FY2008. Unfortunately, these trends suggest that intervention strategies implemented over the past decade have been unsuccessful in sufficiently reducing the underlying errors and violations performed by service members on the roadways.

At the unsafe acts tier, the human factors trends for serious off-duty MVCs captured high levels of skill based errors and violations. Skill based errors were mainly related to technique, specifically driving or riding techniques for negotiating curves/turns and regaining positions on the roadways. Violations were mainly related to procedures, specifically breaking laws and regulations by exceeding posted speed limits and operating motor vehicles while legally intoxicated with a BAC of 0.08% or more.

Serious off-duty MVCs contained a lower level of decision errors and virtually no perceptual errors. Decision errors were mainly related to situational assessment, specifically failing to modify behaviors for potential hazards like selecting legal but inappropriate speeds for travel conditions or pressing on when falling asleep.

While direct comparisons between the unsafe act causal category levels are not possible due to differences in the definitions and calculations used in prior studies, it is possible to compare the overall trends found in the existing MVC literature. For skill based errors, prior studies have identified braking, lane-control, and overcorrection errors as factors in MVCs (Evans, 2004; NHTSA, 2009). For violations, prior studies have identified speeding over the posted speed limits, drunk driving/riding, aggressive driving/riding, and operating a vehicle without legal licensure as factors in MVCs. For decision errors, prior studies have identified travelling too fast for road conditions and improper lane changing as factors in MVCs. These findings from existing literature on

MVCs in the general population are similar to those from the present study of off-duty MVCs in the military.

The unsafe act levels associated with serious off-duty MVCs in the military from the present study and both fatal MVCs from prior studies in the general population (Iden & Shappell, 2006) and accidents in other occupational industries (Berry, 2010) are presented in Table 22. It appears that unsafe act category levels are generally comparable between off-duty MVCs in the military and MVCs in the general US population with the possible exception of skill based errors. In both off-duty MVCs and MVCs in the general population, unsafe act levels were higher for skill based errors and violations and lower for decision errors followed by perceptual errors. The unsafe act category levels were less similar between off-duty MVCs in the military and accidents in other occupational industries. In most industries, unsafe act levels are higher for skill based errors followed by decision errors and lower for violations followed by perceptual errors. Compared to accidents in other industries, off-duty military MVCs contained higher levels of skill based errors and violations and lower levels of decision errors and perceptual errors. These comparisons suggest that serious MVCs for both military personnel and the general population are associated with a higher level of violations than accidents in other domains.

Table 24: MVC and Industry HFACS Unsafe Act Trends

HFACS Category	Military Off-Duty MVCs	General Population MVCs	Occupational Industry Accidents
SBE	70.7%	49%	64.7%
DE	28.8%	30%	43.1%
PE	0.8%	2%	5.2%
VIO	54.0%	52%	10.5%

The differences between the human factors trends for off-duty MVCs in the military and prior studies for other industries may be expected considering the nature of the domain and the serious/fatal nature of the MVCs targeted in the present study. With the combination of a skill-dependent process and a task environment that allows little time to react to hazards, it is not surprising that severe off-duty MVCs contain a higher percentage of skill based errors and a smaller percentage of decision errors than other occupational industries.

The unsafe act trend of greatest concern is likely the high percentage of off-duty MVCs with violations. Violation trends were almost identical for severe off-duty MVCs in the military and fatal MVCs in the general population as found in prior studies by (Iden & Shappell, 2006; Wierwille, et al., 2002). However, violation levels are noticeably higher for off-duty MVCs than for accidents in occupational industries. Violations are not condoned in other domains the way they are for motor vehicle operators on the roadways. Speeding violations are so commonplace that the large majority of drivers in the US admit to travelling at speeds in excess of the posted speed limit (Allstate, 2011). Young males are the likeliest demographic for risk-taking and committing violations on the road. And fatal events have been shown to involve significantly more violations than less serious non-fatal and near-miss events (Wiegmann, et al., 2005). As such, the high levels of violations in MVCs are likely the result of several factors including the domain which condones violations, the population of interest comprised of young, male risk-takers, and the severity of the Class A and B MVCs included in the present study.

6.2 Precondition Trends

The temporal trends for preconditions for unsafe acts affecting military personnel involved in serious off-duty MVCs remained stable between FY1999 and FY2008. Unfortunately, these trends suggest that intervention strategies implemented over the past decade have been unsuccessful in sufficiently reducing the conditions and factors affecting service members operating motor vehicles on the roadways.

At the preconditions tier, the human factors trends for serious off-duty MVCs captured higher levels of adverse physiological state, adverse mental state, and physical environment factors followed by a lower level of physical/mental limitation factors. Serious off-duty MVCs contained low levels of technological environment and communication, coordination, and planning factors and virtually no personal readiness factors.

Adverse physiological state factors were mainly related to physiological conditions and to a lesser extent incapacitation, specifically being impaired due to drugs or alcohol and falling asleep. Adverse mental state factors were mainly related to mental fatigue, psychology, and awareness, specifically drowsiness, personality style (particularly related to risk-taking), and attention issues. Physical environment factors were mainly related to surface conditions and visibility, specifically slippery or debris-covered roads and insufficient lighting. Physical/mental limitation factors were mainly related to mental limitations, specifically limited experience or proficiency. Technological environment factors were mainly related to road sign and design issues. Communication, coordination, and planning factors were mainly related to poor travel planning and inadequate knowledge transfer.

As was the case at the unsafe act tier, the specific levels of each HFACS causal category at the preconditions tier cannot easily be compared directly due to definition and calculation differences. For instance, NHTSA uses the causal factor category "inattention" to capture a mix of factors including distraction, fatigue, physical condition, emotional condition and looked but did not see. Further, NHTSA defines "distraction" is several different ways over the past decade referencing fewer factors in at present than five years ago. However, general comparisons can be made for the key trends identified in the present study and those found in existing MVC literature.

For adverse physiological states, prior studies have identified alcohol use/impairment and falling asleep as factors in MVCs. For adverse mental states, prior studies have identified inattention, drowsiness, and mental/emotional state as factors in MVCs. For physical environment conditions, prior studies have identified slick roads, adverse weather conditions, and visibility issues as factors in MVCs. For physical/mental limitations, prior studies have identified inadequate knowledge and limited experience and exposure as factors in MVCs. For technological environment conditions, prior studies have identified road design, signs/signals/intersections, and vehicle problems as factors in MVCs. These findings suggest that the preconditions that affect service members on the roads are the basically the same as those that affect roads users in the general population.

The precondition causal category levels associated with serious off-duty MVCs in the military from the present study and two groupings of category standards (Berry, 2010) based on accidents in various occupational industries are presented in Table 26. For each of the accident benchmarking standards, the main grouping captures the average category level from a larger group of datasets and the secondary grouping captures the average category level from a smaller group of datasets with more thorough investigations for that particular category.

Table 25: MVC and Industry HFACS Preconditions for Unsafe Act Trends

HFACS Category	Off-Duty MVCs	Accident Benchmarking Standards
PhyE	18.2%	41.0% [13.4%]
TechE	4.1%	13.6%
AMS	21.5%	5.3% [26.4%]
APS	34.7%	1.7%
PML	12.5%	14.0% [2.9%]
CCP	4.8%	6.9% [18.8%]
PR	0.2%	1.3%

The levels of physical and technological environment conditions for off-duty MVCs were lower than the levels for the main grouping of accidents in other industries. The level of physical environment conditions for MVCs was similar to the level for the secondary grouping of accidents in other industries suggesting that these factors are typically investigated and captured with to higher level of detail for MVCs. The higher level of detail likely reflects the relative ease of detection and is able to be determined irrespective of the other details surrounding a MVC. Additionally investigators are accustomed to capturing weather and road conditions which are standard portions of the forms used during crash scene investigations. Technological environment conditions may be less prevalent for MVCs compared to other industries due to the limited involvement of technology for motor vehicle operators compared to workers in other industries who may have to operate several pieces of equipment and tools increasing the probability of experiencing a technological issue that contributes to an event. As such, the lower levels of physical and technological environment factors associated with off-duty MVCs compared to other occupational industries likely reflect a relative lack of association between environmental conditions and MVCs as well as a fairly successful management of potentially hazardous environmental conditions.

The levels of adverse mental state conditions for off-duty MVCs were higher than the main grouping but similar to the secondary grouping of accidents in other industries. The higher level of adverse mental state conditions in the present study may reflect the susceptibility of motor vehicle operators to these types of factors, particularly of motor vehicle operators in the military. Inattention/distraction and drowsiness are prevalent factors for MVCs in the general population (Hendricks, et al., 2001). Furthermore, as part of a courageous force with stressful jobs and demanding schedules, military personnel may be particularly susceptible to adverse mental state conditions like drowsiness, overconfident attitudes, and risky personality styles.

The levels of adverse physiological state conditions were much higher for off-duty MVCs than for accidents in other industries. For the same reasons mentioned in the prior paragraph, military personnel run a real risk of falling asleep on the roads. A bigger issue, however, is that of alcohol impairment which is known to be associated with a large portion of serious and fatal MVCs in the US each year. Several skills integral to driving and riding performance including attention, vision, perception, information processing, psychomotor, and steering are significantly degraded by alcohol. The higher level of adverse physiological state conditions in the present study likely reflects a domain that is deeply sensitive to the negative effects of alcohol. There have been recent improvements in this area with downward trends in alcohol-related MVCs for both the military and civilian populations, but this is still a top area in need of mitigation.

The levels of physical/mental limitation conditions for off-duty MVCs was similar to the main grouping and higher than the secondary grouping of accidents in other industries. Both age and experience have been shown to affect MVC fatality rates for drivers in the general population (Evans, 2004). The relationships between age, experience, and MVC fatalities may be reflected in the slightly elevated level of physical/mental limitation conditions for off-duty MVCs compared to that of other industries. Even though level of physical/mental limitation conditions was not abnormally high, this is an area that could benefit from mitigation efforts. These efforts should focus on providing opportunities for service members to practice their driving and riding skills in order to increase their levels of experience and proficiency.

The levels of both categories of operator factors for off-duty MVCs were lower than the levels for both the main and secondary groupings of accidents in other industries. The lower level of communication, coordination, and planning factors likely stems from the nature of the domain in the present study. While miscommunications can and do occur on the roads, they tend to be difficult to capture especially for fatal MVCs. Furthermore, the concept of coordination amongst road users is slightly foreign and is not as applicable as the concept of coordination amongst workers in other industries. As such, the communication, coordination, and planning causal category primarily captured planning factors. The lower level of personal readiness factors may be a result of inadequate investigation, reporting, or classification for this causal category. In support of the notion that HFACS experts under-classified personal readiness factors was the fact that many off-duty MVCs involved fatigue-related factors such as drowsiness and falling asleep but only one contained the personal readiness factor capturing lack of sleep. The HFACS experts may have overlooked personal readiness factors because they were not accustomed to classifying this category and didn't consider classifying sleep-related issues as anything other than operator conditions or because they did not equate off-duty driving or riding to being at work as referenced within the HFACS framework.

