UNIVERSITÉ DU QUÉBEC À MONTRÉAL

COLLISIONS DE VÉHICULES À MOTEUR DES AMBULANCIERS-PARAMÉDICS DANS UNE RÉGION MÉTROPOLITAINE DU QUÉBEC: ANALYSE STATISTIQUE

THÈSE

PRÉSENTÉE

COMME EXIGENCE PARTIELLE

DU DOCTORAT EN BIOLOGIE EXTENSIONNÉ DE L'UQAC

PAR

MILAD DELAVARYFOROUTAGHE

AVRIL 2024

UNIVERSITÉ DU QUÉBEC À MONTRÉAL

PARAMEDICS' MOTOR VEHICLE COLLISIONS IN A METROPOLITAN AREA OF QUEBEC: STATISTICAL ANALYSIS

THESIS

SUBMITTED

AS PARTIAL REQUIREMENT

FOR PH.D. IN BIOLOGY

EXTENSION OF UNIVERSITÉ DU QUÉBEC À CHICOUTIMI

BY

MILAD DELAVARYFOROUTAGHE

APRIL 2024

ACKNOWLEDGMENTS

My Ph.D. journey has been greatly enriched by the unwavering support and guidance of my academic supervisor, Dr. Martin Lavallière. His expertise, insightful comments, and constructive feedback have been invaluable in shaping the direction and quality of my research, and I am deeply grateful for his mentorship.

I would also like to express my gratitude to Société de l'assurance automobile du Québec for their cooperation and provision of data, which has enabled me to conduct a thorough analysis and draw meaningful conclusions in my thesis.

In addition, I want to acknowledge the invaluable assistance of Dr. Luc de Montigny from Urgences-santé, who helped me gain access to essential data and resources that were crucial to the success of my research.

Finally, I extend my heartfelt thanks to my family, friends, and colleagues for their unwavering support and encouragement throughout my academic journey. Their understanding, patience, and encouragement have been instrumental in helping me to achieve my academic goals, and I am deeply grateful for their presence in my life.

DEDICATION

I am honored to dedicate my thesis to my dear wife, whose unwavering love, support, and encouragement have been my guiding light throughout my Ph.D. journey. Your selfless dedication and sacrifices have made it possible for me to pursue my academic dreams and complete this thesis.

Your constant presence, unwavering support, and boundless optimism have been a source of inspiration and motivation for me. You have been my rock through the ups and downs of this challenging journey, and your belief in me has never wavered.

Your patience, understanding, and unwavering support have sustained me through the long hours of research and writing, and I could not have done this without you.

This thesis is a testament to your unwavering love and support, and I dedicate it to you with all my heart. You have been my partner, confidante, and best friend, and I am forever grateful for your love and support.

Thank you for being my soulmate, my cheerleader, and my better half.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

CUS: Corporation d'urgences-santé

SAAQ: Société de l'assurance automobile du Québec

WHO: World Health Organization

USA: United States of America

CDC: Centres for Disease Control and Prevention

BLS: Bureau of Labor Statistics

EVs: Emergency Vehicles

VKT: Vehicle Kilometres Travelled

LGVs: Large Goods Vehicles

ERs: Emergency Responders

MCTs: Mobile Computer Terminals

WRCs: Work-related Collisions

EMS: Emergency Medical Services

L&S: lights and sirens

CI: Confidence Analysis

WLS: Warning Lights and Sirens

OR: Odds Ratio

MT: Mann-Kendall

VIF: Variance Inflation Factor

ROC: Receiver Operating Characteristic

LIST OF SYMBOLS AND UNITS

$\chi 2$: Chi-squared distribution

ℓ: Log odds,

β: Coefficient

P: Probability

L'objectif de cette thèse est de passer en revue la littérature sur les collisions impliquant des ambulances, en se concentrant sur leur prévalence, leurs caractéristiques et leurs facteurs de risque, et de réaliser une analyse rétrospective des collisions d’ambulances au Québec, Canada, entre 2010 et 2020. Pour atteindre cet objectif, une revue systématique de 26 études publiées dans PubMed entre janvier 1990 et juillet 2021 a été réalisée, et une analyse rétrospective des collisions d'ambulances au Québec a été effectuée à partir des données de la Société de l'assurance automobile du Québec (SAAQ) et d'Urgences-santé. La prévalence, les caractéristiques et les facteurs de risque des collisions avec les ambulances ont été analysés, et des tests statistiques, une analyse descriptive et une régression logit ont été utilisés pour comparer les collisions avec les ambulances et les collisions avec les véhicules en général dans 17 régions du Québec.

Les résultats (Revue systématique) ont montré que les collisions avec des ambulances étaient plus fréquentes et plus graves que les collisions impliquant d'autres conducteurs professionnels ou des véhicules de taille similaire. Les conducteurs plus jeunes et moins expérimentés étaient plus susceptibles d'être impliqués dans des collisions avec des ambulances, qui étaient plus susceptibles de se produire dans des zones urbaines, à des intersections et en répondant à des appels d'urgence. L'analyse rétrospective a révélé que les collisions avec des ambulances se produisaient le plus souvent près des intersections ou entre les intersections, dans les zones commerciales et sur les routes à double sens. La gravité des collisions entre ambulances est liée à des facteurs tels que l'état de l'asphalte, les types de collisions et les lieux.

En conclusion, les collisions entre ambulances représentent un risque important pour la sécurité des intervenants médicaux d'urgence, et des politiques et programmes préventifs adaptés sont nécessaires pour réduire le fardeau de ces collisions professionnelles. Des interventions ciblées sont nécessaires pour réduire le risque de collision aux intersections et lors des interventions d'urgence, en particulier pour les ambulanciers plus jeunes et moins expérimentés, qui devraient faire l'objet de programmes de formation et de sensibilisation.

Mots clés :
Paramédic, Ambulance, Collision, Sécurité au travail, Prévalence, Facteurs de risque, Analyse rétrospective, Analyse statistique, Québec, Montréal

The objective of this thesis is to review the literature on ambulance collisions, focusing on their prevalence, characteristics, and risk factors, and to conduct a retrospective analysis of ambulance collisions in Quebec, Canada, between 2010 and 2020. To achieve this objective, a systematic review of 26 studies published in PubMed between January 1990 and July 2021 was performed, and a retrospective analysis of ambulance collisions in Quebec was conducted using data from the Société de l’assurance automobile du Québec (SAAQ) and Urgences-santé. The prevalence, characteristics, and risk factors of ambulance collisions were analyzed, and statistical tests, descriptive analysis, and logit regression were used to compare ambulance and general vehicle collisions in 17 regions of Quebec.

The results (systematic review) showed that ambulance collisions were more prevalent and severe than collisions involving other professional drivers or similarly sized vehicles. Younger and less experienced drivers were more likely to be involved in ambulance collisions, which were more likely to occur in urban areas, at intersections, and while responding to emergency calls. The retrospective analysis revealed that ambulance collisions occurred most frequently near intersections or between intersections, in commercial areas, and on two-way roads. The severity of ambulance collisions was associated with factors such as asphalt conditions, collision types, and locations.

In conclusion, ambulance collisions pose a significant risk to the safety of medical emergency responders, and tailored preventive policies and programs are needed to reduce the burden of these occupational collisions. Targeted interventions are required to reduce the risk of collisions at intersections and while responding to emergency calls, particularly for younger and less experienced paramedics who should be a particular focus of training and awareness programs.

Keywords :
Paramedic, Ambulance, Collision, Occupational safety, Prevalence, Risk factors, Retrospective Analysis, Statistical Analysis, Quebec, Montreal

CHAPITRE 1: GENERAL INTRODUCTION

1.1 Importance of Proposed Study

1.1.1 Road Safety across the World

Every year, more than 1.25 million people are killed in road-related crashes, and road traffic injuries are a major issue in public health all over the world. Road traffic mortality is the leading cause of death among people aged 15 to 29, and as reported by the World Health Organization (WHO) in 2018, road traffic collisions cost 3% of the gross domestic product for most countries. If no actions are taken, traffic mortality could become the 7th leading cause of death among all age groups by 2030 (World Health Organization (WHO), 2018). In response to this challenge, the United Nations has integrated road safety objectives into the Sustainable Development Goals, with the aim of reducing global road traffic fatalities and injuries by 50 percent upto 2030. In pursuit of these goals, countries have implemented more robust regulations pertaining to road safety (United Nations, 2015). According to the report of the centers for disease control and Prevention (CDC) on 28 October 2020 in the United States of America (USA) and key facts of the WHO on 7 February 2020 in Switzerland, risk factors including human error, speeding, drunk driving, distractions in driving, not wearing seatbelt, helmets and child restraint, inadequate road facilities for all types of users, post-crash care, traffic law enforcement, and unsafe automobiles lead to the death of almost 1.35 million people yearly. Unfortunately, injuries caused by road injuries can lead to financial problems as the cost of treatments, disabilities, and family members who need to take time to care for the injured (Centers for Disease Control and Prevention (CDC), 2020a, 2020b; World Health Organization (WHO), 2020). Also, there are many psychological injuries caused by traffic collisions, for which it is harder to measure their full impacts on one’s health (Marasini, Caleffi, Machado, & Pereira, 2022; Mayou, Bryant, & Duthie, 1993).

1.1.2 Road Safety in Canada

Road mortality rate in Canada was 5.8 fatalities per 100,000 inhabitants, while the rate for motor vehicles was 8.9 fatalities per 100,000 vehicles in 2016 (World Health Organization (WHO), 2019). According to Canadian motor vehicle traffic collision statistics from Transport Canada’s national collision database in 2017, the number of traffic mortality was 1,856 which decreased by 2.3% from 2016 (1,899) (Transport Canada, 2017). The rate of mortality per 100,000 people and billion vehicle kilometers traveled (VKT) was 5.0 and 4.8, respectively in 2017 which was the lowest on record since 1998. Urban and rural areas had 44% and 54% of these deaths, respectively. Also, the number of serious injuries declined from 10,564 in 2016 to 10,107 in 2017. It is important to highlight that drivers aged 65 and older accounted for the highest number of fatalities among all drivers, totaling 364 cases, representing 20% of the total in 2017. Also, young adults aged 25-34 experienced the highest number of serious injuries among all drivers in this year, with 1,841 cases, comprising 19% of the total incidents. Drivers (985), passengers (311), pedestrians (284), motorcyclists (191), bicyclists (36) ranked in order among fatalities in road user classes in 2017. This year, 27.4% and 10.6% of drivers and 31.1% and 16.9% of passengers were suspected of not wearing a seatbelt for crashes that lead to mortality and serious injuries, respectively. After that, the number of mortality and serious injuries in 2018 has slight difference from 2017. The number of deaths per 100,000 people has experienced a slight increase from 5.0 in 2017 to 5.2 in 2018. Furthermore, the rate of mortality per billion VKT has 0.1 increments (4.9) in 2018 compared to the previous year. The distribution of traffic mortality based on location in 2018 was the same as 2017 (44% in urban and 54% in rural). In this year, 960 drivers (49.9%), 340 passengers (17.7%), 332 pedestrians (17.3%), 200 motorcyclists (10.4%), and 44 bicyclists (2.3%) were died due to traffic collisions. People 65 or more died more than other age groups with 430

(out of 1922) in traffic collisions in 2018. However, young people 25-34 years old have a higher number of serious injuries with 1667 (out of 9026) in 2018. The percentage of not wearing seatbelts increased for both drivers and passengers. The percentage of drivers who died and were injured seriously due to not using their seatbelt in crashes had grown from 27.4 to 29.4 and 10.6 to 10.8, respectively, in 2018. This happened for passengers by an increase of 1% and 1.5% for mortality and serious injuries, respectively (Transport Canada, 2018). It should be mentioned that the yearly trend of traffic mortality decreased from 2898 in the years 2005 to 1841 in 2014 and then increased to 1899 in 2016. After that, this number decreased to 1856 in 2017 and then increased to 1922 in 2018. The overall trend of traffic mortality shows an increase from 2014 to 2018. This means that traffic interventions are necessary for reducing traffic mortality. On the other hand, the number of serious injuries decreased by 6.1% and reached to 9,494 in 2018. Based on the report of Société de l'assurance Automobile du Québec (SAAQ) the number of road deaths was 333 and 311 in 2019 and 2018, respectively in Quebec, Canada (Société de l'assurance automobile du Québec, 2020b). Also, the number of road traffic serious and slight injuries was 1334 and 33403 in 2019, and 1233 and 33068 in 2018, respectively. It should be noted that young drivers aged 15-24 and motorcyclists died less in 2019 compared to 2018 with 6.4% and 4.1%, respectively. But, unfortunately, road deaths had a growth of 1.4% in 2019 compared to 2018. This trend is observable in number of Canadians killed in road crashes involving a drinking driver from 2018 (n=466) to 2019 (n=472) (Vanlaar, Lyon, Simmons, & Robertson, 2022). Noting that the trend of traffic death in road crashes involving a driking driver was decreasing from 2016 (n=536) to 2018 (n=466).
According to the recent stats, in Canada, the year 2021 saw a slight increase in motor vehicle fatalities, totaling 1,768, marking a 1.3% rise from the previous year's count of 1,746 (2020). Moreover, serious injuries also escalated, reaching 8,185 incidents, reflecting a 4% increase compared to 2020's figure of 7,868. The overall number of injuries increase to 108,018 in 2021, indicating a 3.6% uptick from the previous year's total of 104,286 in Canada (Canada, 2023).
In Quebec specifically, the most upadted statistics revealed a concerning trend. With 392 fatalities recorded in 2022, there was a notable surge of 46 deaths compared to the 2017-2021 average, constituting a 13.2% increase. Conversely, there was a modest decline in serious injuries, with 1,275 individuals affected in 2022, representing a 4.2% decrease from the 2017-2021 average. Additionally, minor injuries witnessed a notable decrease, with 27,048 cases recorded, marking an 11% downturn compared to the 2017-2021 average. These statistics underscore the need for continued efforts to enhance road safety measures and mitigate the risks associated with motor vehicle accidents (Société de l'assurance automobile du Québec, 2023).