6.3 Upper Tier Trends

A limited number of causal factors for MVCs were classified at the supervisory and organizational tiers in the present study. The causal category levels associated with serious off-duty MVCs in the military from the present study and benchmarking standards associated with accidents in various occupational industries are presented in Table 27. The levels of supervisory and organizational causal categories for off-duty MVCs were lower than the main and secondary groupings of accidents in other industries. These lower levels are likely the result of inadequacies in MVC investigation and documentation processes. In all industries, investigation and identification of causal factors at the upper HFACS tiers are less obvious and more difficult. However, the nature of the industry also complicates the investigation into higher level causal factors. Additional challenges are introduced by the fact that these MVCs occur while service members are off-duty which raises the question of who to consider as people in supervisory and organizational roles – those in leadership positions above the service members within the structure of the US military, those acting in positions of authority within the structure of state law enforcement, or both.

Table 26: HFACS Trend Comparison for Off-Duty MVCs and Non-Filtered Accident Benchmarking Standards

HFACS Category	Off-Duty MVCs	Accident Benchmarking Standards
Outside Influences	5.4	-----
Organizational Influences		
Organizational Climate	0.3	1.1
Organizational Process	0.8	7.6 / 52.0
Resource Management	0.2	1.9
Unsafe Supervision		
Inadequate Leadership	1.0	3.1 / 21.6
Planned Inappropriate Ops	0.6	3.7 / 22.1
Failure to Correct Problems	0.5	4.8
Leadership Violations	0.1	2.3

No industry benchmarking standards were available for comparison to the level of outside influences factors associated with off-duty MVCs. However, more factors were classified at the outside influence tier than at the uppers supervisory and organizational tiers combined. Perhaps this is because identification of outside influence factors which ultimately capture the unsafe acts of other road users are easier to identify than factors which capture inadequate leadership or organizational influences that act upon military road users.

CHAPTER 7: DISCUSSION, COMPARISONS OF TRENDS

A handful of studies have looked at the demographic and behavioral characteristics associated with MVCs in the military but none have done so based on a comprehensive and systematic classification of human factors causes. The present study was able to successfully identify and compare the main human factors trends associated with severe off-duty MVCs for service members by military branch, vehicle type, paygrade, and age group.

This chapter presents the key findings for severe off-duty MVCs across military branches, vehicle types, paygrades, and age groups found in the present study. The main human factors trends associated with off-duty MVCs for each of these demographic variables are reviewed and compared to those from existing literature for MVCs in both the military and general populations. Implications of human factors trends and comparisons found in the present study are discussed.

7.1 MILITARY BRANCHES: USAF, USN, USMC

Interestingly, there were noticeable differences in the number of factors classified for serious off-duty MVCs involving USAF, USN, and USMC service members. Both the average and maximum number of factors classified per case were greatest for USAF MVCs. In fact, USAF MVCs contained an additional causal factor per case on average compared to USN and USMC MVCs. The differences in the number of causal factors classified may reflect differences in the quality of MVC investigation and documentation processes across the three military branches. As such, readers are cautioned to refrain from drawing conclusions about potential differences in the MVC causal factor trends across the branches based on the findings in the present study.

7.1.1 Unsafe Acts

The main HFACS-MVC unsafe act causal category trends associated with serious off-duty MVCs involved skill based errors and violations for all three military branches. Though no significant differences between branches were identified for decision errors, there were significant differences for skill based errors and violations. Specifically, USAF MVCs contained a lower percentage of skill based errors and a higher percentage of violations than both USN and USMC MVCs. In general, HFACS-MVC unsafe act subcategory levels were similar or higher for USAF MVCs and similar or lower for USMC MVCs.

Skill based error category and subcategory differences across the three branches were most intriguing. This was the only HFACS-MVC causal category involving a significantly lower level for USAF MVCs. An interesting trend was found for the percentages of MVCs associated with the skill based error causal factor nanocode "LCU" which captured loss of control for unknown reasons. In many cases, skill based errors classified as "LCU" would likely have been classified using other skill based error nanocodes if the MVC narrative had provided additional information or detail. The branches with the highest percentage of MVCs associated with "LCU" skill based errors were the USMC followed by the USN and finally the USAF. The differences between branches for "LCU" suggest imply that MVC data provided by the USAF were of better quality and contained more detail compared to MVC data provided by the USN and the USMC.

Serious off-duty MVCs contained significantly higher levels of skill based errors for military personnel in the USN and USMC compared to military personnel in the USAF. Higher percentages of MVCs involving USN and USMC personnel contained skill based errors related to attention compared to MVCs involving USAF personnel. A higher percentage of MVCs involving USAF personnel contained skill based errors related to technique compared to MVCs involving USN and USMC personnel.

USAF MVCs were associated a significantly higher percentage of violations than USN and USMC MVCs. At first, this trend was surprising as service members in the USMC are younger and more predominantly male compared to service members in the USN and especially the USAF. With young males committing the most violations on the roads like speeding, racing, and drunk driving, USMC MVCs were expected to have the highest percentage of violations, not the lowest. However, as is discussed in further detail shortly, any difference between the percentages of violations associated with MVCs in the three branches is likely an artifact of the higher quality of MVC investigations in the USAF.

7.1.2 Preconditions for Unsafe Acts

The main HFACS-MVC precondition causal category trends associated with serious off-duty MVCs were significantly higher in the USAF than in the USN and often the USMC for all precondition categories except adverse physiological state (and personal readiness which was excluded from analysis). These findings most likely reflect differences in investigation and reporting practices across the three branches. The USN and USMC appear to be under-investigating and/or under-reporting causal factors from most HFACS-MVC causal categories while the USAF appears to have more thorough investigation and reporting practices. The more thorough investigation and reporting process allowed more instances where causal factors could be identified and classified, resulting in an increased number of causal factors classified for USAF MVCs.

7.2 Vehicle Types: 2W, 4W

Given that only an estimated 10% of military personnel own motorcycles, it initially seemed surprising that over one-third (38%) of the serious and fatal off-duty MVCs between FY1999 and FY2008 involved service members operating 2W vehicles. However, MVCs are more hazardous and less survivable on 2W vehicles than in 4W vehicles. In fact, riders of 2W vehicles are 35 times more likely than drivers of 4W vehicles to be fatally injured in a MVC (NHTSA, 2007). As reflected here, the small subset of riders in the military is disproportionately represented in the set of Class A and B off-duty personal MVCs included in the present study.

7.2.1 Unsafe Acts

The main HFACS-MVC unsafe act causal category trends associated with serious off-duty MVCs were almost identical for 2W and 4W vehicles. Though no significant differences between 2W and 4W MVCs were identified at the causal category level, there appeared to be some differences at the unsafe act subcategory level for skill based errors and violations.

Though safe operation of a 2W vehicle is more challenging and requires a greater level of skill, 2W MVCs did not contain significantly more skill based errors than 4W MVCs. However, the additional intricacies associated with riding 2W vehicles are captured at the skill based error subcategory level where 2W MVCs had a higher percentage of technique errors. In comparison, 4W MVCs had higher percentages of control errors for unknown reasons and attention errors.

The less forgiving nature of riding 2W vehicles is reflected at the violation subcategory level where 2W MVCs were associated with a higher percentage of speeding violations than 4W MVCs. The greater difficulty of recovery from errors on 2W vehicles along with the positive relationship between speed and severity of MVC may help to explain this finding.

Additional differences in violation subcategories between 2W and 4W vehicles were the higher percentage of knowledge violations for 2W MVCs and the higher percentage of drunk driving violations for 4W MVCs. Like fatal MVCs in the US population, 2W MVCs in the present study were associated with a higher percentage of knowledge violations (i.e. lack of licensure) compared to 4W MVCs. However, the actual percentages with unlicensed 2W and 4W motor vehicle operators were higher for fatal MVCs in the US population than for serious off-duty MVCs in the military population perhaps reflecting the composition of the underlying military population of citizens and legal immigrants with fairly clean driving/riding records.

7.2.2 Preconditions for Unsafe Acts

In contrast to unsafe act trends, the main HFACS-MVC precondition causal category trends associated with serious off-duty MVCs were quite different for 2W and 4W vehicles. Significant differences between 2W and 4W MVCs at the causal category level were found for all precondition categories except technological environment (and personal readiness which was excluded from analysis).

A significantly higher percentage of 4W MVCs contained physical environment factors and were associated with more surface condition and visibility factors. Further differences between vehicle types exist at the physical environment nanocode level which indicates that 2W MVCs involved more surface debris and obscured visibility conditions while 4W MVCs involved more slippery road surface and weather visibility conditions. These findings make sense considering that riders are more likely to operate 2W vehicles in better weather and environmental conditions.

A significantly higher percentage of 4W MVCs contained adverse mental state factors and were associated with more drowsiness factors. However, 2W MVCs were associated with more psychology factors perhaps reflecting a difference between 2W and 4W operator personality styles especially for risk-taking.

A significantly higher percentage of 4W MVCs contained adverse physiological state factors and had a higher percentage of cases associated with alcohol/drug impairment and falling asleep. This could again be related to rider preference with regards to weather, environmental, and lighting conditions which may limit the amount of associations of impairment and falling asleep with off-duty MVCs. However, the absence of any occurrences of falling asleep on 2W MVCs may be an artifact of the nature of 2W MVCs which would not really allow for recovery if the rider actually did fall asleep on the vehicle.

A significantly higher percentage of 2W MVCs contained physical/mental limitation factors related to limited experience/proficiency. These findings are similar to those from prior studies which have found that a high percentage of riders in fatal 2W MVCs had only a matter of a few months of experience operating the mishap motorcycle. The much higher percentages of both lack of experience/proficiency and knowledge violations for 2W MVCs stresses how critical it is for riders to have adequate levels of experience and proficiency prior to operating 2W vehicles. This is especially true for service members in situations where they are trying to ride for the first time (by themselves or with friends) without adequate instruction or understanding and where they are riding with one or more people in situations that exceed their skill levels.

A significantly higher percentage of 4W MVCs contained communication, coordination, and planning factors and were associated with more pre-travel planning factors. Again, this is likely related to the rider preference for operating 2W vehicles in more agreeable weather and visibility conditions.