1.1.3 Work-related Road Safety

Collisions are one of the main causes of death at work. It has been estimated that 33% of drivers involved in traffic collisions are professionals and that these collisions occur during their work shifts (European Agency for Safety and Health at Work(EU-OSHA), 2019). For instance, in Quebec, although work-related collisions are only responsible for 2% of occupational injuries, they are the cause of 25 to 30% of accidental deaths at work (2000-2008) (Bellavance, 2016). The average age of victims was 39 years old and 74% were males. More specifically, 25-35 years old workers rank first (28%) followed by 35-44 years old workers (27%) in terms of prevalence. Furthermore, 20,606 occupational injuries were related to road collisions at work between 2001 and 2015 in Quebec. The estimated cost of occupational injuries related to work-related collisions is $2.70 billion from 2001 to 2015 (Lebeau, 2021). The average cost per injury is estimated at $131,200, which is double the average cost of an occupational injury, and deaths related to work-related collisions represent only 1.6% (out of total collisions) while 42.9% of total cost in Quebec (Lebeau, 2021).
An initial review of this study revealed several studies that investigate work-related crashes. For instance, a study that focused on over 2000 collisions from 1996 to 2004 shows the drivers of company cars,

vans/pickups, and large goods vehicles (LGVs) have a high frequency in the responsibility of crashes (D. D. Clarke, Ward, Bartle, & Truman, 2009). In this case, speeding, observational failures, and fatigue in the car, van, and LGV drivers are the important factors involved in crashes, respectively. In addition, another research found that company car drivers in the UK are 49% more likely to be involved in a collision than an ordinary driver, even after demographic variables and their relatively high mileage are taken into account (Lynn & Lockwood, 1999). The research compared company car drivers with a sample of non-business drivers matched for factors such as age, gender, annual mileage, and percentage of annual mileage done on motorways. Drivers who drove more than 80% of their annual mileage on work-related journeys had about 53% more collisions than similar drivers who had no work-related mileage (Broughton, Baughan, Pearce, Smith, & Buckle, 2003). A study was conducted on 13,124 drivers who were injured or died to find factors involved in work-related crashes in New South Wales, Australia with data between 1998 and 2002. It found that males are involved in traffic collisions and mortality as 75% and 93% of the total, respectively. Male drivers were faced to be fatigued (16.6%) and sped (7.6%) more than females. Drivers of heavy trucks show almost half of the total mortality of on-duty work-related crashes (Boufous & Williamson, 2006). Varieties of environmental, mechanical, and individual factors involving in work crashes between 2017 and 2020 were examined among cargo and passenger transport drivers in Spain. According to this study, type of road and collision, the light, meteorological and vehicle conditions, individual characteristics and risky driving behaviors were significant variables in fatal work traffic collisions and serious injuries (Sergio A. Useche, 2020). In addition, time pressure exposure, work schedule fatigue, larger average engine size of fleet cars, reduced personal cost of collisions, and psychological characteristics such as aggression or extraversion were found as causes of work crash in another research (Grayson, 1999).

1.1.4 Emergency Vehicle Road Safety

The social costs of emergency vehicles (EVs) involved in road traffic crashes are thus expected to be higher than other road traffic crashes (National Highway Traffic Safety Administration (NHTSA)). Moreover, if an ambulance carrying a patient gets involved in a road crash, it poses a threat to both the patient along with EV occupants, and other road users (American Medical Association, 2001). EV crashes are often also incurred in many lawsuits costing millions of dollars due to the loss of lives, the associated injuries, and property damages. It is estimated that the global cost of EV accidents is $250 billion annually. In the United States, the cost of EVs is computed to be $35 billion annually (San Francisco Trial Lawyer Association (SFTLA), 2019). In this case, overall, between 2001 and 2010, more than 0.3 million EVs were involved in road crashes in the United States. Among these crashes, 49.3% of the fatalities involving EVs occurred when EVs were operating in emergency mode with lights and sirens (National Highway Traffic Safety Administration (NHTSA)). The national crash fatality rates, in the United States, for EV personnel are 2.5–4.8 times higher than the national average for all occupations (Savolainen, Dey, Ghosh, Karra, & Lamb, 2009). From 1996 to 2012, 137 civilian fatalities and 228 civilian injuries were reported from fire truck-involved crashes in the USA (U.S. Fire Administration, 2014). In Europe, six Swedish firefighters died because of traffic crashes in the 5 years 2012–16. They died mostly from single-vehicle crashes (Yasmin, Anowar, & Tay, 2021).

Crash reports from various states in the USA have shown high numbers of emergency vehicle crashes, especially in law enforcement situations. Crash reports from various states in the USA have shown high numbers of emergency vehicle crashes, especially in law enforcement situations. In terms of police cars, in the USA, this emergency responders (ER) are reported to be involved in 300 fatalities each year, and 50% of fatalities among law enforcement officers were reported to be from road crashes (San Francisco Trial Lawyer Association (SFTLA), 2019). In Australia, police car crash risk is identified to be 11.8 crashes per million kilometers traveled. It is also reported that police pursuits result in a relatively higher crash risk representing one crash per 120 kilometers traveled (Symmons, Haworth, & Mulvihill, 2005). In the United States, from 1979 through 2013, crashes involving police cars resulted in more than 2400 civilian fatalities (H. Hsiao, J. Chang, & P. Simeonov, 2018). It has also been reported that 18% of police fatalities occur when officers are working near speeding motor vehicles, directing traffic, or issuing traffic summonses either on the road or on the side of the road (C. Clarke, Zak, M.J., 1999). In Sweden, in the 10 years (from 2003 to 2012), at least 9 people were killed and 1457 injured in crashes involving police cars. These numbers do not include injuries and fatalities in crashes caused by police pursuits if the police car was not involved (damaged) in the crash (Yasmin et al., 2021). In 2016, fatalities among law enforcement officers rose to their highest level in 5 years (National Law Enforcement Officers Memorial Fund, 2016) (National Law Enforcement Officers Memorial Fund, Preliminary 2016). There were 53 officers' deaths because of traffic incidents in 2016, a 10% increase compared to 2015. Twenty-eight officers and 10 officers died in automobile and motorcycle collisions, respectively, which is an 18% and 150% reduction compared to 2015. There are insufficient national data on nonfatal motor vehicle collisions; however, one state-based study in the USA found that for every officer killed in a traffic collision, there were approximately 234 officers injured (Wolfe, Rojek, Alpert, Tiesman, & James, 2015). Another study showed the leading cause of death for law enforcement officers is still collisions. In this regard, although traffic fatalities have steadily decreased for all users in past decades, this has not been the trend among law enforcement officers (Gustafson, 2015). Furthermore, the recent trend of law enforcement officers involved in motor vehicle crashes shows it has become the major cause of fatalities among them by using Federal Bureau of Investigation datasets (Noh, 2011). There were 39 officers killed by collisions over this study period and 7,684 officers who received some type of injury. Incidents involving officers on motorcycles represented 39% of officer fatalities and 39% of severe injuries. During the study period in California, USA, the estimated financial impact of collisions reached the hundreds of millions of dollars when considering related fatality, injury, and vehicle damage costs combined. Characteristics of law enforcement officers fatalities in motor vehicle crashes were analyzed using the fatality analysis reporting system data for 772 crashes that involved at least one law enforcement officer's fatality (Gustafson, 2015).

1.1.5 Paramedics Road Safety

Work-related collisions among emergency respondents are the leading cause of mortality among these workers. Motor vehicle crashes involving emergency vehicles (EV; police, fire trucks, ambulances, etc.) and non-ER drivers have been a known problem that contributes to fatal and nonfatal injuries (Drucker, 2013). The risk of occupational death mainly due to traffic collisions is high for emergency medical services (AJ. Heightman, 2006; AJ Heightman, 2009; Nordberg, 2006a, 2006b; Sagarra, 2015). A literature review that worked on rural ambulance crashes showed that the frequency and severity of ambulance collisions are more than crashes involving vehicles of similar size and weight (N. D. Sanddal, Albert, Hansen, & Kupas, 2008). The national crash fatality rates, in the United States, for emergency vehicles (EV) personnel are 2.5–4.8 times higher than the national average for all occupations (Savolainen et al., 2009). More specifically, work-related collisions among emergency respondents are the leading cause of mortality among work-related collisions (San Francisco Trial Lawyer Association (SFTLA), 2019). In the United States, ambulances are reported to be involved in more than 6500 crashes per year, 35% of which are associated with at least one injury and/or fatality (San Francisco Trial Lawyer Association (SFTLA), 2019). In this country, a study reviewed 617 injury records of emergency medical service between January 1, 1998, and July 15, 2002. The overall injury rate was 34.6 per 100 full-time workers per year (B. J. Maguire, Hunting, Guidotti, & Smith, 2005). For the emergency responders (ERs), the social costs involved in traffic collisions are thus expected to be higher than others (National Highway Traffic Safety Administration (NHTSA)). Moreover, if an ambulance carrying a patient gets involved in a road crash, it poses a threat to both the patient along with ER occupants, and other road users (American Medical Association, 2001). ER crashes

are often also incurred in many lawsuits costing millions of dollars due to the loss of lives, the associated injuries, and property damages. It is estimated that the global cost of ER accidents is $250 billion annually (San Francisco Trial Lawyer Association (SFTLA), 2019). In the United States, the cost of ERs has been estimated to be $35 billion annually (San Francisco Trial Lawyer Association (SFTLA), 2019). In Great Britain, between 1999 and 2004, a total of 38 fatal crashes and 204 serious injury crashes involving ambulances were documented (Lutman, Montgomery, Ramnarayan, & Petros, 2008b). In Denver, and Colorado, USA, 206 emergency medical vehicle collisions were reported, 192 of them moving collisions and 14 while the ambulance was parked, from 1989 through 1997. This yielded an estimated incidence rate of 4.3 collisions per 10,000 responses. There were 39 injury collisions (81 people injured or killed) and 167 non-injury collisions which is a rate of 1.7 injuries or fatalities per 10,000 responses (Custalow & Gravitz, 2004). In Sweden, 2003–13 saw 173 police-reported crashes involving ambulances, injuring 218 people in the ambulances, 26 of them seriously injured. A majority of the seriously injured were emergency medical technicians in the back of the ambulance, unable to wear seatbelts while performing their duties. Two people died because of these crashes. A recent in-depth study of injury crashes involving ambulances in a county in Sweden showed that the ambulance driver was the prime contributor (caused) 80% of the crashes (Elvik et al., 2007). In the Quebec Province, the total number of paramedics collisions is 1228, 370 cases with injury and 858 cases without injury between 2010 and 2020 (Société de l'assurance automobile du Québec 2020). In Taiwan, 715 ambulance traffic accidents caused 8 deaths and 1844 injuries between January 1, 2011, to October 31, 2016. On average, there is one ambulance traffic accident for every 8598 ambulance runs. Compared to overall traffic accidents, ambulance traffic accidents were 1.7 times more likely to result in death and 1.9 times more likely to have injuries (P.-W. Chiu et al., 2018). Traffic fatalities are a significant proportion of annual firefighter mortality. There are almost 16,00 collisions involving fire department emergency vehicles each year in the United States. The cost of these collisions is estimated to be in the millions of dollars and accounts for the greatest cause of monetary liability within the industry (Finucane, 2010). Also, a study used national data from the USA including 1,050 injuries and 30 mortality to investigate the traffic collisions among paramedics between 2006 and 2008 (B. J. Maguire, 2011). Crashes involving ambulances were documented to result in 64 civilian fatalities and 217 civilian injuries between 1996 and 2012 in the United States (Hongwei Hsiao, Joonho Chang, & Peter Simeonov, 2018; Pino, Baldari, Pelosi, & Giucastro, 2014). Paramedics-related injuries were analyzed with data from 1 July 2010 through 1 June 2014 in the USA. And, by completing the interviews with 572 staff, it was found that the injury rate was 8.6 per 100 full-time equivalent workers (Reichard, Marsh, Tonozzi, Konda, & Gormley, 2017). Furthermore, 99,400 injuries and 65 deaths were recorded between 2003 and 2007 for paramedics and emergency respondents from the Bureau of Labor Statistics (BLS) in the United States of America (USA) which shows a higher rate compared to all kinds of workers. It should be noted that most mortality was related to traffic collisions (45%) (Reichard, Marsh, & Moore, 2011).
Therefore, it is of utmost importance to better describe these events and their surrounding characteristics to facilitate proactive regulation and programs that can decrease work-related collisions, injuries, and fatalities related to paramedics' driving activities.

1.2 Paramedics: Bridging Emergency Care

A paramedic's job involves providing emergency medical care to patients, including assessing their condition, administering necessary treatments, and ensuring safe transportation to a medical facility (Société de l'assurance automobile du Québec, July 21, 2021). Ambulance personnel, which may include paramedics, firefighters, nurses, or doctors, regardless of their formal titles, are responsible for assessing, loading, and safely moving patients while maintaining a professional relationship with them and their significant others (Holmberg, Nørgaard, Eriksson, & Svensson, 2020; World Health Organization, 2008). In some settings, the duties of driving the ambulance and providing medical care are separated, while in others, a team of individuals is trained to fulfill both roles (Holmberg et al., 2020). However, regardless of the organizational structure, patients rely on the competence of ambulance caregivers throughout all phases of prehospital care, including transportation to the hospital or other destination.

Ambulance services aim to transport patients from one location to another, often during the provision of medical care, which can be crucial, especially in time-critical conditions (X. Chen et al., 2019; Lilitsis et al., 2018). A paramedic's job involves stabilizing people with life-threatening injuries and transporting them to a higher level of care, typically an emergency department. They work autonomously across various health and care settings and may specialize in clinical practice, education, leadership, and research (McCann, 2022). Paramedics also play a crucial role in responding rapidly to emergencies and delivering urgent care (Corman, 2018). They are trained to handle life-threatening trauma and disease, but most callouts consist of unplanned primary care (Bęczkowska, Grabarek, & Mróz, 2020).

An integrative review found that ambulance driving, including factors such as speed, driving pattern, navigation, and communication between the driver and the patient, significantly influences both the patient's medical condition and the quality of care provided during transport (J. Becker & Hugelius, 2021). Furthermore, the driver's health and ability to manage stress, influenced by factors such as traffic, time pressure, sirens, and disturbing moments, significantly affect ambulance transport safety (J. Becker & Hugelius, 2021). Driving plays a crucial role in the overall responsibilities of paramedics and ambulance personnel, directly impacting patient health, wellbeing, and safety. Therefore, driving should be considered an essential aspect of the medical care offered within emergency medical services, requiring specific skills and competence beyond technical driving abilities.

1.3 Explanatory and Response Variables

1.3.1 Explanatory Variable

After presenting studies showing the importance of first responders' collisions, this section will focus on factors that can impact the frequency and severity of collisions. One of the references used to classify the factors influencing Collisions is the Haddon matrix (Haddon Jr, 1972). This matrix shows the factors including human, vehicle, and road/environment impact collisions in the periods before, during, and after it. As a result of this classification, a three-by-three matrix is obtained to describe the factors improving road safety (Haddon Jr, 1972). The human factors emphasizing the influence of human behavior and characteristics (e.g., distraction or drowsiness) on road safety. The vehicle factor highlighting the importance of vehicle features in preventing and mitigating collisions (e.g., barking system or ability to Remove the injured easily). And road and environment factor shows how road and environmental conditions like road surface friction, or road shoulder can affect collision and post-collision responses (arrival time of emergency services).

Although the initial review for this proposal revealed many studies which investigate influential variables for road safety, there is comparatively less research on contributing factors to the crash involvement of emergency vehicles. This study will focus on the variables involved in ambulance vehicle collisions as shown in Table 1.1. This table shows different types of variables including paramedics, collision, environment, road, and traffic characteristics. It should be mentioned that there are studies that used the environment as input variables to analyze road safety. For instance, a study in 2011 used two types of roads defined in urban areas including roads near residential areas and other urban roads to better understand the difference in collision risk (Borowsky, Oron-Gilad, Meir, & Parmet, 2012). In another study, the number of students collisions near schools has been analyzed. In this research, geometric factors of roads and educational level have been identified as effective variables in pedestrian, supposed as a student, collisions (Mirbaha, Safaarzadeh, & Noruzoliaee, 2012). Some studies show that age has a relation to increasing the probability of having a higher risk of collisions (Hatamabadi et al., 2012; Vorko-Jović, Kern,

& Biloglav, 2006). Research has also shown that the age of drivers varies in their behavior in different traffic areas. More experienced drivers often identify intersections as dangerous places. And they are more concentrated in other areas where there is a risk. Young and inexperienced drivers, on the other hand, tend to stare only in the opposite direction when approaching intersections and ignore vertical paths to the intersection (Borowsky et al., 2012; Pollatsek, Narayanaan, Pradhan, & Fisher, 2006). In addition, experienced drivers consider the roadside environment while driving and behave differently in residential and interurban areas, but younger drivers in different areas often follow the same driving pattern (Chapman & Underwood, 1998). Also, there are studies on the effect of weather such as snow and rain, visibility distance, and wind speed on different road users (Grande, Castillo, Mora, & Lo, 2017; Huang, Chin, & Haque, 2008; Król, 2014a; Pino et al., 2014; Rezapour, Moomen, & Ksaibati, 2019; Zeng, Wen, Huang, & Abdel-Aty, 2017). In this case, for instance, traffic accident researchers have considered wind blow to be effective in increasing injuries from collisions (C. Chen et al., 2015).

Table 1.1 Crash, environment, and Road and traffic characteristics

Paramedics Characteristics	Collisions Characteristics	Environment Characteristics	Road and Traffic characteristics
Age	Time of a Day	Type of Environment	Speed Limit Posts at the Scene
Gender	Days of Week	Surface State	Configuration of Road
Experience	Number of Vehicles involved in Collisions	Lighting Conditions	Traffic Condition
	Type of Collisions	Weather Conditions	Work Zone
	Other Road Users involved (Mode of Transportation involved in Collisions)	Work Zone	Lighting Conditions
			Localization of Collisions
			Asphalt Condition

1.3.1.1 The role of distraction, fatigue, and visual distraction

Paramedics demonstrate a heightened ability in hazard perception, responding faster to potential dangers compared to civilian drivers (Johnston & Scialfa, 2016). This advantage may stem from their extensive experience in emergency vehicle operations, including driving with lights and sirens, at high speeds, and through intersections. Similar to police officers, paramedics spend more time observing areas where

hazards may emerge, contributing to their quicker response times. Hazard perception training has been shown to benefit novice drivers, suggesting its potential value for novice paramedics as well as experienced ones. Even experienced drivers have shown improvement in hazard perception with training.
In emergency medical services, paramedics often engage in multitasking, where attention is divided between multiple active tasks (Keebler, Lazzara, & Misasi, 2017). This includes driving to a scene while monitoring traffic, radio chatter, and navigation, as well as attending to patients, administering medication, and monitoring vital signs during transport. Multitasking in emergency medical services requires rapid shifts of attention between tasks, increasing the risk of errors. While some multitasking is unavoidable, it's important to prioritize tasks and complete them one at a time with full attention to minimize the risk of medical errors.

The impact of distraction, and visual distraction on the road safety of ambulance drivers is a critical concern for ensuring the effective and safe delivery of emergency medical services. Distraction, such as managing calling or dispatching, can lead to impaired driving and an increase in collisions (Soares et al., 2021). Visual distraction, including the use of information technology devices, can lead to changes in visual behavior, increased driving errors, and a deterioration of driving performance (Luo, Yi, Shao, & Xu, 2022). These factors can negatively affect ambulance drivers' ability to concentrate on the road, react quickly to emergencies, and maintain safe driving behaviors. These factors can negatively impact the concentration, emergency response speed, and safe driving practices of ambulance drivers. Addressing these challenges is important, which can be achieved through training programs, the establishment of shift schedules, and enhancing awareness about the risks of distraction and fatigue within the ambulance driving community (Botzoris, Profillidis, Galanis, Lemonakis, & Argyropoulos, 2022; Taylor, 2020).

The impact of distraction, particularly visual distraction, on paramedics' driving can be significant, especially when operating emergency vehicles with light-and-siren (LAS) systems. Research indicates that ambulance drivers face more manual distractions when traveling with LAS compared to non-light-and-siren (NLAS) travel, primarily due to operating the light-and-siren system. In a study conducted at a rural rescue station in southern Germany, it was found that drivers operated the light-and-siren system on average every 37 seconds during LAS travel, with this task constituting almost 50% of the total distraction time (Grundgeiger, Scharf, Grundgeiger, & Scheuchenpflug, 2014). This manual distraction can lead to compromised attention on the main driving task and increase the risk of accidents, injuries, and fatalities (Kahn, Pirrallo, & Kuhn, 2001b; C. E. Saunders & Heye, 1994). Furthermore, the study revealed that for about 8% of the driving time when using LAS, drivers had at least one hand off the steering wheel, which can result in longer stopping times and pose a significant concern for road safety. While drivers may try to minimize additional distractions such as operating the car radio or searching for items, the operation of the light-and-siren system remains a significant contributor to distraction during LAS travel. These findings underscore the importance of managing distractions effectively to ensure safe driving practices among paramedics.

Fatigue poses a significant risk to paramedics' driving performance and overall well-being. Fatigue, caused by long hours of working or night shifts, can result in cognitive impairment, reduced vigilance, and an increased risk of fatigue-related incidents (Nabatilan, 2007). Anecdotal reports suggest that some ambulance agencies schedule personnel for extended shifts of 24 hours or more, which can have detrimental effects on alertness and cognitive function. Research indicates that being awake for 21 hours produces impairment comparable to a blood alcohol concentration (BAC) of 0.08%, exceeding the legal limit for commercial drivers (Arnedt, Wilde, Munt, & MacLean, 2001; Dawson & Reid, 1997). The legal limit for commercial drivers in the United States is 0.04% BAC (US National Highway Traffic Safety Administration, 2014). A tragic example of the consequences of fatigue-related impairment occurred in July 1997 when Heather Brewster's car was rear-ended by a medical resident who had just completed a 36-hour hospital shift (Gotbaum, 2005). Brewster suffered severe brain injuries, resulting in permanent disability and legal incapacitation. This case underscores the critical importance of addressing fatigue-related risks in EMS agencies. EMS organizations should reassess their scheduling practices to mitigate the potential risks posed by long shifts, not only to employees but also to patients and the community at large (Keebler et al., 2017).

There is an interrelationship between stress, fatigue, and workload in the context of emergency medical services. While stress, fatigue, and workload are distinct constructs, they are closely related and can interact in complex ways (Keebler et al., 2017). The concept of operator functional state, proposed by Hockey (2003), offers a valuable framework for understanding these interactions. This concept integrates stress, fatigue, and workload into a common state construct defined by an operator's adaptive capacity (Hockey, 2003). This information emphasizes the importance of considering these factors together when examining their impact on performance and well-being in emergency medical services settings.