7.3 Paygrades: Enlisted, Officer

The percentage of enlisted personnel was higher for those in serious off-duty MVCs from the present study (93%) than for service members in the general US Active Duty military population (84%) (OneSource). The disproportion between MVCs by paygrade was not unexpected given that prior military MVC studies have found enlisted personnel to have higher MVC fatality rates than officers (Bowes & Hiatt, 2008; Hooper, et al., 2006). Furthermore, both the present study and a prior study of MVCs involving Army service members contained the same percentage (93%) of enlisted personnel (Bell, et al., 2000).

7.3.1 Unsafe Acts

The main HFACS-MVC unsafe act causal category and subcategory trends associated with serious off-duty MVCs were fairly similar for enlisted and officer paygrades, particularly for errors. There was a significant difference between enlisted and officer MVCs for violations.

A significantly higher percentage of enlisted MVCs contained violations and were associated with higher percentages of almost all violation subcategories especially speeding and drunk driving. This discrepancy may reflect the differences between enlisted and officer paygrades with regards to age, educational background, marital status and especially their roles and responsibilities within the military. Enlisted personnel are held to a high standard of conduct, but tend to have some slack from the military when it comes to traffic offenses. However, officers are held to an even higher standard of conduct and are expected to act reasonably and responsibly both on and off duty. The military does not tolerate officers being convicted of serious moving traffic violations such as speeding, reckless driving, or driving while intoxicated. Even seasoned officers can expect to be discharged if convicted for driving under the influence (DUI). Based on these high expectations and the severe consequences of violating procedures, it is only logical that significantly fewer MVCs involved violations for officers than for enlisted personnel.

7.3.2 Preconditions for Unsafe Acts

The main HFACS-MVC preconditions for unsafe act causal category trends associated with serious off-duty MVCs were similar for enlisted and officer paygrades suggesting that they are negatively affected by basically the same general preconditions on the roads. Though no significant differences in enlisted and officer MVC trends were identified for any precondition causal categories, there were some interesting trends at the subcategory level.

Officer MVCs were associated with higher percentages of road surface, visibility, awareness, incapacitation (particularly falling asleep), and planning factors than enlisted MVCs. Looking at these trends together suggests that officers may have performed their pre-travel planning inadequately particularly by selecting poor travel times and durations which increased their exposure to hazards. For example, selecting a poor departure time or route may increase the risk of encountering adverse weather and lighting conditions or of experiencing personal conditions related to attention and fatigue. These trends are not surprising considering that officers are more likely to have families (particularly spouses and children) and be juggling several different roles and responsibilities that compete for their time.

Enlisted MVCs were associated with higher percentages of factors related to operator impairment and lack of experience/proficiency than officer MVCs. These findings were in line with what is known about the enlisted military population. Enlisted personnel are typically younger with fewer responsibilities within the military compared to officers and have relatively less education and experience both in life and in operating motor vehicles. The serious MVCs in the present study reflect their lower levels of experience and proficiency particularly with 2W vehicles. Additionally, the comparatively high percentage of MVCs with impairment for enlisted personnel suggests that they may not grasp the entirety of all the ramifications of drunk driving/riding on both their personal and professional lives.

A significantly higher percentage of 2W MVCs contained physical/mental state factors and had a much higher percentage of cases associated with limited experience/proficiency. These findings are similar to those from prior studies which have found that a high percentage of riders in fatal 2W MVCs had only a matter of a few months of experience operating the mishap motorcycle.

7.4 Age Groups: 17-20, 21-25, 26-30, 31-35, 36-40, >40

The majority (81%) of military personnel in the present study were under the age of 30 with the largest portion in the 21-25 year old age group. These findings were similar to those from prior studies which found that younger military personnel under the age of 26 were most likely to be involved in serious MVCs (Bell, et al., 2000; Hooper, et al., 2006).

7.4.1 Unsafe Acts

The main HFACS-MVC unsafe act causal category and subcategory trends associated with serious off-duty MVCs were fairly similar for service members in the six age groups, particularly for errors. For the most part, error subcategory trends also appeared fairly similar for MVCs involving the six age groups. However, significant differences were found for the percentages of MVCs associated with violations for 21-25 year old and over 40 year old service members.

At the subcategory level of decision errors, an interesting result was the higher percentages of MVCs associated with prioritization decision errors for older (36-40 and >40 year old) service members. Older service members are generally busy with families at home and several off-duty roles and responsibilities that compete for their time. Prioritization decision errors may relate to placing a higher priority on an off-duty role or responsibility than on personal safety on the roadway.

At the category level of violations, 21-25 year old service members and service members over the age of 40 had the highest and lowest percentages of MVCs associated with violations respectively. In fact, 21-25 year old service members had a significantly higher percentage of MVCs associated with violations than both the next youngest (17-20 year old) and next oldest (26-30 year old) age groups. MVCs involving 21-25 year old service members had the highest percentage of speeding violations and a higher percentage of drunk driving violations than both 17-20 year old and 26-30 year old service members. These findings, particularly the association with speeding, has been identified in prior MVC studies which have found young males as the most likely demographic to engage in risky behaviors such as speeding and racing.

In contrast to the younger service members, MVCs for the oldest age group (>40 year old) were associated with a significantly lower percentage of violations than all other age groups. The violation subcategory trends showed that MVCs had decreasing percentages of speeding violations with increased age starting with 26-30 year old service members. Furthermore, MVCs involving the oldest group of service members (>40 years old) were associated with much lower percentages of both speeding and drunk driving violations than other age groups.

7.4.2 Preconditions for Unsafe Acts

The main HFACS-MVC precondition causal category trends associated with serious off-duty MVCs were fairly similar for service members in the six age groups. The only precondition causal category associated with significantly different percentages of MVCs across age groups was adverse physiological state. Significantly higher percentages of MVCs were associated with adverse physiological state factors for 36-40 year old service members compared to all age groups except 31-35 year olds and for 21-25 year old service members compared to the youngest (17-20 year old) and oldest (>40 years old) service members. These differences predominantly reflected the relative involvement of alcohol impairment/drunk driving for service members in different age groups.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions and Implications

The overall purpose of the present study was to identify the main human factors trends associated with serious off-duty MVCs involving military personnel with the end goal of preventing future losses of service members to MVCs. The five main research questions as outlined in Chapter 1 were addressed.

Q1: What are the main human factors trends for serious off-duty MVCs involving military service members?

At the unsafe acts level, the main human factors trends for serious off-duty MVCs are skill based errors and violations related to procedures. At the preconditions level, the main human factors trends for serious off-duty MVCs are adverse physiological states, adverse mental states, and physical environment conditions.

Now that the main human factors trends associated with serious off-duty MVCs in the military have been identified and assessed using the HFACS-MVC framework, the next step is to select which problems to address first and the manner with which to target them. Prevention efforts based on the skill based error trends identified in the present study should focus on technique skills related to negotiating curves/turns and regaining road positions. Providing military personnel with opportunities to practice these specific skills may help to reduce their involvement in MVCs. Prevention efforts based on the violation trends identified in the present study should focus on procedural violations related to speeding and drunk driving. Enforcing existing rules and implementing stricter penalties for military personnel who commit speeding and drunk driving violations may help to reduce their involvement in MVCs.

Q2: Are the main human factors trends different for MVCs involving service members from the USAF, USN, and USMC?

The main human factors trends for USAF, USN, and USMC MVCs are generally similar for unsafe acts but significantly different for preconditions. Specifically, 4W MVCs are more affected by physical environment, adverse mental state, adverse physiological state, and communication, coordination, and planning factors while 2W MVCs were more affected by physical and mental limitations.

Similarities between the three military branches for some human factors trends but not others may indicate that some trends are universal for service members and others are service-specific or may actually reflect differences in MVC data quality across the branches. The quality of an investigation process and subsequently the data captured during the investigation may affect the number and types of factors identified. Data quality differences across branches are provided in more detail in the limitations section of this chapter.

Due to the differences between data quality for MVCs in the USAF, USN, and USMC, it is not possible to make any valid conclusions about similarities or differences in human factors trends between the three military branches. Prior to performing further comparisons of MVC human factors trends, the MVC investigation and reporting practices should be evaluated and compared amongst the USAF, USN, and USMC military branches.

Q2: Are the main human factors trends different for MVCs involving 2W and 4W vehicles?

At the unsafe acts causal category level, the main human factors trends for 2W and 4W MVCs are not significantly different though 2W MVCs are associated with more technique errors and knowledge violations. At the preconditions causal category level, the main human factors trends for 2W and 4W MVCs are significantly different with 4W MVCs associated with more physical environment, adverse mental state, adverse physiological state, and communication, coordination, and planning factors and 2W MVCs were associated with physical and mental limitations.

Differences in human factors trends for MVCs involving 2W and 4W vehicles suggest that military personnel may benefit most from vehicle-specific prevention strategies. These findings suggest that there may be benefit in developing additional vehicle-specific strategies based on the problem areas for 2W and 4W MVCs identified in the present study.

Q4: Are the main human factors trends different for MVCs involving enlisted and officer service members?

At both the unsafe acts and preconditions category levels, the main human factors trends for MVCs are generally similar for enlisted and officer personnel. The only difference between human factors trends between paygrades is in violations which are associated with a higher percentage of MVCs for enlisted personnel.

Similarities between the human factors trends for MVCs involving enlisted and officer paygrades suggest that creating specialized prevention strategies for officers and enlisted personnel may not be necessary. However, the significantly higher percentage of violations for enlisted MVCs may be a reflection of the underlying differences between paygrades related to authority, accountability, and responsibility. As such, one potential strategy to combat these violations involves changing the standards to which enlisted service members are held by enforcing existing rules and implementing stricter penalties for enlisted personnel who receive moving traffic citations both on and off base.

Q5: Are the main human factors trends different for MVCs involving service members in different age groups?

At both the unsafe acts and preconditions category levels, the main human factors trends for MVCs are generally similar for service members in different age groups except for violations and adverse physiological states. Significantly higher percentages of MVCs involving 21-25 year old service members and significantly lower percentages of MVCs involving service members over the age of 40 are associated with violations (particularly speeding and drunk driving) and adverse physiological states (particularly impairment due to alcohol) compared to MVCs for other age groups.

The similarities between human factors trends for MVCs involving all age groups suggest that prevention strategies may not need to be targeted towards specific age groups. Additionally, other age groups could potentially benefit from prevention programs that are currently in place but only mandated for young service members such as AAA DIP. Instead, larger streamlined prevention programs should be developed and provided to all military personnel that can be followed up with smaller age-specific programs.

Any age-specific programs, if deemed necessary, should be applied to areas in which they can make the most impact. Though one of the age groups with the most unique human error trend profile is that for service members over the age of 40, it may be more sensible to focus resources set aside for age-specific strategies to younger age groups due to the relative lack of involvement of older service members in off-duty MVCs. The 21-25 year old and 17-20 year old service member age groups may be the best candidates for age-specific strategies. Both age groups are involved in high percentages of serious off-duty MVCs with unique human factors trends for MVCs and may be able to benefit from tailored preventions specialized to the nuances unique to their specific age groups.