1.3.2 Response Variable

Policymakers must consider numerous contributing factors when making decisions due to the multidisciplinary nature of road safety. For example, crash severity is often divided into categories according to the KABCO scale, which provides five levels of injury severity, including fatal injury, incapacitating injury, non-incapacitating evident injury, possible injury, and no injury/property damage only (Bonneson, 2014). This challenge brings the question of "which indicator provides a better understanding of the condition of road safety" to our mind. Answering this question is complicated and depends on many factors like the availability of data and sources to get those indicators that give the most realistic map of the current condition of road safety. Much research have been done on the causes affecting the quantity and quality of collisions. In most studies, the causes affecting the rate or severity of injuries caused by collisions have been investigated. Collision rates are usually classified as the ratio of the number of crashes to the volume of traffic over a period and the severity of collisions is usually classified into three categories: fatal, injury and, damage or non-injury (Chapman & Underwood, 1998; C. Chen et al., 2015; Chiou & Fu, 2015; Garber & Ehrhart, 2000).

There are studies that focused on ambulance crashes and their statistics and independent variables involving collisions. For instance, Saunders and Heye focused on characterizing the ambulance crashes in San Francisco in 1994. They used retrospective epidemiological analysis for independent variables considered as the roadway, environment, and crash factors (C. E. Saunders, Heye, C.J., 1994). Weiss et al. (2001) compared urban and rural ambulance crashes between 1993–97 in Tennessee. They used a two-tailed χ^2 test Fisher's exact test to know the impact of contextual, roadways, environmental, and driver/occupant factors (S. J. Weiss, Ellis, R., Ernst, A.A., Land, R.F., Garza, A., 2001.). Kahn et al. (2001) identified the characteristics of fatal ambulance crashes including contextual, roadway, environmental, crash, and occupant factors between 1987–97 in the United States with the Pearson χ^2 test approach. Fatality factors including roadway, environment, crash, vehicle, and driver factors for Emergency Medical Services (EMS) workers were examined by focusing on ambulance crashes between 1991 and 2000 in the United States with descriptive analysis (Proudfoot, 2005.). Ambulances and similar-sized vehicle crashes were compared by focusing on the roadway and, Crash factors in Pennsylvania with utilizing two-tailed χ^2, and Fisher's exact test between 1997 and 2001 (A. F. Ray, Kupas, D.F., 2005). Chiu et al. (2018) studied the characteristics of ambulance crashes from 2011 to 2016 in Taiwan. They used descriptive analysis, two-sample t-test, and analysis of variance to know the relation between contextual, roadway, and environmental factors and ambulance collisions (P. W. Chiu, Lin, C.H., Wu, C.L., Fang, P.H., Lu, C.H., Hsu, H.C., Chi, C.H., 2018). The risk factors including environmental and driver charchteritics associated with emergency response driving were analyzed with inductive content analysis in 2019 (Koski & Sumanen, 2019). In another study, researchers used driver interviews and binary logit methods to identify the roadway, environment, and crash factors associated with injury risk from 1983 to 1986 in Tennessee (Auerbach, Morris, Phillips, Redlinger, & Vaughn, 1987). Custalow and Gravitz (2004) utilized binary logit to identify the roadway, environment, crash, and driver factors related to ambulance crashes between 1989 and 1997 in Denver. In another study, generalized ordered logit was used to know the contextual, roadway, environmental, vehicle, and driver factors associated with emergency vehicle crash severity in Alberta (1999–2008) (Yasmin, Anowar, & Tay, 2012). Drucker et al. (2013) worked on the fatality risk of emergency and civilian vehicle crashes in the United States (2002–10). They focused on the contextual, roadway, environmental, crash, veh,icle and, driver factors with binary logit. Crash risk associated with emergency vehicles, police vehicles, ambulances, and fire vehicles was studied in Iowa between 2005 and 2013 (Missikpode, Peek-Asa, Young, & Hamann, 2018). They used binary logit models to analyze roadway factors, environmental factors, contextual factors, and driver factors.

This study researched contributing factors like different categories of environments, time of day and days of the week, weather conditions, gender and experience of drivers, etc., to crash involvement of paramedics by using statistical analysis. In this regard, the response indicators are crash severity, including injury/fatality or non-injury. In the following section, explanatory variables some of which are used in the current thesis will be explained in more detail with their literature.

1.4 Analyzing Characteristics of First Responders' Collisions

There are some studies related to the relationship between traffic offenses and emergency vehicle collisions. For instance, a study worked on fatality, injury, and non-injury collisions, including fatality, injury, and non-injury, among police officers in California from January 2000 and December 2009. Descriptive analyses were used to analyze the collision characteristics. As a result, in 38% and 29% of fatality cases, officers were not wearing a seatbelt and did not state the usage of seatbelts, respectively (Wolfe et al., 2015). Discomfort appears to be a significant factor, with 82.8% of paramedics indicating that they refrain from wearing safety belts for this reason (Thorvaldsen, Bergem, Holst, & Häikiö, 2022). Also, paramedics feel that wearing seatbelts restricts their ability to fully access and care for patients during transport (Lindridge, Blackwood, & Edwards, 2022). Another factor is the layout and design of the ambulance, as the seats and restraints are often inadequate and impractical for paramedic work (George, 2017). And, the lack of standardized equipment across different ambulances could contribute to discomfort or challenges in wearing seatbelts (Thomas, O'Meara, Edvardsson, & Spelten, 2020).

A study collected 63 unique episodes from a reality-based television series was analyzed between September 1, 2005, and January 1, 2006 (Cowan Jr, Jones, & Ho, 2006). These episodes were originally broadcasted from 1990 to 2004. The study focused on safety belt usage status, which was determined per police officer per driving scene (N = 250). A driving scene was considered a continuous trip with an on-camera time exceeding 5 seconds, excluding scenes with uncertain safety belt status. In addition to safety belt usage, the study also recorded information on high-speed driving, officer gender, and officer race. The findings revealed that there were no significant differences in safety belt usage rates based on officer gender ($p = 0.930$) or officer race ($p = 0.900$). Overall, the study highlights a low rate of safety belt usage among police officers. It has been reported that 18% of police fatalities occur when officers are working near speeding motor vehicles, directing traffic, or issuing traffic summonses either on the road or on the side of the road (C. Clarke, Zak, M.J., 1999).

Another factor that plays an important role in first responders' collisions is human error. Analyzing task demands and usability issues in police officers showed accessing call notes, checking plate numbers, which is the most visually and cognitively demanding task, and finding location on the map is the most important a frequently performed tasks for officers (Zahabi & Kaber, 2018b). Furthermore, several crash reports have identified in-vehicle distraction to be a primary cause of emergency vehicle crashes, especially in law enforcement. For instance, the use of mobile computer terminals (MCTs) while driving significantly reduces the perceived level of driving environment awareness for police officers and increases cognitive workload (Zahabi & Kaber, 2018a). A systematic integrative review studied essential components of emergency medical services using both quantitative and qualitative designs between 2011 and 2020 (J. Becker & Hugelius, 2021). The results showed the actual speed, driving patterns, navigation, and communication between the driver and the patient, influenced both the patient's medical condition and the possibility of providing adequate care during the transport. Furthermore, the driver's health and ability to manage stress caused by traffic, time pressure, sirens, and disturbing moments also significantly influenced ambulance transport safety. A project worked on collisions that have involved parked police vehicles. Cognitive factors, such as vigilance failure, are involved in these collisions. Furthermore, an emergency vehicle parked in the direction of travel, with only its blue lights flashing, may encourage drivers to believe that the vehicle is moving rather than stationary. Parking at an angle in the road, and avoiding the use of blue lights alone while parked, are two steps that drivers of parked emergency vehicles should consider in preventing such collisions (Langham, Hole, Edwards, & O'Neil, 2002).

In addition, the impact of fatigue on the frequency and severity of collisions is significant. For instance, the impact of fatigue associated with work shifts and drowsy driving on officers' non-operational driving was evaluated with generalized linear mixed-model analyses (James & Vila, 2015). The data was collected from

78 experienced police patrol officer volunteers from all four shifts of a medium-sized city's police department. The model revealed officers working night shifts had significantly greater lane deviation during post-shift than those working day shifts. Also, controlled laboratory experiments were conducted during which participants drove high-fidelity driving training simulators on two occasions: immediately following five consecutive 10:40-hour patrol shifts (fatigued condition) and again 72 hours after completing the last shift in a work cycle (rested condition). The same method also significantly predicted both lane deviation and collisions during the simulated drives. The impact of long work hours, shift work, and insufficient sleep on police officers was investigated with governmental data as well as meetings with sleep researchers, police executives, and union officials in the United States. It revealed that long work hours and shift work threaten police officer health (like psychological disorders), safety, and performance (Vila, 2006).

Furthermore, the driving behavior of emergency drivers effect their safety significantly. In this regard, driving behavior factors involved in fire service crashes were identified by penalized logistic regression. Driving data and crashes were collected using vehicle telematics devices and administrative crash reports from each fire service department, respectively. Harsh braking and hard cornering were associated with increased odds of crashes. For every kilometer of nonemergency speeding, the odds of a crash increased. (D. Bui et al., 2018). The SAAQ data made it possible to identify the characteristics of the most expensive work-related collisions (WRCs) from police reports. The two causes that generate the most costs of WRCs are speeding and reckless driving behavior as well as inattention, distraction, and the use of a cell phone in Quebec (Lebeau, 2021). Factors involved in emergency medical vehicle collisions in the city of Denver, and Colorado, USA, from 1989 through 1997 were analyzed with multiple logistic regression models. According to the results, the responsible emergency medical vehicle driver had a history of multiple collisions in 71% of the events. The mean age of drivers is 32 years old and males are more involved in collisions.

Vehicle and standard design can be a really important characteristics of collisions. For example, a problem with the vehicle, mainly tires which are not suitable for the winter, is the cause that generates the highest average cost per collision (Lebeau, 2021). The results also showed the importance of restraint or protective devices (e.g., seatbelt, helmet) on the severity of injuries suffered by WRC victims. It leads to a very high average cost per WRCs when these devices are non-existent, not used, or misused (Lebeau, 2021). A narrative review revealed the inherent risks of driving/riding in an ambulance, poor ambulance safety standards and design, and increased provider vulnerability to injury while delivering critical patient care in the back of a moving ambulance as three main factors involved in EMS injuries and fatalities (AJ. Heightman, 2006; AJ Heightman, 2009; Nordberg, 2006a, 2006b; Sagarra, 2015).

There are a variety of studies working on environmental factors as well as collision characteristics of emergency drivers. For instance, head-on collisions and WRCs that occur in rural areas are also identified as the highest cost, both in terms of total costs and the average cost per injury. Also, work-related collisions that involve either a heavy truck/road tractor, a pedestrian, or an emergency vehicle (police car, ambulance, fire truck) have higher than average costs (J. Becker & Hugelius, 2021). Also, factors related to non-emergency vehicle drivers involved in collisions are investigated with epidemiological methodologies and multivariate logistic regression modeling. In this regard, distraction, vision obstructed by external objects, intersections, time of day (night), and driving in opposite directions of emergency vehicles are the leading cause in which non-emergency vehicle drivers are involved in nonfatal emergency vehicles' collisions. Moreover, driving on urban roads, straight through intersections of four points or more, and at night can increase the risk of fatal collisions (Drucker, 2013). A retrospective, cross-sectional, and largely descriptive study was used to evaluate the ambulance collisions in Taiwan from January 1, 2011, to October 31, 2016. The results show all 8 fatalities during this studied period were associated with motorcycles and occurred on urban roads. Most of the fatal and nonfatal collisions happened at four-point intersections. Most of fatal collisions and half of the non-fatal collisions happened in the evening and the daytime, respectively. All ambulance drivers in the fatal collisions were males and all had undetectable levels on alcohol inhalation tests. Motorcycles are involved in most fatal collisions (8 out of 9 fatal collisions during the studied period) (P.-W. Chiu et al., 2018). Also, a T-bone mechanism, collision at an intersection, and alcohol intoxication of the civilian driver were all significant variables involved in injury collisions. Most collisions happened when emergency medical vehicles are run with warning lights and sirens (Custalow & Gravitz, 2004).

1.5 Analyzing Interventions Regarding First Responders' Collisions

After identifying the factors involved in the collisions of emergency vehicles based on the Haddon matrix, this section will focus on interventions and implementing the programs that can improve the safety of first responders.

Administration policies can be changed or revised to improve the safety of emergency drivers. For instance, a study worked on the impact of administration and policy changes including the reduction of using unnecessary emergency lights and sirens in vehicle crash incidents by developing an algorithm. This algorithm utilizes field indicators to determine whether a lights and siren dispatch was warranted for vehicle crash incidents or not. This method was 97% sensitive and 33% specific in identifying incidents where patients required prompt trauma care and result in a 10-78% reduction in crashes (Wilbur, 2011).

The effectiveness of worksite-based interventions in increasing the use of safety belts among employees was evaluated with using electronic databases, review articles, USA government documents, and reports of research agencies. Safety belt use had to be measured in an objective manner, and a comparison group was necessary. All interventions increased safety belt use among employees. 15 (out of 33) interventions in which follow-up observations were reported, safety belt use continued significantly. Interventions incorporating incentives seemed to have stronger effects in increasing safety belt use (Segui-Gomez, 2000).

Track driving systems like vehicle data recorders, black boxes, and in-cab driver alerts which are reviewed by safety managers can impact the safety of emergency drivers. For example, black box devices with audible in-cab alerts showed significant improvement in EMS driving behaviors like reduction of speeding (Barishansky & O'Connor, 2007). Moreover, it is reported a significant reduction in annual cost because of decrease in vehicle repair, crash cost,s and ESVIs attributable to these systems (80-95%) (Barishansky & O'Connor, 2007). The effectiveness of two types of feedback from an in-vehicle monitoring system (IVMS) on the incidence of risky driving behaviors were analyzed as a main cause of work-related death in the United States. IVMS were installed in 315 vehicles over an approximately two-year period in intervention and control groups. In one period, intervention group drivers were given feedback from in-cab warning lights from an IVMS that indicated the occurrence of harsh vehicle maneuvers. In another period, intervention group drivers viewed video recordings of their risky driving behaviors with supervisors and were coached by supervisors on safe driving practices. The results show that lights-only feedback was not found to be significantly different from the control group's decline from the baseline. The largest decline in the rate of risky driving behaviors occurred when feedback included both supervisory coaching and lights (Bell, Taylor, Chen, Kirk, & Leatherman, 2017). A study worked on the installation of an on-board, computer-based, monitoring device in 36 ambulances with an 18-month period capturing real-time electronic auditory feedback (a group with more than 250 drivers). The objective was to investigate the impact of installing an onboard device on emergency vehicle driver behavior. The results showed the drivers' performance was improved based on more than 1.9 million recorded miles. For instance, seatbelt violations dropped drastically from 13,500 to 4. Also, vehicle maintenance costs decreased by 20 per cent within 6 months (Levick & Swanson, 2005). Crash reductions were reported between 30 and 90% by installing the drive Cam as an on-board event recorder which captures the significant change in longitudinal or latitudinal g-forces (Erich, 2007). Also, the number of unsafe driving events using an onboard event recorder was evaluated with 54 vehicles in 2008. It shows using onboard event recorders can reduce all events per mile and all events per response. The institution of video event recorder technology along with formal review and feedback resulted in a change in driving behavior. Given that call volumes increased and driving events decreased, these measures may serve as surrogates for improvements in traffic safety (Myers, Russi, Will, & Hankins, 2012).

New technologies can be utilized to assist the first responders and reduce the collisions. Advanced warning devices, like in-cab civilian alerts, can improve the performance of driving. In this case, the risk of emergency vehicle collisions was evaluated in a simulation study by using advanced warning devices. The founding shows this risk is reduced significantly by drivers' performance (like improving driver braking) compared to control groups (D. P. Bui et al., 2018). An experimental study evaluated the effectiveness of advanced warning device on the safety of driver interactions with emergency vehicles. This warning device provides drivers with advance warning of approaching on-call emergency vehicle via visual and auditory warnings when they are within a 300- to 400 m radius (Lenné, Triggs, Mulvihill, Regan, & Corben, 2008). The data including measures of speed, braking, and visual scanning collected from 22 participants. An earlier lane changes to clear a path for the emergency vehicles in the car-following event can be seen by installing advanced warning devices. In addition, the speed is reduced significantly which may result in safety benefits (Lenné et al., 2008). A study evaluated in-vehicle driver support systems that alert non-emergency vehicle drivers to approaching emergency vehicles in urban environments with eighty-five participants completing a driving simulator trial based on driving performance and usability measures under distracting and non-distracting conditions. The analysis indicated improved responses and roadway safety among participants presented with driver support systems compared with no driver support systems. Also, the risk of collisions with ERs decreased by utilizing a driver support system. In addition, this system did not increase in-vehicle distractions or the perceived mental workload of the driving tasks (Drucker, 2013). A geocasting application is used, also, to notify the vehicles on the road that the ambulance will approach to yield the way and reduce the risk of collisions. In this case, the traffic lights are set to green for the convenience of ambulances to pass for ambulance service (Lee & Huang, 2014). Furthermore, new technologies assist responders by giving an early warning signal to road users that emergency vehicles are approaching. A study evaluated this technology named early emergency detection system as potential to reduce collisions and have benefits for other road users (Finucane, 2010). In addition to the application of technology that mentioned above, V2I-based cooperative communication was, also, used to assist the emergency vehicle to reach the destination effectively by coordinating traffic information through a wireless communication network and prevent disruption due to traffic congestion in the road traffic mobility of Banda Aceh City. This cooperative communication used a simulation to provide route guidance and navigation for the emergency vehicles. The results showed using this route guidance and navigation can reduce travel time and increase the average speed by avoiding congested area (Afdhal & Elizar, 2015). Another study worked on the impact of cooperative vehicle-infrastructure systems, which is a development of the vehicle-to-vehicle (v2v) and vehicle-to-infrastructure systems with wireless communication technologies, on emergency vehicle operations at two adjacent intersections in Taicang City, China. This system is a great opportunity to provide appropriate traffic signal pre-emption for emergency vehicles based on real-time emergency vehicle data, traffic volume data, and traffic signal timings. The proposed system can improve the efficiency of emergency vehicle operations with less waste of traffic resources based on the results. (Wang, Wu, Yang, & Huang, 2013) In addition, a signal pre-emption system to switch the traffic light in the direction of travel to green for emergency service vehicles while switching opposing and cross-traffic lights red reported significant reductions in response times and traffic flow. But it showed no significant changes to the intersection crash risk after the adoption of pre-emption (McGowan, 2014).

Proactive risk management utilized a formalized procedure of identifying, evaluating, and ranking risks, and implementing controls. This has been implemented in various industries to prevent and reduce occupational risks and hazards. After some emergency departments used it, they found a 58% reduction in emergency vehicle injuries, a 19% reduction in overall crash rates, and a 36% reduction in crash-related injuries. (Mund, 2010).

There are some studies that evaluated the redesign of emergency vehicles for the safety of emergency and civilian drivers. A study evaluated the redesign of mobile computing terminal interface on task demands and usability issues of police officers. In this case, the usability principles of "using simple and natural dialog" and "minimizing user memory load" were violated by the current design. Founding shows that the enhanced design has the potential for reducing cognitive demands and task completion time

(Zahabi & Kaber, 2018b). The impact of an enhanced police MCT interface design on officer driving distraction is evaluated with 20 police officers participating in a driving simulator-based assessment of visual behavior, performance, workload, and situation awareness. In general, usability improvements for enhanced police MCT can reduce visual distraction and secondary-task completion time (Zahabi & Kaber, 2018a). Road and environment redesign or changes can, also, improve road safety. In a study, the effect of implementing a road reservation for emergency vehicle responses such as ambulances, fire trucks, and police cars using ubiquitous sensor networks was investigated on speed, traffic c,ongestion and safety. Results show that road reservations can guarantee safe driving of emergency vehicles while the speed is increasing (between 9% and 20%). Also, it can help to mitigate traffic congestion as well (Yoo, Kim, & Park, 2010).

An effective dispatch framework may reduce lights and sirens' responses which have a relation with the safety of ambulance drivers and other road users. This framework contains a simplified approach to assess the need for lights and sirens in ambulance responses to motor vehicle collisions. For instance, it considers factors such as the ambulatory status of all patients involved in the collision. Dispatch protocols require an ambulance to be sent with lights and sirens (L&S) to the vast majority of motor vehicle collisions. The rate of injuries among prehospital workers is nearly 15 times higher among ambulances operating with L&S than those without (Isenberg, Cone, & Stiell, 2012). In this regard, a study worked on deriving a dispatch rule to reduce the need for L&S response by using motor vehicle collisions characteristics that could easily be described by a 9-1-1 caller. Data were extracted from prehospital patient care reports of patients transported by ambulance to a level I trauma center between July 2007 and June 2008 with injuries sustained in motor vehicle collisions. Five motor vehicle collisions characteristics were extracted that could easily be identified by a 9-1-1 caller. The sensitivity and specificity of this dispatch rule were calculated for both patients who met trauma center triage criteria, and those who used trauma center resources. This dispatch rule was 95.9% sensitive and 33.5% specific for patients who met trauma center criteria, and 97.7% sensitive and 32.5% specific for patients who required trauma center resources among 509 patients who were evaluated in the study. Thus, a simple three-step dispatch rule for motor vehicle collisions could safely reduce L&S responses by one-third, and could improve the safety of ambulance drivers and the public as well (Isenberg et al., 2012).

There is a lack of accountability, liability, and discipline for violations as contributing to safety cultures and recommended strict enforcement of disciplinary policies to intervene and improve the safety. Some articles recommended holding both driver and officer accountable for all vehicle incidents with discipline including suspension, remedial training, termination, or fines. One key informant implemented a seatbelt policy with clearly defined disciplinary measures for non-compliance. The findings indicated a lack of evidence supporting the notion that increased discipline and accountability led to a reduction in crash risks. This suggests that strict rules can not necessarily yield benefits for officers. The one department that implemented a seatbelt policy with discipline reported an over 50% increase in seatbelt usage (Erich, 2007).

Driving simulator training which allows trainees to experience driving in various conditions and navigate various scenarios is useful for improving the performance of emergency drivers. It reported that using driving simulator training caused a 12% reduction in overall collisions and a 38% decrease in collisions that happened at intersections (D. P. Bui et al., 2018). Furthermore, a study evaluated the effectiveness of adding a driving simulator to a traditional training program with a sample consisting of students attending the National Emergency Medical Services Academy in Lafayette, Louisiana. A total of 52 participants were in the control group and 50 participants were in the treatment group. In addition to the classroom training, the treatment group used a driving simulator before driving. The results show that the treatment group took significantly less time to drive through the competency course on the first run than the control group. It also acquired significantly fewer penalty points on the first run and required significantly fewer runs to complete the course (Lindsey & Barron, 2008). Another study evaluated traffic safety knowledge gained by simulator-based training with questionnaires. The questions were designed to study associated and influencing factors, such as objective experience, subjective attitudes, personality, motivation, and demographic data. The results show that younger age, higher qualification, higher number of license classes, fewer traffic violations, and more traffic safety training were positively associated with knowledge, whereas less yearly driving mileage, more traffic safety training, and higher risk sensitivity positively influenced knowledge gain through the training (Prohn, 2022). There are a few projects focused on the impact of enhanced training or refresher training on collisions. In this case, some emergency departments reported their crash rates decreased by 19-50% with data collected from interviews. One department reported an average of $3-4 million in annual cost savings (Erich, 2007). However, it is worth mentioning that education and training programs, like internet-based and online programs, are increasing in emergency respondents but there is not enough evidence or evaluation to know about their impact on emergency vehicles collisions yet (Nordberg, 2006a, 2006b).

1.6 Standardized Training for Ambulances:

Ensuring safe ambulance operation necessitates the cultivation and evaluation of requisite skills. These competencies are outlined in the professional competency profiles for paramedics (Pirrallo & Swor, 1994). This lack of research extends to preventive and emergency driving training across various first responder professions, including police, paramedics, and firefighters. Additionally, there appears to be no independent evaluation method in place to assess the effectiveness of these programs in enhancing the road safety performance of first responders (D. P. Bui et al., 2018).