8.2 Strengths and Limitations

The present study had several strengths including the data set, framework, and methods used for classification. First, the MVCs provided by the service centers contained the entire population of Class A and B off-duty MVCs for all three military branches, not just a subset that would require extrapolation to the larger military population. Using the same framework and methodology for classification of human factors trends for MVCs in all three branches offers a potential for comparisons across branches in the future.

Next, the present study used original MVC narratives to identify the causal factors instead of previously identified human factors data containing potential errors and inconsistencies. Focusing solely on MVCs where service members were operating a motor vehicle, multiple HFACS experts evaluated each MVC which reduced bias or oversight on the part of a single individual.

Finally, causal factors were identified and classified using an established human error framework (HFACS) already adopted throughout the military and modified specifically for the MVC domain. Using an HFACS-based framework for classification of MVCs allowed for comparisons of human factors trends across multiple industries.

The present study had a few limitations as well including sample size and data quality. Though almost a decade of data was classified for USAF and USN MVCs, there was only a few years of data for USMC MVCs. Further complicating matters were differences between the variables captured for MVCs by the different military branches. On a related topic, due to the archival nature of the data, the quality of available data was restricted by what was originally investigated and documented for each MVC.

Several findings from the present study suggest that investigation and reporting practices for USAF MVCs were superior to those for USN and USMC MVCs. First, several of the HFACS experts coding the off-duty MVCs commented on the relative lack of detail contained in the narratives for MVCs in the USMC compared to the USN and especially the USAF. Next, the counts of causal factors classified for each MVC and for MVCs overall were so much higher for the USAF cases than either USN or USMC cases. Further, the frequencies of classifying skill based errors with the “LCU” nanocode which captured loss of control for unknown reasons were highest for USMC MVCs followed by USN MVCs and lowest for USAF MVCs. Also, MVCs contained a higher percentage of skill based errors related to technique in the USAF compared to both the USN and

USMC. Additionally, USAF MVCs were associated with significantly higher levels of virtually all precondition causal categories and had similar or higher percentages of almost all subcategories. Finally, there were only a few causal factors classified at the upper two HFACS-MVC tiers in the entire study and all were identified in MVCs from the USAF.

More thorough investigations may capture less salient factors (e.g. poor driving technique as opposed to speeding) and provide more opportunities for causal factors to be identified increasing the number of causal factors classified. Based on the findings of the present study, it is likely that the similarities and differences in the main trends are indicative of underlying differences in MVC data quality and reflect differences in investigation and reporting practices across the three branches. As such, any significant differences between human factors trends for MVCs in the USAF, USN, and USMC may be an artifact of better data quality for USAF MVCs, not an indication of differences in the underlying human factors trends across branches.

8.3 Unanswered Questions and Recommendations

Findings from the present study have generated a new set of additional questions related to the study of human factors trends associated with MVCs. Future analyses of the HFACS-MVC data from the present study might look at the human factors trends over time in order to find how the main issues have been changed throughout the years. Comparisons of the human factors trends for other demographic factors such as geographic locations and time since deployment may provide additional insight into the profile of service members who at-risk for off-duty MVCs.

Based on the results of the present study, future studies should look at differences in investigation and reporting practices for MVCs in the USAF, USN, and USMC. Identification of these differences would provide the basis for streamlining investigation and reporting practices across the branches and for comparing the human factors trends across branches. Additional research should develop and evaluate previous, current, and future prevention strategies to combat the common human factors plaguing military MVCs. A historical look at the human factors trends in combination with a timeline of implemented prevention programs can aid in evaluating the effectiveness of prior programs on the causal factors associated with MVCs. Additional benefits may result from applying the prospective Human Factors Intervention Matrix (HFIX) tool to assist with the development of targeted programs by identifying and assessing intervention strategies in a comprehensive and systematic manner. Future research might also look at evaluating the HFACS-MVC framework with other data sets including both MVCs in the military and civilian populations. Future benefits could also be achieved by developing data collection tools that allow investigators to quickly and easily capture the information necessary for complete and thorough classification with the HFACS-MVC framework.

APPENDICES

APPENDIX A: TERMINOLOGY AND DEFINITIONS

TERMS	DEFINITIONS
Motor Vehicle	a privately owned non-government, non-commercial vehicle that can be operated on public highways (USAF, 2008); includes motorcycles, passenger vehicles, and light trucks
Two Wheeled (2W) Motor Vehicle	a powered motor vehicle with two wheels; includes cruisers, sport, touring, standard, and dual-purpose motorcycles
Four Wheeled (4W) Motor Vehicle	a powered motor vehicle with four wheels; includes cars and light trucks
Motor Vehicle Crash (MVC)	an event in which a motor vehicle in motion collides with obstacle(s) in the environment resulting in injury and/or property damage
Crash Demographics	characteristics capturing the setting of a MVC such as location (rural or urban) and temporal information (month, day, and time)
Road Traffic Fatality	death of a person due to injuries sustained in a MVC within 30 days of the event (WHO, 2009)
Permanent Total Disability	permanent nonfatal incapacitation that prevents a service member from keeping gainful employment after losing multiple body parts (hands, feet, eyes); also includes non-medically induced coma (USAF, 2008)
Permanent Partial Disability	permanent nonfatal impairment that restricts a service member's range of motion after losing the use of body part(s) (USAF, 2008)
Mishap	an unplanned event or chain of events caused by unidentified or uncorrected hazards that result in property damage, injury, or death (DoN, 2005); includes afloat, ground, industrial, motor vehicle categories of mishaps (USAF, 2008)
Class A	a mishap resulting in property damage costs in excess of $1,000,000, the loss of a destroyed DoD aircraft, or the permanent total disability or death of a service member (DoN, 2005)
Class B	a mishap resulting in property damage costs between $200,000 and $1,000,000, the inpatient hospitalization of three or more service members for care, or the permanent partial disability of a service member (DoN, 2005)
Class C	a mishap resulting in property damage costs between $20,000 and $200,000 or a loss of work days for a service member (DoN, 2005)

APPENDIX B: HFACS-MVC FRAMEWORK AND NANOCODE GUIDE

UNSAFE ACTS
Skill Based Errors: Occur during highly automated tasks, often without thought; Vulnerable to attention, memory, and/or technique failures
Attention Failures (ATT) 1. Forgot to check blind spot 2. Forgot to use communication device (e.g. horn or turn signal) 3. Didn't keep eyes on the road 4. Inadvertent operation of wrong control (e.g. pressed gas instead of brake, put vehicle into reverse instead of drive) 5. Inadvertently drifted out of lane (note: not due to falling asleep) Postural Error (POS) 1. Operated vehicle from an awkward position/posture Technique Error (TQ) 1. Improper passing maneuver (e.g. passed without looking at the road situation – enough room, vehicle approaching, etc.) 2. Improper application of acceleration or brakes 3. Usual method of executing procedure is flawed/improper/imperfect 4. Failed to maintain a sufficient following distance (due to speed and/or distance between vehicles; not due to misjudgment of distance or speed) 5. Over-steered/overcorrected when avoiding collision 6. Over-steered/overcorrected when attempting to regain position on roadway 7. Failed to negotiate curve/turn/bend/ramp 8. Failed to negotiate lane change/passing maneuver Timing Error (TM) 1. Reacted too slowly 2. Reacted too quickly Lost Control due to Unknown Reason (LCU) Skill Based Error – Other (SO)
Decision Errors: Occur when chosen action is inadequate or inappropriate for the situation; "Honest mistake", poor choice; often due to inadequate knowledge
Information Processing (IP) 1. Misinterpreted information 2. Selected a poor or unfamiliar route for travel (e.g. selected a shorter route) Prioritization (PRI) 1. Misplaced prioritization (e.g. swerved into traffic to avoid a small animal) 2. Ignored caution or recommendation (e.g. from a friend) 3. Wrong response to abnormal situation Procedural Decision Error (DPRO) 1. Failed to give way/yield 2. Inappropriate behavior/maneuver 3. Improper passing or lane change (without adequate passing room, within a turn, in

UNSAFE ACTS
oncoming lane of traffic, etc.) Situational Assessment (SA) 1. Failed to recognize hazardous conditions 2. Failed to modify behavior to protect against potentially hazardous conditions (tactical planning decisions on the road like pressing on when tired) Vehicular Decision Error (DPMV) 1. Inadvertently exceeded capabilities of vehicle 2. Inadequate loading/securing of items within vehicle 3. Improper loading/securing of items on top of vehicle 4. Poor maintenance of PMV (e.g. failure to change oil regularly) 5. Inadvertently used defective/inadequate vehicle Decision Error – Other (DO)
Perceptual Errors: Occur when degraded or “unusual” sensory input lead to an error.
Perceptual Error (PE) 1. Misjudged distance 2. Misjudged speed 3. Misjudged depth 4. Misjudged height 5. Misjudged surface conditions 6. Missed information due to degraded sensory input (e.g. sensory information led to misreading a sign or equipment) 7. Misheard traffic cue (e.g. horn) due to noise issues/degradation Perceptual Error – Other (PEO)
Violations: Conscious decisions to bend/break existing rules/regulations
Procedural Violations (VPRO) 0. Speeding – unknown illegal speed (over the limit) 1. Speeding 10-19 mph over the speed limit 2. Speeding 20-29 mph over the speed limit 3. Speeding 30-39 mph over the speed limit 4. Speeding 40+ mph over the speed limit 5. Illegal passing or lane changing behavior 6. Reckless/erratic operation of PMV 7. Racing with another vehicle 8. Excessive risk taking 9. Violation of training rules/laws 10. Disregard of traffic signals Knowledge Violations (VKNO) 1. Operated vehicle without a valid license/endorsement 2. Entry into unauthorized areas Drunk Driving – BAC $\geq$ 0.08% (VDD) Violation – Other (VO)