In the United States, there exist numerous drivers training programs, varying from brief 1-hour lectures to extensive courses exceeding 40 hours of theoretical and practical training (Keebler et al., 2017). Despite the common belief that these programs enhance driver safety, we discovered a lack of published research examining their effectiveness.

The current standardized training for ambulance drivers in Quebec varies among different agencies or organizations, and it encompasses both theoretical and practical components. In Quebec, individuals must hold a class 4A driver's license or a higher class (1, 2, or 3) to drive an emergency vehicle, including ambulances (Division IV, Ambulance Technicians) (Proulx, Vacon, Couturier, & Lavallière, 2016). The conditions for obtaining a class 4A license include passing a theoretical exam covering road signs, the Road Safety Code, and driving techniques specific to emergency vehicles, as well as meeting medical requirements and accumulating driving experience. Moreover, to qualify for a Class 4A license in Quebec, applicants must either have a minimum of 24 months of experience with a valid Class 5 probationary license and have successfully completed an SAAQ-approved emergency vehicle driving course or possess a valid Class 5 license (Société de l'assurance automobile du Québec, 2022). These requirements ensures that drivers are adequately prepared for the responsibilities associated with operating emergency vehicles, such as ambulances, police cars, or fire trucks, emphasizing both practical driving experience and specialized training.

College training for future paramedic technicians includes theoretical and practical instruction on driving ambulances as part of their pre-hospital emergency care program (Proulx et al., 2016). Previously, students were required to complete a course on driving ambulances from the point of service to the place of intervention and to the receiving center (DIVISION IV, Ambulance Technicians) (Ministère de l'Emploi et de la Solidarité social, 2023). Currently, students must complete a course as college training relating to driving an ambulance in defensive driving of emergency vehicles, which includes theoretical training and practical exercises on a closed circuit, road circuit, and/or using an ambulance driving simulator. However, the specific content and duration of the driving course vary among educational institutions, with training ranging from 45 to 60 hours. For example, at CÉGEP de St-Hyacinthe, the ambulance driving course consists of 39 hours of theory and 21 hours of practice on a closed circuit and road (total of 60 hours) (https://www.cegepsth.qc.ca/programme/soins-prehospitaliers-durgence/), while at Ahuntsic College, theory is spread over 15 hours, and practice comprises approximately 30 hours, including simulator training (College training relating to driving an ambulance) (https://www.collegeahuntsic.qc.ca/programmes-dec/techniques/soins-prehospitaliers-durgence). The timing of the driving course within the pre-hospital emergency care program also differs among colleges, with most offering it in the 5th or 6th session, and Ahuntsic College offering it in the 4th session (College training relating to driving an ambulance). Employers may expect newly hired paramedic technicians to operate ambulances safely from the beginning of their employment. To address concerns about the lack of scientific evidence supporting ambulance driver training, the Corporation d'urgence-santé previously implemented a closed-circuit ambulance driving assessment test, which was later replaced with an evaluation format involving on-the-job supervision during the first 10 regular shifts (Training and assessment) (Proulx et al., 2016). This new evaluation format allows employers to assess drivers' actual behavior in various situations and ensure their competence in driving emergency vehicles.

1.6.1 An example: Training Program at Urgences-santé :

At Urgences-santé, the training and assessment of new paramedic technicians' driving skills involve a comprehensive evaluation process conducted over a period of 10 actual work shifts by an instructor integrated into the team (Proulx et al., 2016). During these shifts, two new paramedic technicians are paired together, and the instructor assesses each individual's capacity and skill to drive an ambulance in both urgent and non-urgent situations. The evaluated driver receives feedback and advice from the instructor throughout the evaluation period.
Some of the regulations (beside respecting the traffic rules) that paramedic ambulance technicians must follow:

• Demonstrate good knowledge of the size and different blind spots of the vehicle.

• Have the skill to use mirrors during different maneuvers.

• Demonstrate safe behavior (wearing a seat belt, adequate speed depending on the situation)

• Demonstrate the ability to adequately adjust the driving space (mirror, bench)

• Use hand positioning at 9:15

• Demonstrate proper use of the vehicle (use of brakes, acceleration)

• Complete all courses in the required time (closed circuit only)

• Perform the visual scan properly

Prior to hiring, Urgences-santé conducts verification of demerit points on candidates' driving records. Candidates with more than 6 demerit points are excluded from the hiring process, although re-evaluation is possible once points are recovered. However, no verification of collision records with insurers' central files is currently conducted during the hiring process, despite recommendations for improvement in a Quality and Risk Management report. The evaluation of new paramedic technicians' driving skills has evolved over time. Before 1995, conduct assessment was carried out by an external company, followed by closed circuit evaluations until March 2013. Since then, evaluations have been conducted during shifts by paramedic technician instructors. The evaluation criteria include demonstrating knowledge of the vehicle's size and blind spots, proper use of mirrors, adherence to rules, safe behavior, and effective vehicle operation.

Both assessment methods have advantages and limitations. Evaluation during shifts allows observation of the driver in real-life scenarios, providing insight into actual behaviors and reactions to various driving situations. This method also eliminates the need for external risk assessment and is more cost-effective than closed circuit evaluations. However, closed circuit training, previously recognized by the SAAQ, is no longer offered, removing the privilege of obtaining a class 4A license without 24 months of driving experience.

Despite the assessment process, there is no personalized follow-up based on weaknesses or assessment results, and no advanced training is provided to enhance driving skills for specific situations such as winter driving or aquaplaning. This challenge is not unique to Urgences-santé and is observed in other professions like police and firefighting due to budget constraints and the volume of employees (M Lavallière & Bellavance, 2020).

It is important to develop a training program that incorporates a variety of aspects such as an understanding of the psychological elements associated with road safety for first responders. As an example, a study on law enforcement officers' risk perceptions towards on-duty motor-vehicle events emphasizes the importance of understanding and addressing the psychological aspects of road safety among police personnel (Tiesman, Heick, Konda, & Hendricks, 2015). The study's findings highlight a critical aspect of law enforcement safety, showing that motor-vehicle-related events (MVEs) significantly impact officers' risk perceptions, especially following personal experiences or knowledge of colleagues' incidents. Recognizing that officers perceive motor-vehicle-related incidents as a significant risk - often more so than intentional acts of violence - this awareness underscores the need for comprehensive safety programs. These programs should not only focus on physical safety measures, such as improved training and policy reforms but also on raising awareness about the risks of on-duty driving.

1.6.2 The Role of Employer in Delivering Training Programs:

Under the regulations governing ambulance technicians in Quebec, employers play a crucial role in facilitating access to training courses and incentivizing their employees to participate in continuing education programs (Ministère de l'Emploi et de la Solidarité social, 2023).

Access to Training Courses: Employers are responsible for ensuring that ambulance technicians have access to the necessary training courses required for their role. This includes providing opportunities for technicians to complete initial college training recognized by the Ministère de l'Enseignement supérieur, de la Recherche, de la Science et de la Technologie. Also, employers may facilitate access to equivalent training programs recognized by the national medical director or other forms of official occupational certification issued in Canada (DIVISION IV, Section 63).

Continuing Education Requirements: Employers must also support ambulance technicians in meeting continuing education requirements mandated by the government. The government may determine the conditions for registration in the national workforce registry and obtaining an ambulance technician qualification certificate, including ongoing education requirements and qualification assessment processes to be completed every four years (DIVISION IV, Section 64).

Therefore, employers have a responsibility to ensure that ambulance technicians have access to initial training programs and ongoing education opportunities necessary for maintaining their qualifications. Additionally, they should provide incentives and support for technicians to engage in continuing education activities to enhance their skills and knowledge in the field of emergency medical services. As an example, the Las Vegas Metropolitan Police Department implemented a comprehensive crash prevention program targeting on-duty motor vehicle crash fatalities and injuries among officers, following a year marked by three motor vehicle fatalities within the department (Tiesman et al., 2019). This multifaceted initiative included policy revisions, enhanced training mandates, and a progressive marketing campaign aimed at promoting safe driving behaviors. The program enforced a speed limit policy for officers and introduced mandatory annual emergency vehicle operations course training for the first three years, with subsequent biennial requirements. The outcomes were significant, demonstrating a reduction in both nonfatal motor vehicle crashes and motor vehicle-related injuries among officers, underscoring the effectiveness of a well-rounded safety strategy.

1.7 Traffic Policies and Regulations:

1.7.1 Road Users

The behavior of other road users when they are surrounding ambulances is a critical aspect of ensuring the safety and effectiveness of emergency response. One common policy regarding the behaviours of civilian drivers surrounding emergency vehicles is to give signal priority to them, such as ambulances, to ensure they can move quickly through congested areas and reach their destinations without delay (Asgharizadeh et al., 2022).

The behavior of other road users in response to ambulances varies significantly. Some drivers may opt to change lanes, while others might resort to mounting the sidewalk or altering their approach to intersections (Cortés & Stefoni, 2023). A study conducted in Thailand revealed that vehicles such as cars, motorcycles, and tricycles were most inclined to yield space to ambulances when the latter activated their signal lights and sirens (Apiratwarakul et al., 2018). Interactions between the public and emergency ambulances using lights and sirens were surveyed, with most participants having positive interactions, but a significant fraction found the interactions difficult to handle (G. Saunders & Gough, 2003). Also, the behavior of other road users poses a significant challenge when driving in a police context (G. Saunders & Gough, 2003). Motorists often fail to adhere to the Highway Code, ignore sirens and flashing lights, and exhibit difficulty in yielding the right of way to emergency vehicles.

When surrounding ambulances in Quebec, the behavior of other road users is regulated by specific laws and guidelines (Gouvernement du Québec, 2023b). Emergency vehicle drivers are authorized to operate their lights or siren when necessary, allowing them to override certain traffic rules as long as safety is maintained. According to Quebec regulations, when an emergency vehicle approaches with its lights or sound signals activated, other road users must yield the right of way. This includes reducing speed, moving as far to the right as possible, and stopping the vehicle if necessary. The main types of emergency vehicles covered by these regulations include police vehicles, ambulances, fire safety vehicles, and other vehicles recognized as emergency vehicles by the Société de l'assurance automobile du Québec.

Additionally, civilian drivers in Quebec must adhere to the Move-Over Law when encountering stopped emergency vehicles with activated yellow arrow light signals, flashing lights, or rotating lights (Gouvernement du Québec, 2021). This law requires drivers to leave a free space between their vehicle and the stopped emergency vehicle to ensure the safety of workers performing interventions. Failure to comply with the Move-Over Law can result in fines ranging from $200 to $300 and the imposition of 4 demerit points on the driver's license. To further enhance compliance with the Move-Over Law in Quebec, it is essential to supplement these regulations with educational materials aimed at the general public. Raising awareness through targeted campaigns, driver education programs, and accessible informational resources could improve understanding and adherence to this law.

1.7.2 Medical Emergency Vehicles

1.7.2.1 Ambulance drivers:

As paramedics in Quebec, when emergency vehicles like ambulances activate their lights or sirens, they are exempted from certain traffic regulations to ensure swift response to emergencies while maintaining safety (Gouvernement du Québec, 2023b). Moreover, according to the sections 592 and 592.1 of road safety code in Quebec, Canada, the law provides exemptions for certain road vehicles from being found guilty of offenses detected by photographic speedometers or red light camera systems (Gouvernement du Québec, 2023a). This exemption applies specifically to vehicles that are critical to emergency and public safety operations, including police force vehicles, ambulance service vehicles, fire safety service vehicles, and certain emergency vehicles registered in the name of the Société. Additionally, emergency vehicles designated for the urgent transport of medical personnel or equipment, as well as those used for rapid intervention with rescue equipment for immediate medical care, are also exempt. This policy ensures that these essential services can perform their duties without the concern of legal penalties for traffic violations, highlighting the prioritization of public safety and emergency response efficiency. Other vehicles require authorization from the SAAQ to use flashing or rotating red or white lights for emergency purposes as explained in C-24.2 of highway safety code (Société de l'assurance automobile du Québec, July 21, 2021). Paramedics are not obliged to adhere to road signage, traffic lights, speed limits, or roadway markings. Furthermore, they are not required to use turn signals while maneuvering. Paramedics are also permitted to execute maneuvers typically prohibited, including making zigzag passes, passing using the opposite lane at intersections, passing on the right, and stopping in restricted areas, such as sidewalks or highways, if necessary for emergency response.