PRECONDITIONS FOR UNSAFE ACTS
Physical Environment: Operational and ambient environment.
Surface Conditions (SC) 1. Slippery road surface (e.g. due to ice, rain) 2. Debris on road surface (e.g. dirt, loose rocks, mud) 3. Inadequate maintenance of road surface (e.g. potholes, ruts) Visibility (VIS) 1. Inadequate visibility due to sun/sun glare, rain, snow, or fog 2. Inadequate visibility due to insufficient lighting 3. Obscured view of traffic due to interaction of vehicle and environment (e.g. obscured view of environment due small vehicle, like a motorcycle, travelling behind larger vehicle, like a truck or bus) Miscellaneous (MIS) 1. Clutter/loose items inside vehicle 2. Congestion due to traffic 3. Noisy environment 4. Wind Physical Environment – Other (PHYO)
Technological Environment: Vehicle and road environment.
Protective Devices on the Road (PPE) 1. Median: inadequate or missing 2. Guardrail: inadequate or missing 3. Traffic control: inadequate/defective or missing; poor location 4. Signs (informational/warning): inadequate/defective or missing; poor location Vehicle (TPMV) 1. Defective or dysfunctional vehicle 2. Defective or dysfunctional vehicular equipment 3. Inadequately maintained vehicle/vehicular equipment Design (DES) 1. Inadequate design of control systems/signs/displays 2. Inadequate road design (e.g. extremely curvy, too narrow, etc.) 3. Inadequate road gradient 4. Inadequate shoulder for road (e.g. missing or very narrow) 5. Inadequate placement of objects alongside the road 6. Inadequate ergonomic design/Poor man-system interface (in vehicle) Technical Environment – Other (TEO)
Adverse Mental States: Mental conditions of the operator that affect performance.
Attitude (A) 1. Overconfidence/Lack of confidence 2. Get-home-it is 3. “It won’t happen to me” attitude 4. Complacency 5. Overaggressive

PRECONDITIONS FOR UNSAFE ACTS
6. Frustration 7. Stress 8. Focus/attitude towards task Awareness (AW) 1. Attention (inattention, distraction, channelized attention, task fixation, preoccupation with problems, etc.) 2. Time pressure (perceived haste to complete task/rushing) 3. Confusion 4. Boredom 5. Extreme concentration/perception demands 6. Inappropriate peer pressure Mental Fatigue (AMF) 1. Drowsy driving (e.g. mental fatigue after a taxing workday; *note: differs from fell asleep*) Psychology (PSY) 1. Personality style 2. Pre-existing personality disorder 3. Fears or phobias 4. Emotional overload Adverse Mental State – Other (AMO)
Adverse Physiological States: Medical/physiological conditions of the operator that affect performance.
Physiological Condition (PC) 1. Visual illusions 2. Impairment due to drugs or alcohol 3. Overexertion of physical activities Medical Condition (MC) 1. Medical illness 2. Dehydration 3. Inability to sustain body position 4. Previous injury or illness 5. Influenced by medication Incapacitation (INC) 1. Fainted/passed out 2. Fell asleep Adverse Physiological State – Other (APO)
Physical/Mental Limitations: Occur when situation exceeds the capabilities of the operator.
Mental Limitations (ML) 1. Pre-existing psychological disorder 2. Incompatible intelligence/aptitude 3. Not familiar with job performance standards

PRECONDITIONS FOR UNSAFE ACTS
4. Limited experience/proficiency Sensory Deficiencies (SD) 1. Visual limitations or deficiencies 2. Hearing limitations or deficiencies Physical Limitations (PL) 1. Lack of competency 2. Lack of proficiency 3. Incompatible physical capabilities 4. Inadequate practice of skills 5. Musculoskeletal disorder 6. Inability to sustain body movement 7. Restricted range of body movement 8. Inappropriate height, weight, size, strength, etc. 9. Motor skill, coordination, or timing deficiencies 10. Substance sensitivities or allergies Physical/Mental Limitation – Other (PMO)
Communication, Coordination, and Planning: Poor coordination/communication between road users (vehicle operators, passengers, bicyclists, pedestrians) and planning prior to operating the vehicle.
Coordination (COR) 1. Failed to use all available resources 2. Lack of teamwork Communication (COM) 1. Ineffective/no communication methods 2. Misunderstood instructions (e.g. verbal training or writing manuals) 3. Inadequate communication of hazards 4. Incorrect instructions provided 5. Inadequate knowledge transfer Planning (PLA) 1. Poor travel planning (e.g. starting a long trip at 02:00, without adequate rest) Communication, Coordination, Planning – Other (CCPO)
Personal Readiness: Activities performed prior to operating a vehicle that affect performance.
Personal Readiness (PR) 1. Inadequate rest requirements 2. Self-medication 3. Use of illicit drugs and alcohol 4. Hung-over 5. Inadequate nutrition/diet 6. Overexertion off duty 7. Lack of sleep Personal Readiness – Other (PRO)

UNSAFE SUPERVISION
Inadequate Supervision (IS) 1. Training 2. Guidance/Oversight Inadequate Supervision – Other (ISO)
Planned Inappropriate Operations (PI) 1. Scheduling 2. Task Assignment Planned Inappropriate – Other (PIO)
Failed to Correct Known Problem (FC) 1. Deficiencies not addressed 2. Deficiencies inadequately addressed Failed to Correct – Other (FCO)
Supervisory Violations (SV) 1. Violated rules and regulations 2. Failed to enforce rules and regulations Supervisory Violations – Other (SVO)

ORGANIZATIONAL INFLUENCES
Resource Management (RM) 1. Human resources 2. Monetary/budget resources 3. Equipment/facility resources Resource Management – Other (RMO)
Organizational Climate (OC) 1. Structure 2. Policies 3. Culture Organizational Climate – Other (OCO)
Organizational Process (OP) 1. Operations 2. Procedures 3. Oversight Organizational Process – Other (OPO)

OUTSIDE INFLUENCES
Outside Influences: Causes completely outside the control of the military motor vehicle operator; Often due to other drivers/riders not following safe road procedures.
Outside Influences (OI) • Civilian operator entered roadway on which military operator travelling • Civilian operator changed lanes or merged while travelling in the same direction on roadway as military operator • Civilian operator exited roadway on which military operator travelling • Civilian operator failed to yield right of way at intersection • Civilian operator travelled in wrong direction/opposite direction of traffic; military operator struck head-on by civilian operator • Rear-ended by civilian operator • Civilian operator performed a U-turn in path of travel • Civilian operator intoxicated

APPENDIX C: HFACS DRIVING SAMPLES

Causal Factor	HFACS Causal Category
While waiting to turn onto the highway, a driver started to inch forward when he saw an oncoming truck in the right lane of traffic. He tried to stop the vehicle, but accidentally hit the gas instead forcing the truck to swerve to avoid a collision.	Skill Based Error
The driver failed to adjust his braking technique to accommodate for the icy road conditions and slid into the car in front of him at the stop sign.	Skill Based Error
Late one night a driver opted to take an unfamiliar shortcut to get home. He realized his mistake when the shortcut took him on a small, curvy road with no lighting.	Decision Error
At an intersection, a driver misjudged his distance from an approaching motorcycle. It was actually closer than the driver thought, but the motorcycle's single headlight provided poor visual cues regarding its position.	Perceptual Error
The driver drove 10 to 15 mph over the posted speed limit on the highway.	Violation
With a school bus dropping kids off ahead, a driver opted to pass illegally instead of stopping the vehicle at least 10 feet behind the bus.	Violation
There were patches of black ice on the road.	Physical Environment
One of the car's headlights was burned out.	Technical Environment
On his way home, a driver became frustrated by everyone driving too slowly.	Adverse Mental State
The driver was physically impaired after going out for a few drinks.	Adverse Physiological State
The driver's eyesight was so poor that he could not navigate his vehicle safely.	Physical/Mental Limitation
A driver went to an all-night party the night before a long-distance drive.	Personal Readiness
The driver received no indication that a truck was merging from an entrance lane on his right because the truck's left blinker was not flashing.	Communication/Coordination and Planning
A driver departed for a long road trip over winter vacation without checking traffic or weather forecasts.	Communication/Coordination and Planning
A driving school instructor did not consistently provide adequate training. From time to time, he took personal calls while a student was driving.	Inadequate Supervision
The driving school instructor told his student to drive in	Planned Inappropriate

Causal Factor	HFACS Causal Category
traffic on the highway during her first lesson.	Operation
Several accidents and near misses occurred at a particular intersection but local police had not yet put up a stop sign.	Failed to Correct Known Problem
Though considered an authority figure, an officer drove his police vehicle faster than the posted speed limit and did not signal before changing lanes.	Supervisory Violation
The state did not allocate adequate funding for road maintenance or sufficient highway patrol.	Resource Management
Police in county A were pressured to issue a specified weekly quota of tickets for particular violations (e.g. speeding or not wearing a seatbelt.)	Organizational Climate
Due to the lack of standardization in traffic laws, drivers who moved from one state to another were able to transfer licensure without showing proficiency in state laws.	Organizational Process

APPENDIX D: HFACS-MVC DRIVING SAMPLES

Causal Factor	HFACS Causal Category	HFACS-MVC Nanocode
While waiting to turn onto the highway, a driver started to inch forward when he saw an oncoming truck in the right lane of traffic. He tried to stop the vehicle, but accidentally hit the gas instead forcing the truck to swerve to avoid a collision.	Skill Based Error	ATT4 Inadvertent operation of wrong control
The driver failed to adjust his braking technique to accommodate for the icy road conditions and slid into the car in front of him at the stop sign.	Skill Based Error	TQ2 Improper application of acceleration or brakes
Late one night a driver opted to take an unfamiliar shortcut to get home. He realized his mistake when the shortcut took him on a small, curvy road with no lighting.	Decision Error	SA2 Failed to modify behavior to protect against potentially hazardous conditions
At an intersection, a driver misjudged his distance from an approaching motorcycle. It was actually closer than the driver thought, but the motorcycle's single headlight provided poor visual cues regarding its position.	Perceptual Error	PE1 Misjudged distance
The driver drove 10 to 15 mph over the posted speed limit on the highway.	Violation	VPRO1 Speeding 10-19 mph over the speed limit
With a school bus dropping kids off ahead, a driver opted to pass illegally instead of stopping the vehicle at least 10 feet behind the bus.	Violation	VPRO5 Illegal passing or lane changing behavior
There were patches of black ice on the road.	Physical Environment	SC1 Slippery road surface
One of the car's headlights was burned out.	Technical Environment	TPMV3 Inadequately maintained vehicle/vehicular equipment
On his way home, a driver became	Adverse Mental	A6 Frustration

Causal Factor	HFACS Causal Category	HFACS-MVC Nanocode
frustrated by everyone driving too slowly.	State	
The driver was physically impaired after going out for a few drinks.	Adverse Physiological State	PC2 Impairment due to drugs or alcohol
The driver's eyesight was so poor that he could not navigate his vehicle safely.	Physical/Mental Limitation	PL3 Incompatible physical capabilities
A driver went to an all-night party the night before a long-distance drive.	Personal Readiness	PR7 Lack of sleep
The driver received no indication that a truck was merging from an entrance lane on his right because the truck's left blinker was not flashing.	Communication/ Coordination and Planning	COM1 Inadequate or lack of communication between road users
A driver departed for a long road trip over winter vacation without checking traffic or weather forecasts.	Communication/ Coordination and Planning	PLA2 Selected a poor or unfamiliar route for travel (e.g. selected a route that was shorter, faster, etc.)
A driving school instructor did not consistently provide adequate training. From time to time, he took personal calls while a student was driving.	Inadequate Supervision	IS
The driving school instructor told his student to drive in traffic on the highway during her first lesson.	Planned Inappropriate Operation	PIO
Several accidents and near misses occurred at a particular intersection but local police had not yet put up a stop sign.	Failed to Correct Known Problem	FC
Though considered an authority figure, an officer drove his police vehicle faster than the posted speed limit and did not signal before changing lanes.	Supervisory Violation	SV
The state did not allocate adequate funding for road maintenance or sufficient highway patrol.	Resource Management	RM
Police in county A were pressured	Organizational	OC

Causal Factor	HFACS Causal Category	HFACS-MVC Nanocode
to issue a specified weekly quota of tickets for particular violations (e.g. speeding or not wearing a seatbelt.)	Climate	
Due to the lack of standardization in traffic laws, drivers who moved from one state to another were able to transfer licensure without showing proficiency in state laws.	Organizational Process	OP

APPENDIX E: MISHAP NARRATIVE SAMPLES

Sample	Narrative
1	Summary: Vehicle crossed centerline, left highway and impacted tree. Narrative: [Servicemember] was traveling to residence and was involved in a single car accident. There were no witnesses to the accident so it is difficult to determine any specific cause. Currently awaiting police investigation report to help determine possible causes so that unit can try and prevent any further incidents of this nature. Upon receipt of the final police investigation report, an update will be made to this [sic] report with lessons learned and recommendations.
2	Summary: SNM was in a motorcycle accident. Narrative: Be aware of your surroundings at all times. SNM suffers from a punctured lung, broken wrist, dislocated jaw and a fractured pelivc bone. SNM is still in the hospital release date to return to work is still unknown.
3	Narrative: Servicemember lost control of his vehicle while negotiating a curve in the road. The vehicle slid off of the road, collided with a tree and burst into flames. Driver and one of the passengers died of severe smoke inhalation and thermal burns. The other passenger died of cervical spine fracture and skull fracture. Although it is unknow how much sleep the driver had gotten prior to the accident, it is known that he was at a party with his passengers the night before the accident and that there was a percentage of blood alcohol in his system. The driver was also apparently drinking underage. Alcohol and probably a lack of sleep contributed to this incident. Another servicemember is under investigation by civilian authorities for providing alcohol to a minor. The Commanding Officer personally conducted a brief with each of the five shift sections (both staff and student) which included the details of the police report to again reeemphasize the consequences of drinking and driving and the importance of operational risk management in their personal lives.
4	Narrative: [Servicemember] was involved in a single vehicle mishap while on liberty. [Servicemember] was the only occupant of his vehicle. The police report stated that [servicemember] drove at approximately 80 MPH over train tracks and through an intersection. The vehicle struck a ditch and rolled multiple times. Upon impact, [servicemember] was ejected from the vehicle. [Servicemember] was not wearing a seat belt at the time. He was pronounced dead at the scene by local authorities. The coronoer cited massive brain herniation as the cause of death. Alcohol has not been determined, still waiting on toxicology report. [Servicemember] received safety briefs from four levels of his chain of command. His squad leader asked if any members of the unit planned to travel outside of the local area. [Servicemember] did not reveal his plans to travel out of the 300 mile liberty limits. He rented a vehicle that night and drove 515 miles straight to his girlfriend's residence in GA. Two days later, he began driving back to base. He was the only occupant of his rented vehicle. [Servicemember] stopped and cited for speeding and not wearing seat belt at 2355 in SC. The

Sample	Narrative
	citing officer stated he was traveling over 80 MPH. He was again stopped and cited for speeding at 0135 in SC. The citing officer stated he was traveling 20 MPH over the speed limit. Each officer warned him to slow down and reduced the speeding violations to 9 MPH the speed limit. He continued to drive probably fatigued and at excessive speeds until the mishap occurred. He ran over train tracks and continued through the stop required intersection. The high speed crossing of the train tracks caused the vehicle to veer right and impact the right ditch on the far side. The vehicle continued to roll for 340 feet after the initial point of impact. He was not wearing his seat belt at the time of the mishap and was ejected.
5	Summary: Operator 1 (O1) was traveling in PMV 1 (2001 Pontiac Grand Prix) northbound on [sic] Boulevard at a high rate of speed and under the influence of alcohol. Operator 2 (O2) was traveling in PMV 2 (2001 Chrysler Concord LXI) southbound. O1 lost control of PMV 1 and collided with PMV 2. Narrative: This mishap was [originally] reported as a class B and the report was released. [Subsequently], Operator 1 died from his injuries. [On the day of the mishap], O1 had spent an unknown amount of time at a local bar with classmates. At approximately 2333 hours, O1 left the bar and was traveling in PMV 1 northbound in the 2800 block of [sic] Boulevard. O1 was traveling at a high rate of speed, attempted to pass a vehicle that was also heading northbound, crossed the centerline, and lost control of PMV 1, sliding sideways directly into the path of PMV 2. O2 was unable to react in time and PMV 2 collided with PMV 1 on the passenger side. O1 was initially transported to a local emergency room but was later flown by care flight to a [local] hospital due to a ruptured aorta and a ruptured bladder and will undergo surgery when able. O2 was the designated driver for PMV 2 and was transporting five friends to a local club. O2 suffered a bruised right wrist and was treated and released. Passenger 1 (P1) was sitting in the rear seat passenger side by the door and suffered a kidney injury that required removal of the kidney, head injuries, and a lacerated liver; P1 was placed on quarters after surgery. Passenger 2 (P2) was also in the rear seat sitting on the left side of P1. P2 was admitted to the hospital for exploratory surgery where they found a lacerated kidney; P2 was placed on quarters after surgery. PMV 2 was equipped for five persons; therefore, P1 and P2 were seat belted together with one seatbelt which contributed to the severity of their injuries. Passenger 3 (P3) was seated in the rear seat behind the driver and suffered a laceration to the forehead and received 16 stitches to close the wound. P3 also sustained a mild concussion and was kept in the hospital for one day for observation. Passenger 4 (P4) was seated in the rear seat to the right of P3. P4 received nine stitches to the chin and was released. Passenger 5 (P5) was seated in the front passenger seat and suffered a laceration to the left side of the forehead from the airbag, was treated, and was released. Investigation and Analysis: O1's 72-hour history was found to be uneventful. O1 had a check ride flight on Wednesday which he passed. O1 did not fly on Thursday or Friday. The 12-hour crew rest policy was

Sample	Narrative
	enforced. O1 and roommate went home on Friday and O1 cooked dinner and had a undetermined amount of alcohol. O1 and roommate then went to a local bar where they had an undetermined amount of drinks and signed up for a local motorcycle rally. O1 and roommate proceeded to the final destination bar at approximately 2200 hours. O1 had a lot of interaction with people at the bar and gave no indication of internal distractions. O1 and classmates frequent this particular establishment. Roommate stated that the person that is usually their designated driver was not available on this weekend so their plan was to take a taxicab home. Witnesses in the bar stated that O1 was having drinks at several different tables, but were unable to state how many drinks O1 consumed. O1's roommate stated that O1 had said he was not having a good time but made no indication to him that he was leaving. A short time later, the roommate saw O1 leaving the bar in PMV 1. The following factors were investigated and found not to be contributory to this mishap: road/weather conditions: the 2800 block of [sic] Boulevard is a two-lane asphalt road with no median and posted 35 mph zone. The road was in good condition. Residential areas border the east and west side of the roadway. The roadway is well marked with a yellow dashed center line. The weather was clear and the roadway was dry. Lighting in mishap area: although not contributory, the 2800 block of [sic] Boulevard has very poor lighting with only infrequent lamp post lighting. Personal protective equipment used: O1 was wearing a seat belt; PMV 1's airbag deployed. Vehicle condition: PMV 1 seemed to have been in good condition prior to the accident, with good tread life on the tires. O1 was cited for driving while intoxicated and toxicology results for O1 is .25 BAC.

APPENDIX F: CONTINGENCY TABLES BY MILITARY BRANCH

Cell Contents: Count
Expected Count

ANALYSES FOR EACH CATEGORY: Found significant differences for 7 categories (SBE, VIO, PhyE, TechE, AMS, PML, CCP)

		Skill Based Error	
		0	1
Branch	AF	130 110.0	245 265.0
	MC	30 39.3	104 94.7
	N	99 109.7	275 264.3

Pearson Chi-Square=9.743, DF=2, P-Value=0.008 Significant

		Decision Error	
		0	1
Branch	AF	254 267.1	121 107.9
	MC	100 95.5	34 38.5
	N	275 266.4	99 107.6

Pearson Chi-Square=3.957, DF=2, P-Value=0.138 Insignificant

		Violation	
		0	1
Branch	AF	133 172.4	242 202.6
	MC	79 61.6	55 72.4
	N	194 172.0	180 202.0

Pearson Chi-Square=30.997, DF=2, P-Value=0.000 Significant

		Physical Environment	
		0	1
Branch	AF	290 306.6	85 68.4
	MC	112 109.6	134 134.0
	N	320 305.8	54 68.2

Pearson Chi-Square=8.852, DF=2, P-Value=0.012 Significant

		Technological Environment	
		0	1
Branch	AF	348 359.7	27 15.3
	MC	134 128.5	0 5.5
	N	365 358.8	9 15.2

Pearson Chi-Square=17.716, DF=2, P-Value=0.000 Significant

		Adverse Mental State	
		0	1
Branch	AF	234 294.3	141 80.7
	MC	118 105.2	16 28.8
	N	341 293.5	33 80.5

Pearson Chi-Square=100.399, DF=2, P-Value=0.000 Significant

		Adverse Physiological State	
		0	1
Branch	AF	239 245.0	136 130.0
	MC	99 87.6	35 46.4
	N	239 244.4	135 129.6

Pearson Chi-Square=5.084, DF=2, P-Value=0.079 Significant

		Physical/Mental Limitation	
		0	1
Branch	AF	306 328.6	69 46.7
	MC	127 117.3	7 16.7
	N	340 327.4	34 46.6

Pearson Chi-Square=22.459, DF=2, P-Value=0.000 Significant

		Communication, Coordination, and Planning	
		0	1
Branch	AF	344 357.2	31 17.8
	MC	129 127.6	5 6.4
	N	368 356.2	6 17.8