1.7.2.2 Employers in Medical Emergency Sector in Quebec:

To explore the intricacies of workplace safety within the ambulance service sector in Quebec, it's important to delve into the "Law on Occupational Health and Safety (Loi sur la santé et la sécurité du travail, LSST)." Under this law, employers in Quebec have specific obligations and responsibilities regarding the prevention and protection of the health and physical and mental integrity of their employees, including paramedics (Ministère de l'Emploi et de la Solidarité social, 2023). This legislation stands as the cornerstone of the framework designed to mitigate occupational illnesses and accidents in the workplace. To effectively formulate recommendations aimed at enhancing the prevention of collisions involving ambulances, it is important to undertake a comprehensive review of the existing workplace safety regulations in Quebec such as employers' responsibilities to safeguard employee health. Such an inventory would identify areas for potential improvement, ensuring that the safety of paramedics and the broader public is prioritized in regulatory updates.

Prevention and Protection of Employee Health and Integrity: according to the LSST, employers are obligated to ensure the safety and wellbeing of their employees at work. This includes providing a safe work environment, implementing preventive measures to minimize risks of workplace accidents and occupational diseases, and providing adequate training and equipment to perform their duties safely (LSST, Chapter II, Roles and Responsibilities at the National Level, Division I, Sections 12 and 14).

Maintenance of Equipment and Vehicles: employers are also responsible for the maintenance of equipment, including vehicles used in pre-hospital emergency services such as ambulances. The LSST mandates that vehicles used as ambulances must meet technical specifications set by the government and undergo regular inspections to ensure compliance with safety standards (LSST, Chapter V, Vehicles, Division I, Ambulances, Section 77).

Specifically, employers are obliged to:

Ensure that vehicles used for pre-hospital emergency services, including ambulances, meet the technical specifications set by the government (LSST, Chapter V, Vehicles, Division I, Ambulances, Section 77).
Adhere to inspection standards established by the government to ensure the safety and functionality of ambulances and their equipment (LSST, Chapter V, Vehicles, Division I, Ambulances, Section 77).
Therefore, under the LSST, employers in Quebec are mandated to prioritize the safety and health of their employees, including paramedics, by providing a safe work environment, proper training, and equipment, as well as ensuring the maintenance and safety of vehicles used in pre-hospital emergency services.

1.8 Novelty of the Approach

Although the initial review for this proposal revealed a large number of studies that investigate influential variables for the safety of work-related vehicles, there is comparatively few research on contributing factors to improve the safety of paramedics in this regard.
In addition, updating the Corporation Urgences-santé (CUS) dataset was another important part of the current study. According to the CUS dataset, some collisions are not updated to know whether they have injuries or not. This is because the CUS does not update the dataset after each collision. While the SAAQ updates its records even after 30 days of each collision. In addition, this study measured the accuracy of SAAQ and CUS datasets to know whether it is reliable to use the updated data of the CUS for statistical modeling. For the current project, data from SAAQ and the CUS have been used covering a period from 2010-2020 for the area of Quebec and Montréal, respectively. In Quebec, road crash data is aggregated through the SAAQ which provides detailed crash data for all transportation modes, with data being updated with a delay of approximately one year (https://saaq.gouv.qc.ca/en/saaq/documents/road-safety-record/). This research is also performed based on collision records collected by CUS for the islands of Montreal and Laval, and by the SAAQ for the metropolitan area of Montréal (Société de l'assurance automobile du Québec 2020; Urgences-Sante, 2020).
In this study, a logistic regression was used to predict the probability of category membership, which includes injury/fatality and non-injury collisions as binary, on a response variable based on multiple explanatory variables. Multiple logit models will be developed to explore the impact of factors and relevant levels in the odds ratio of collision severity in Quebec and Montreal Island.
The current study focused on paramedics' work-related collisions. Therefore, it is of utmost importance to better describe these events and their surrounding characteristics if we want to facilitate proactive regulation and programs that can decrease work-related collisions, injuries, and fatalities related to paramedics' driving activities in Quebec.
The results of this Ph.D. will provide insights for policymakers and road safety advocates to make recommendations for targeted preventive actions and effective regulation. The academic community will benefit from a clear application of state-of-the-art analytical methods and the proposed scientific publications will help to disseminate this knowledge among other researchers and knowledge users among the health and safety community.

1.9 Research Objectives:

The following overall objectives of the current Ph.D. thesis are as below:

1. Conducting a systematic review of the literature on ambulance collisions, focusing on the prevalence and characteristics of such events and comparing it to other similarly sized vehicle collisions (Chapter 1 and 2).
2. Processing data collected from CUS and SAAQ to verify the accuracy between these data sources (Chapter 4).
3. To determine the prevalence and describe the distribution and the temporal trends of injury and fatal collisions involving ambulances and compared them to other general vehicle in different regions of Quebec (Chapter3).
4. To identify factors associated with ambulance collisions, such as day and time of collision, weather and surface conditions, type of environment, type of driving activity, driver's age, and experience, and history of citations (Chapter 3 and 4).
    - Examining the relationship between ambulance collisions and the use of lights and sirens during emergency responses.
    - To determine the relationship between collision severity and various factors, such as asphalt conditions, collision types, and locations.
    - Analyze the location patterns of ambulance collisions, and identify the riskiest locations for injury collisions.
5. Providing recommendations for preventive policies and training programs targeting younger and less experienced paramedics and addressing risky locations and emergency responses to improve paramedics' safety (Chapter 5).

1.10 Hypotheses of the Studies

The following are our hypotheses in the current study.

- The prevalence of injury and fatal collisions is higher for ambulances compared to other commercial or similarly sized vehicles (Objective 1 and Chapter 1 and 2).
- The SAAQ and CUS datasets show a significant degree of overlap. SAAQ primarily focuses on collecting data on severe collisions involving fatalities and injuries while CUS records information on all types of ambulance collisions in their territory (islands of Montreal and Laval in Quebec, Canada), including those resulting in damage, injuries, and fatalities. (Objective 2 and Chapter 4)
- The distribution of work-related collisions involving paramedics in Quebec differs from general vehicle collisions (Objective 3 and Chapter3)
- Younger drivers with low experience and drivers with a history of citations are more likely to be involved in ambulance collisions (Objective 4 and Chapter 3 and 4).
- Ambulance collisions are more likely to occur in urban areas, particularly at intersections (Objective 4).
- Ambulance collisions are more likely to happen when the ambulance is responding to an emergency call and using lights and sirens (Objective 4 and Chapter 3 and 4).
- Various factors, such as asphalt conditions, collision types, and locations, are associated with collision severity for both ambulances and general vehicles (Objective 4 and Chapter 3 and 4).
- Intersections and traffic lights are riskier locations for injury collisions compared to other areas (Objective 4 and Chapter 3 and 4).

1.11 Structure of Thesis:

The Ph.D. thesis comprises three interconnected papers, each contributing to a comprehensive understanding of the research topic. These studies are summarized below, highlighting their structure and connection:

The first study presents a systematic review synthesizing the literature on ambulance collisions, revealing a high prevalence of injury and fatal incidents compared to other commercial vehicles. Factors such as young age, low experience, and history of citations contribute to the likelihood of ambulance collisions, which mostly occur in urban areas, with intersections being the riskiest locations. The study highlights the need for tailored preventive policies to enhance paramedics' safety, need for further research into the distribution and occurrence of work-related collisions involving paramedics, as explored in the next study.

The second study aims to describe the distribution and occurrence of ambulance collisions involving paramedics in Quebec, comparing them with general vehicle collisions. The data comes from SAAQ covering a period from 2010-2020 for the area of Quebec. The study identifies specific areas, such as intersections and speed limit zones, where ambulance collisions are more frequent. It also found significant associations between collision severity and factors like asphalt conditions and collision types. These findings emphasize the importance of examining the factors involved in paramedics' collisions in a specific region, a deep next study searched to know the factors affecting paramedics' collisions.

The third study focuses on a retrospective study aimed at describing the factors involved in paramedics' collisions using data from a CUS in Montreal. The study highlights the lack of a significant reduction trend for monthly ambulance collisions but a significant decrease in annual non-injury collisions per paramedic. It also emphasizes the higher involvement of young and less experienced drivers in multiple collisions and identifies intersections and traffic lights as the riskiest locations for injury collisions. These findings underscore the importance of preventive policies targeting younger and less experienced paramedics and addressing risky locations.

The implications drawn from these studies suggest that ambulance collisions pose a significant risk to medical emergency responders leading to more injuries and deaths compared to other professional drivers. It's especially risky for young drivers with less experience and those drivers with a history of citations or collisions. To make things safer, we need specific safety policies and training programs for paramedics. The research points out that ambulance collisions are more likely in urban areas and intersections, especially when they are responding to emergencies with lights and sirens on. Policymakers should focus on making these places safer. To reduce these collisions, we can have awareness and training programs that target specific groups or risky behaviors in dangerous locations. This will help reduce the burden of these occupational collisions and enhance the overall safety for both ambulance occupants and road users.

CHAPITRE 2
PAPER 1: PREVALENCE AND CHARACTERISTICS OF AMBULANCE COLLISIONS, A SYSTEMATIC LITERATURE REVIEW

Milad Delavary [1,2], Zahra Ghayeninezhad [1,2] and Martin Lavallière [1,2,*]

[1] Department of Health Sciences, Université du Québec à Chicoutimi, Chicoutimi, QC, Canada, G7H 2B1; mdelavaryf@etu.uqac.ca (M.D.); zghayeni@uqac.ca (Z.G.)
[2] Laboratoire BioNR and Centre Intersectoriel en Santé Durable (CISD), Université du Québec à Chicoutimi, Chicoutimi, QC, Canada
***** Correspondence: Martin_Lavalliere@uqac.ca

Manuscript published in Safety, 2023 Vol. 9, No. 2

DOI: 10.3390/safety9020024

Abstract

The risk of dying or being injured as a result of traffic collisions is higher for medical emergency responders than for other professional drivers. This systematic review synthesizes the literature regarding the collisions of ambulances, focusing on the prevalence and characteristics surrounding such events. Keywords including paramedics and traffic collisions were searched in papers available in PubMed from January 1990 to July 2021. Two independent reviewers screened the abstracts of 2494 papers and ended up with 93 full-text articles to assess for eligibility, of which 26 papers were finally kept for this review. There was a total of 18 studies conducted in the United States, followed by 3 in Turkey, 2 in Taiwan, 1 in both the United States and Canada, 1 in France, and 1 in Poland. There is a high record of injury and fatal collisions for ambulances compared to other commercial or similarly sized vehicles. Drivers less than 35 years old with low experience and a history of citations are more likely to be involved in such collisions. Ambulance collisions are more likely to happen in urban areas and intersections are the riskiest locations. Most collisions occur when the ambulance is responding to an emergency call (i.e., going to the patient or the hospital) and using lights and sirens. Tailored preventive policies and programs for improving paramedics' safety should be sought to reduce the burden of these occupational collisions.

Keywords

Paramedics; emergency medical services; work-related collisions; injury; mortality; characteristics

2.1 Introduction

Work-related collisions are one of the main causes of death at work and it is estimated that 33% of drivers involved in traffic collisions are professional drivers (European Agency for Safety and Health at Work(EU-OSHA), 2019). Numerous studies have identified that a significant percentage of emergency medical services injuries and mortality are due to traffic collisions (Reichard & Jackson, 2010). For instance, it is found that 41.3% of work-related injuries (WRIs) were due to ambulance collisions and traffic collisions are the main cause of these injuries (31.9%) (Yilmaz, Serinken, Dal, Yaylacı, & Karcioglu, 2016). Another study showed that 81.4% of WRIs were due to ambulance collisions, leading to the death of three paramedics and seven civilian drivers between March 2014 and July 2014 in Turkey (Gülen et al., 2016).