Pearson Chi-Square=18.713, DF=2, P-Value=0.000 Significant

SUBSEQUENT ANALYSES FOR SIGNIFICANT CATEGORIES: SBE, VIO, PhyE, TechE, AMS, PML, and CCP

		Skill Based Error	
		0	1
Branch	AF	130 117.9	245 257.1
	MC	30 42.1	104 91.9

Pearson Chi-Square=6.906, DF=1, P-Value=0.009 Significant

$$OR_{\text{MA}}=\frac{(130)(104)}{(30)(245)}=1.84$$

		Skill Based Error	
		0	1
Branch	MC	30 34.0	104 100.0
	N	99 95.0	275 279.0

Pearson Chi-Square=0.868, DF=1, P-Value=0.352 Insignificant

		Skill Based Error	
		0	1
Branch	AF	130 114.7	245 260.3
	N	99 114.3	275 259.7

Pearson Chi-Square=5.926, DF=1, P-Value=0.015 Significant

$$OR_{\text{NA}}=\frac{(130)(275)}{(99)(245)}=1.47$$

		Violation	
		0	1
Branch	AF	133 156.19	242 218.81
	MC	79 55.81	55 78.19

Pearson Chi-Square=22.412, DF=1, P-Value=0.000 Significant

$$OR_{\text{AM}}=\frac{(242)(79)}{(133)(55)}=2.61$$

		Violation	
		0	1
Branch	MC	79 72.01	55 61.99
	N	194 200.99	180 173.01

Pearson Chi-Square=1.991, DF=1, P-Value=0.158 Insignificant

		Violation	
		0	1
Branch	AF	133 163.7	242 211.3
	N	194 163.3	180 210.7

Pearson Chi-Square=20.487, DF=1, P-Value=0.000 Significant

$$OR_{\text{AN}}=\frac{(242)(194)}{(133)(180)}=1.96$$

		Physical Environment	
		0	1
Branch	AF	290 296.2	85 78.8
	MC	112 105.8	22 28.2

Pearson Chi-Square=2.322, DF=1, P-Value=0.128 Insignificant

		Physical Environment	
		0	1
Branch	MC	112 114.0	22 20.0
	N	320 318.0	54 56.0

Pearson Chi-Square=0.304, DF=1, P-Value=0.581 Insignificant

		Physical Environment	
		0	1
Branch	AF	290 305.4	85 69.6
	N	320 304.6	54 69.4

Pearson Chi-Square=8.388, DF=1, P-Value=0.004 Significant

$$OR_{\text{AN}}=\frac{(320)(85)}{(290)(54)}=1.72$$

		Technological Environment	
		0	1
Branch	AF	348 355.1	27 19.9
	MC	134 126.9	0 7.1

Pearson Chi-Square=10.188, DF=1, P-Value=0.001 Significant

$OR_{\mathrm{MA}}=\frac{(348)(0)}{(134)(27)}=0$

		Technological Environment	
		0	1
Branch	MC	134 131.63	0 2.37
	N	365 367.37	9 6.63

Pearson Chi-Square=3.283, DF=1, P-Value=0.070 Insignificant

		Technological Environment	
		0	1
Branch	AF	348 357.0	27 18.0
	N	365 356.0	9 18.0

Pearson Chi-Square=9.404, DF=1, P-Value=0.002 Significant

$OR_{\mathrm{AN}}=\frac{(365)(27)}{(348)(9)}=3.13$

		Adverse Mental State	
		0	1
Branch	AF	234 259.3	141 115.7
	MC	118 92.7	16 41.3

Pearson Chi-Square=30.473, DF=1, P-Value=0.000 Significant

$OR_{\mathrm{AM}}=\frac{(118)(141)}{(234)(16)}=4.35$

		Adverse Mental State	
		0	1
Branch	MC	118 121.1	16 12.9
	N	341 337.9	33 36.1

Pearson Chi-Square=1.100, DF=1, P-Value=0.294 Insignificant

		Adverse Mental State	
		0	1
Branch	AF	234 287.9	141 87.1
	N	341 287.1	33 86.9

Pearson Chi-Square=86.945, DF=1, P-Value=0.000 Significant

$OR_{\text{AN}}=\dfrac{(341)(141)}{(234)(33)}=6.25$

		Physical/Mental Limitation	
		0	1
Branch	AF	306 319.0	69 56.0
	MC	127 114.0	7 20.0

Pearson Chi-Square=13.494, DF=1, P-Value=0.000 Significant

$OR_{\text{AM}}=\dfrac{(127)(69)}{(306)(7)}=4.17$

		Physical/Mental Limitation	
		0	1
Branch	MC	127 123.2	7 10.8
	N	340 343.8	34 30.2

Pearson Chi-Square=1.988, DF=1, P-Value=0.159 Insignificant

		Physical/Mental Limitation	
		0	1
Branch	AF	306 323.4	69 51.6
	N	340 322.6	34 51.4

Pearson Chi-Square=13.681, DF=1, P-Value=0.000 Significant

$OR_{\text{AN}}=\frac{(340)(69)}{(306)(34)} = 2.27$

		Communication, Coordination, and Planning	
		0	1
Branch	AF	344 348.5	31 26.5
	MC	129 124.5	5 9.5

Pearson Chi-Square=3.090, DF=1, P-Value=0.079 Insignificant

		Communication, Coordination, and Planning	
		0	1
Branch	MC	129 131.10	5 2.90
	N	368 365.90	6 8.10

Pearson Chi-Square=2.107, DF=1, P-Value=0.287
Fisher's exact test: P-Value=0.527691 Insignificant

		Communication, Coordination, and Planning	
		0	1
Branch	AF	344 356.5	31 18.5
	N	368 355.5	6 18.5

Pearson Chi-Square=17.700, DF=1, P-Value=0.000 Significant

$OR_{\text{AN}}=\frac{(368)(31)}{(344)(6)} = 5.56$

APPENDIX G: CONTINGENCY TABLES BY VEHICLE TYPE

Cell Contents: Count
Expected Count

ANALYSES FOR EACH CATEGORY: Found significant differences for 5 categories (PhyE, AMS, APS, PML, CCP)

		Skill Based Error	
		0	1
Number of Wheels	2W	93 98.3	242 236.7
	4W	166 160.7	382 387.3

Pearson Chi-Square=0.642, DF=1, P-Value=0.423 Insignificant

		Decision Error	
		0	1
Number of Wheels	2W	233 238.6	102 96.4
	4W	396 390.4	152 157.6

Pearson Chi-Square=0.745, DF=1, P-Value=0.388 Insignificant

		Violation	
		0	1
Number of Wheels	2W	149 154.0	186 181.0
	4W	257 252.0	291 296.0

Pearson Chi-Square=0.490, DF=1, P-Value=0.484 Insignificant

		Physical Environment	
		0	1
Number of Wheels	2W	288 273.9	47 61.1
	4W	434 448.1	114 99.9

Pearson Chi-Square=6.397, DF=1, P-Value=0.011 Significant

$$OR_{4,2}=\frac{(288)(114)}{(434)(47)}=1.61$$

		Technological Environment	
		0	1
Number of Wheels	2W	319 321.3	16 13.7
	4W	528 525.7	20 22.3

Pearson Chi-Square=0.675, DF=1, P-Value=0.411 Insignificant

		Adverse Mental State	
		0	1
Number of Wheels	2W	275 262.9	60 72.1
	4W	418 430.1	130 117.9

Pearson Chi-Square=4.159, DF=1, P-Value=0.041 Significant

$OR_{4,2} = \frac{(275)(130)}{(418)(60)} = 1.43$

		Adverse Physiological State	
		0	1
Number of Wheels	2W	271 218.9	64 116.1
	4W	306 358.1	242 189.9

Pearson Chi-Square=57.639, DF=1, P-Value=0.000 Significant

$OR_{4,2} = \frac{(271)(242)}{(306)(64)} = 3.35$

		Physical/Mental Limitation	
		0	1
Number of Wheels	2W	248 293.3	87 41.7
	4W	525 479.7	23 68.3

Pearson Chi-Square=90.376, DF=1, P-Value=0.000 Significant

$OR_{2,4} = \frac{(525)(87)}{(248)(23)} = 8.33$

		Communication, Coordination, and Planning	
		0	1
Number of Wheels	2W	327 319.1	8 15.9
	4W	514 521.9	34 26.1

Pearson Chi-Square=6.684, DF=1, P-Value=0.010 Significant

$$OR_{4,2} = \frac{(327)(34)}{(514)(8)} = 2.70$$

Appendix H: Contingency Tables by Paygrade

Cell Contents: Count
Expected Count

ANALYSES FOR EACH CATEGORY: Found significant difference for 1 category (VIO)

		Skill Based Error	
		0	1
Paygrade	E	208 211.9	481 477.1
	O	19 15.1	30 33.9

Pearson Chi-Square=1.584, DF=1, P-Value=0.208 Insignificant

		Decision Error	
		0	1
Paygrade	E	491 487.3	198 201.7
	O	31 34.7	18 14.3

Pearson Chi-Square=1.413, DF=1, P-Value=0.235 Insignificant

		Violation	
		0	1
Paygrade	E	293 300.62	396 388.38
	O	29 21.38	20 27.62

Pearson Chi-Square=5.162, DF=1, P-Value=0.023 Significant

$$OR_{\mathrm{E,O}}=\frac{(396)(29)}{(293)(20)}=1.96$$

		Physical Environment	
		0	1
Paygrade	E	563 560.2	126 128.6
	O	37 39.8	12 9.2

Pearson Chi-Square=1.158, DF=1, P-Value=0.282 Insignificant

		Technical Environment	
		0	1
Paygrade	E	655 655.39	34 33.61
	O	47 46.61	2 2.39

Pearson Chi-Square=0.072, DF=1, P-Value=0.789
Fisher's exact test: P-Value=1 Insignificant

		Adverse Mental State	
		0	1
Paygrade	E	525 527.5	164 161.5
	O	40 37.5	9 11.5

Pearson Chi-Square=0.753, DF=1, P-Value=0.386 Insignificant

		Adverse Physiological State	
		0	1
Paygrade	E	435 438.8	254 250.2
	O	35 31.2	14 17.2

Pearson Chi-Square=1.361, DF=1, P-Value=0.243 Insignificant

		Physical/Mental Limitation	
		0	1
Paygrade	E	590 592.84	99 96.16
	O	45 42.16	4 6.84

Pearson Chi-Square=1.467, DF=1, P-Value=0.226 Insignificant

		Communication, Coordination, and Planning	
		0	1
Paygrade	E	656 654.46	33 34.54
	O	45 46.54	4 2.46

Pearson Chi-Square=1.093, DF=1, P-Value=0.296
Fisher's exact test: P-Value=0.299239 Insignificant

APPENDIX I: CONTINGENCY TABLES BY AGE GROUP

Cell Contents: Count
Expected Count

ANALYSES FOR EACH CATEGORY: Found significant differences for 2 categories (VIO and APS)

		Skill Based Error	
		0	1
Age	17-20	48 44.94	99 102.06
	21-25	105 98.75	218 224.25
	26-30	33 40.97	101 93.03
	31-35	20 21.71	51 49.29
	36-40	15 12.87	27 29.16
	>40	8 9.78	24 22.22

Pearson Chi-Square=4.286, DF=5, P-Value=0.509 Insignificant

		Decision Error	
		0	1
Age	17-20	98 103.82	49 43.18
	21-25	229 228.13	94 94.87
	26-30	98 94.64	36 39.36
	31-35	54 50.15	17 20.85
	36-40	30 29.66	12 12.34
	>40	20 22.60	12 9.40

Pearson Chi-Square=3.570, DF=5, P-Value=0.613 Insignificant

		Violation	
		0	1
Age	17-20	71 64.18	76 82.82
	21-25	117 141.02	206 181.98
	26-30	65 58.50	69 75.50
	31-35	31 31.00	40 40.00
	36-40	20 18.34	22 23.66
	>40	23 13.97	9 18.03

Pearson Chi-Square=20.453, DF=5, P-Value=0.001 Significant

		Physical Environment	
		0	1
Age	17-20	117 119.72	30 27.28
	21-25	262 263.06	61 59.94
	26-30	115 109.13	19 24.87
	31-35	61 57.82	10 13.18
	36-40	29 34.21	13 7.79
	>40	26 26.06	6 5.94

Pearson Chi-Square=7.266, DF=5, P-Value=0.202 Insignificant

		Technological Environment	
		0	1
Age	17-20	143 139.93	4 7.07
	21-25	303 307.48	20 15.52
	26-30	129 127.56	5 6.44
	31-35	67 67.59	4 3.41
	36-40	40 39.98	2 2.02
	>40	31 30.46	1 1.54

Pearson Chi-Square=3.395, DF=5, P-Value=0.639 Insignificant
NOTE 3 cells with expected counts less than 5

		Adverse Mental State	
		0	1
Age	17-20	111 112.85	36 34.15
	21-25	242 247.96	81 75.04
	26-30	103 102.87	31 31.13
	31-35	61 54.51	10 16.49
	36-40	33 32.24	9 9.76
	>40	25 24.57	7 7.43

Pearson Chi-Square=4.189, DF=5, P-Value=0.523 Insignificant

		Adverse Physiological State	
		0	1
Age	17-20	103 93.81	44 53.19
	21-25	192 206.13	131 116.87
	26-30	92 85.52	42 48.48
	31-35	46 45.31	25 25.69
	36-40	20 26.80	22 15.20
	>40	25 20.42	7 11.58

Pearson Chi-Square=14.162, DF=5, P-Value=0.015 Significant

		Physical/Mental Limitation	
		0	1
Age	17-20	121 126.79	26 20.21
	21-25	281 278.58	42 44.42
	26-30	113 115.57	21 18.43
	31-35	64 61.24	7 9.76
	36-40	37 36.22	5 5.78
	>40	30 27.60	2 4.40

Pearson Chi-Square=5.035, DF=5, P-Value=0.412 Insignificant

		Communication, Coordination, and Planning	
		0	1
Age	17-20	139 139.74	8 7.26
	21-25	299 307.04	24 15.96
	26-30	132 127.38	2 6.62
	31-35	70 67.49	1 3.51
	36-40	41 39.93	1 2.07
	>40	31 30.42	1 1.58

Pearson Chi-Square=10.432, DF=5, P-Value=0.064 Insignificant
NOTE 3 cells with expected counts less than 5

SUBSEQUENT ANALYSES FOR SIGNIFICANT CATEGORIES: VIO and APS

		Violation	
		0	1
Age	17-20	71 58.80	76 88.20
	21-25	117 129.20	206 193.80

Pearson Chi-Square=6.139, DF=1, P-Value=0.013 Significant

$$OR_{21-25,17-20}=\frac{(206)(71)}{(117)(76)}=1.64$$

		Violation	
		0	1
Age	17-20	71 71.15	76 75.85
	26-30	65 64.85	69 69.15

Pearson Chi-Square=0.001, DF=1, P-Value=0.972 Insignificant

		Violation	
		0	1
Age	17-20	71 68.78	76 78.22
	31-35	31 33.22	40 37.78

Pearson Chi-Square=0.414, DF=1, P-Value=0.520 Insignificant

		Violation	
		0	1
Age	17-20	71 70.78	76 76.22
	36-40	20 20.22	22 21.78

Pearson Chi-Square=0.006, DF=1, P-Value=0.938 Insignificant

		Violation	
		0	1
Age	17-20	71 77.20	76 69.80
	>40	23 16.80	9 15.20

Pearson Chi-Square=5.857, DF=1, P-Value=0.016 Significant

$$OR_{17-20,>40}=\frac{(76)(23)}{(71)(9)}=2.74$$

		Violation	
		0	1
Age	21-25	117 128.63	206 194.37
	26-30	65 53.37	69 80.63

Pearson Chi-Square=5.964, DF=1, P-Value=0.015 Significant

$$OR_{21-25,26-30}=\frac{(206)(65)}{(117)(69)}=1.66$$

		Violation	
		0	1
Age	21-25	117 121.33	206 201.67
	31-35	31 26.67	40 44.33

Pearson Chi-Square=1.373, DF=1, P-Value=0.241 Insignificant

		Violation	
		0	1
Age	21-25	117 121.24	206 201.76
	36-40	20 15.76	22 26.24

Pearson Chi-Square=2.059, DF=1, P-Value=0.151 Insignificant

		Violation	
		0	1
Age	21-25	117 127.38	206 195.62
	>40	23 12.62	9 19.38

Pearson Chi-Square=15.495, DF=1, P-Value=0.000 Significant

$$OR_{21-25,>40}=\frac{(206)(23)}{(117)(9)}=4.50$$

		Violation	
		0	1
Age	26-30	65 61.66	69 72.34
	31-35	31 33.25	40 37.75

Pearson Chi-Square=0.438, DF=1, P-Value=0.508 Insignificant

		Violation	
		0	1
Age	26-30	65 64.72	69 69.28
	36-40	20 20.28	22 21.72

Pearson Chi-Square=0.010, DF=1, P-Value=0.920 Insignificant

		Violation	
		0	1
Age	26-30	65 71.04	69 62.96
	>40	23 16.96	9 15.04

Pearson Chi-Square=5.663 DF=1, P-Value=0.017 Significant

$$OR_{26-30,>40} = \frac{(69)(23)}{(65)(9)} = 2.71$$

		Violation	
		0	1
Age	31-35	31 32.04	40 38.96
	36-40	20 18.96	22 23.04

Pearson Chi-Square=0.167, DF=1, P-Value=0.683 Insignificant

		Violation	
		0	1
Age	31-35	31 37.22	40 33.78
	>40	23 16.78	9 15.22

Pearson Chi-Square=7.040, DF=1, P-Value=0.008 Significant

$$OR_{31-35,>40} = \frac{(40)(23)}{(31)(9)} = 3.30$$

		Violation	
		0	1
Age	36-40	20 24.41	22 17.59
	>40	23 18.59	9 13.41

Pearson Chi-Square=4.390, DF=1, P-Value=0.036 Significant

$$OR_{36-40,>40} = \frac{(22)(23)}{(20)(9)} = 2.81$$

		Adverse Physiological State	
		0	1
Age	17-20	103 92.3	44 54.7
	21-25	192 202.7	131 120.3

Pearson Chi-Square=4.880, DF=1, P-Value=0.027 Significant

$$OR_{21-25,17-20} = \frac{(103)(131)}{(192)(44)} = 1.60$$

		Adverse Physiological State	
		0	1
Age	17-20	103 102.0	44 45.0
	26-30	92 93.0	42 41.0

Pearson Chi-Square=0.066, DF=1, P-Value=0.798 Insignificant

		Adverse Physiological State	
		0	1
Age	17-20	103 100.47	44 46.53
	31-35	46 48.53	25 22.47

Pearson Chi-Square=0.617, DF=1, P-Value=0.432 Insignificant

		Adverse Physiological State	
		0	1
Age	17-20	103 95.67	44 51.33
	36-40	20 27.33	22 14.67

Pearson Chi-Square=7.244, DF=1, P-Value=0.007 Significant

$$OR_{36-40,17-20} = \frac{(103)(22)}{(20)(44)} = 2.58$$

		Adverse Physiological State	
		0	1
Age	17-20	103 105.12	44 41.88
	>40	25 22,88	7 9.12

Pearson Chi-Square=0.837, DF=1, P-Value=0.360 Insignificant

		Adverse Physiological State	
		0	1
Age	21-25	192 200.7	131 122.3
	26-30	92 83.3	42 50.7

Pearson Chi-Square=3.418, DF=1, P-Value=0.064 Insignificant

		Adverse Physiological State	
		0	1
Age	21-25	192 195.1	131 127.9
	31-35	46 42.9	25 28.1

Pearson Chi-Square=0.696, DF=1, P-Value=0.404 Insignificant

		Adverse Physiological State	
		0	1
Age	21-25	192 187.6	131 135.4
	36-40	20 24.4	22 17.6

Pearson Chi-Square=2.134, DF=1, P-Value=0.144 Insignificant

		Adverse Physiological State	
		0	1
Age	21-25	192 197.4	131 125.6
	>40	25 19.6	7 12.4

Pearson Chi-Square=4.277, DF=1, P-Value=0.039 Significant

$$OR_{21-25,>40}=\frac{(25)(131)}{(192)(7)}=2.44$$

		Adverse Physiological State	
		0	1
Age	26-30	92 90.20	42 43.80
	31-35	46 47.80	25 23.20

Pearson Chi-Square=0.316, DF=1, P-Value=0.574 Insignificant

		Adverse Physiological State	
		0	1
Age	26-30	92 85.27	42 48.73
	36-40	20 26.73	22 15.27

Pearson Chi-Square=6.116, DF=1, P-Value=0.013 Significant

$$OR_{36-40,26-30}=\frac{(92)(22)}{(20)(42)}=2.41$$

		Adverse Physiological State	
		0	1
Age	26-30	92 94.45	42 39.55
	>40	25 22.55	7 9.45

Pearson Chi-Square=1.113, DF=1, P-Value=0.291 Insignificant

		Adverse Physiological State	
		0	1
Age	31-35	46 41.47	25 29.53
	36-40	20 24.53	22 17.47

Pearson Chi-Square=3.202, DF=1, P-Value=0.074 Insignificant

		Adverse Physiological State	
		0	1
Age	31-35	46 48.94	25 22.06
	>40	25 22.06	7 9.94

Pearson Chi-Square=1.832, DF=1, P-Value=0.176 Insignificant

		Adverse Physiological State	
		0	1
Age	36-40	20 25.54	22 16.46
	>40	25 19.46	7 12.54

Pearson Chi-Square=7.092, DF=1, P-Value=0.008 Significant

$$OR_{36-40,>40}=\frac{(22)(25)}{(20)(7)}=3.93$$

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