The risk of occupational death, mainly due to traffic collisions, is high in emergency medical services (AJ. Heightman, 2006; AJ Heightman, 2009; Nordberg, 2006a, 2006b; Sagarra, 2015). The national crash fatality rates, in the United States (USA), for emergency vehicle (EV) personnel are 2.5–4.8 times higher than the national average for all occupations (Savolainen et al., 2009). Compared to overall traffic collisions, ambulance traffic collisions were 1.7 times more likely to result in death and 1.9 times more likely to include injuries (P.-W. Chiu et al., 2018). More specifically, among work-related collisions, those of emergency respondents are the leading cause of mortality (San Francisco Trial Lawyer Association (SFTLA), 2019). In the USA, ambulances are reported to be involved in more than 6500 crashes per year, 35% of which are associated with at least one injury and/or fatality (San Francisco Trial Lawyer Association (SFTLA), 2019). Another study showed that the overall injury rate in emergency medical services in the USA was 34.6 per 100 full-time workers per year between 1 January 1998 and 15 July 2002 (B. J. Maguire et al., 2005).

A review study of rural ambulance crashes showed that the frequency and severity of ambulance collisions are greater than those of crashes involving vehicles of a similar size and weight (N. D. Sanddal et al., 2008). Additionally, the percentage of injury-causing collisions for ambulances (76%) is more than for other similar-sized vehicles (61%) (A. F. Ray & Kupas, 2005). Furthermore, it is found that there are high rates of ambulance collisions in different countries, e.g., 5 collisions per 10,000 ambulance responses in the USA in 2016 (Watanabe, Patterson, Kempema, Magallanes, & Brown, 2019), 1 ambulance collision per 8598 ambulance runs in Taiwan from January 2011 to October 2016 (P.-W. Chiu et al., 2018), and 13.3 collisions per 100,000 miles traveled in the USA from June 1989 to August 1991 (C. E. Saunders & Heye, 1994).

The estimated cost of occupational injuries associated with work-related collisions is high compared to industrial accidents (Lebeau, 2021). For instance, the cost of these collisions was about CAD 2.70 billion in Quebec, Canada, from 2001 to 2015 (Lebeau, 2021). Social costs of involvement in traffic collisions for emergency responders (ERs) are thus expected to be higher than for others (National Highway Traffic Safety Administration (NHTSA)). Moreover, if an ambulance carrying a patient is involved in a road crash, it poses a threat to the patient, ERs, and other road users (American Medical Association, 2001). ERs' crashes also incur many lawsuits costing millions of dollars due to the loss of lives, the associated injuries, and property damage depending on the jurisdictions where they happen. It is estimated that the global cost of ER collisions is USD 250 billion annually (San Francisco Trial Lawyer Association (SFTLA), 2019). In the United States, the cost of ER crashes has been estimated to be USD 35 billion annually (San Francisco Trial Lawyer Association (SFTLA), 2019). Additionally, research has shown that the probability of being killed or injured in a collision involving a civilian driver is higher than that of a crash involving a paramedic, meaning that the total cost of such collisions could be significantly greater than current estimates suggest (T. L. Sanddal, Sanddal, Ward, & Stanley, 2010).

Ambulance drivers face a greater risk of collisions than other commercial drivers due to the nature of their work, resulting in injuries and fatalities among not only emergency responders but also ambulance occupants and other road users. The objectives of the study are to conduct a systematic literature review to analyze the prevalence of ambulance collisions and to identify variables that explain such events, including driver or collision characteristics. Our hypothesis is that paramedics experience a higher prevalence of collisions compared to other commercial drivers. Additionally, it is hypothesized that factors such as ambulance drivers' age, experience, sex, and history of collisions, collision characteristics such as time, date, and mechanism of collisions, response mode of ambulances, and weather conditions can increase the probability of collisions.

The methods used in the article include a systematic literature review through PubMed using specific keywords, blind screening of identified papers by two independent reviewers, and assessment of the quality of the papers using the QualSyst method. In the final review stage, the Results section summarizes the prevalence of collisions, driver and collision characteristics, weather conditions, response modes, and the use of lights and sirens during collisions from the selected papers. This is the first study, to our knowledge, including such a systematic literature review focusing on the prevalence of paramedic collisions and relevant factors involved in such events to improve the safety of emergency responders, ambulance occupants, and other road users.

2.2 Method

This systematic review was carried out through steps that are described below in Figure 2.1. In the first step of this review, we utilized the PubMed search engine, since it is a very comprehensive database of health-related subjects, developed by the National Library of Medicine (White, 2020). Then, we defined keywords and the pattern of our search. The keywords were classified into two groups. The first group of words (ambulance, emergency service vehicle, emergency medical service vehicle, emergency medical vehicle, and emergency response) referred to the study population. The second group defined the outcome of interest (fatal, injury, crash, collision, traffic collision, incident). Any article that contained one or more words of each group in the abstract or the title was included only if it was published between January 1990 and July 2021. By these search patterns, 2494 papers were obtained from the PubMed search engine. In the second step, two independent reviewers blind-screened all identified papers by reading the above-mentioned 2494 titles and abstracts using independent Excel spreadsheets that were then compared for inclusion or exclusion of papers. If the paper's relevance could not be determined with the title and abstract, the full text was carefully reviewed to ensure that it was aligned with our specific keywords. After this initial step, 93 papers were selected for a full read. In this third step, the two reviewers independently read all the papers and decided on the papers to be excluded or included. For deciding on the papers, the reviewers had five exclusion criteria adjusted to the scope of this systematic literature review (SLR). These exclusion criteria are listed below.

- The English version of the paper was not available (due to linguistics limitations).
- Reviews, editorials, commentary articles as well as qualitative studies.
- Target population of the study was not paramedics.
- The outcome of the interest was not describing road safety, i.e., crashes, injuries, and road fatalities.
- Insufficient detail of either population or outcome that prevented concluding whether it is completely relevant.

The number of papers excluded due to each of the criteria is presented in Figure 2.2. Finally, 24 papers were considered for the SLR. Of note, in the final step, while the reviewers read all the papers to decide on their relevancy, two other papers that were cited in the initial 24 papers were in the scope of this study and thus were kept for final analysis. Thereafter, all 26 papers were assessed by the QualSyst method formulated by (Kmet, Cook, & Lee, 2004). Using this method, each of the reviewers gave a score to each paper based on 14 questions, i.e., a score between 0 and 1, with a score closer to 1 meaning higher quality of the paper. Table 2.1 provides a summary of the QualSyst scores assigned to the papers included in this study. These scores, which represent the average of the scores given by the two reviewers, indicate a high level of quality for the majority of the papers. As such, the results of these papers are likely to be considered a valuable contribution to their respective fields.

Table 2.1 Summary of papers included in the final review.

Number	Author/s	Year	Study Title	Country	Method	Studied Period	Quality *
1	Chiu P.W. et al.	2018	Ambulance traffic accidents in Taiwan (P.-W. Chiu et al., 2018)	Taiwan	Descriptive analysis and two-sample *t*-tests	1 January 2011–31 October 2016	0.88
2	Custalow C.B., Gravitz C.S.	2004	Emergency medical vehicle collisions and potential for preventive intervention (Custalow & Gravitz, 2004)	USA	Multiple logistic regression model	1989–1997	0.93
3	Pirrallo R.G., Swor R.A.	1994	Characteristics of fatal ambulance crashes during emergency and non-emergency operation (Pirrallo & Swor, 1994)	USA	Descriptive analysis and statistical tests (Pearson χ^2 test)	1987–1990	0.9
4	Bentley M.A., Levine R.	2016	A National Assessment of the Health and Safety of Emergency Medical Services Professionals (Bentley & Levine, 2016)	USA	Average, weighted percentages, and 95% confidence interval (CI) analysis	Questionnaires; 1999–2008	0.78
5	Ray A.F., Kupas D.F.	2005	Comparison of crashes involving ambulances with those of similar-sized vehicles (A. F. Ray & Kupas, 2005)	USA	Chi-square and Fisher's exact tests	1997–2001	0.9
6	Becker L.R. et al.	2003	Relative risk of injury and death in ambulances and other emergency vehicles (L. R. Becker, Zaloshnja, Levick, Li, & Miller, 2003)	USA	Ordinal logistic regression analyses	1988–1997	0.83
7	Clawson J.J. et al.	1997	The wake-effect—emergency vehicle-related	USA	Mean values and 95% CIs	Questionnaires; 1996	0.68

			collisions (Clawson, Martin, Cady, & Maio, 1997)				
8	Ray A.M., Kupas D.F.	2007	Comparison of rural and urban ambulance crashes in Pennsylvania (A. M. Ray & Kupas, 2007)	USA	Chi-square and Fisher's exact tests	1997–2001	0.88
9	Gałązkowski R. et al.	2015	Occupational injury rates in personnel of emergency medical services (Galazkowski, Binkowska, & Samolinski, 2015)	Poland	Descriptive analysis	1 January 2008–31 December 2012	0.7
10	Sanddal T.L. et al.	2010	Ambulance Crash Characteristics in the USA Defined by the Popular Press: A Retrospective Analysis (T. L. Sanddal et al., 2010)	USA	Descriptive analysis and two-sample *t*-tests	1 May 2007–30 April 2009	0.93
11	Biggers W.A., Jr. et al.	1996	Emergency medical vehicle collisions in an urban system (Biggers, Zachariah, & Pepe, 1996)	USA	Chi-square and Fisher's exact tests	1993	0.95
12	Fournier M. et al.	2013	Crew and patient safety in ambulances: results of a personnel survey and experimental side impact crash test (Fournier et al., 2013)	France	Frequency, percentages, and median with interquartile range	Survey; January 2007–December 2007	0.66
13	Saunders C.E., Heye C.J.	1994	Ambulance collisions in an urban environment (C. E. Saunders & Heye, 1994)	USA	Retrospective analysis, CI analysis	June 1989–August 1991	0.85
14	Kahn C.A. et al.	2001	Characteristics of fatal ambulance crashes in the United States: an 11-year retrospective analysis (Kahn, Pirrallo, & Kuhn, 2001d)	USA	Pearson χ^2 tests and logistic regression	1987–1997	0.93

15	Weiss S.J. et al.	2001	A comparison of rural and urban ambulance crashes (S. J. Weiss, Ellis, Ernst, Land, & Garza, 2001)	USA	Two-tailed chi-square or Fisher's exact test, odds ratio and 95% CIs	1993–1997	0.95
16	Schwartz R.J. et al.	1993	The prevalence of occupational injuries in EMTs in New England (Schwartz, Benson, & Jacobs, 1993)	USA	Descriptive analysis	Questionnaires; 1990	0.82
17	Watanabe B.L. et al.	2019	Is Use of Warning Lights and Sirens Associated with Increased Risk of Ambulance Crashes? A Contemporary Analysis Using National EMS Information System (NEMSIS) Data (Watanabe et al., 2019)	USA	Multivariable logistic regression	2016	0.98
18	Lai Y.L. et al.	2018	An intelligent IoT emergency vehicle warning system using RFID and Wi-Fi technologies for emergency medical services (Lai, Chou, & Chang, 2018)	Taiwan	Descriptive analysis	2011–2015	0.58
19	Yilmaz A. et al.	2016	Work-related Injuries Among Emergency Medical Technicians in Western Turkey (Yilmaz et al., 2016)	Turkey	Descriptive analysis	Interviews; 2015	0.8
20	Reichard A.A., Jackson L.L.	2010	Occupational injuries among emergency responders (Reichard & Jackson, 2010)	USA	Classical variances of a stratified sample and 95% CIs	2000–2001	0.8
21	Gülen B. et al.	2016	Work-related injuries sustained by emergency medical technicians and paramedics in Turkey (Gülen et al., 2016)	Turkey	Kruskal–Wallis, chi-square, and Mann–Whitney U tests with Bonferroni correction	Questionnaire; March 2014–July 2014	0.7

22	Studnek J.R., Fernandez A.R.	2008	Characteristics of emergency medical technicians involved in ambulance crashes (Studnek & Fernandez, 2008)	USA	Multivariable logistic regression, fractional polynomials, and Hosmer–Lemeshow and Wald chi-square tests	2004	0.86
23	Larmon B. et al.	1993	Differential front and back seat safety belt use by prehospital care providers (Larmon, LeGassick, & Schriger, 1993)	USA and Canada	Mean, standard deviation, percentage, and kappa statistic	Survey; February 1991–December 1991	0.94
24	Tennyson J., Maranda L., Darnobid A.	2015	Knowledge and Beliefs of EMS Providers toward Lights and Siren Transportation (Tennyson, Maranda, & Darnobid, 2015)	USA	Kolmogorov–Smirnov and Mann–Whitney U tests and histograms	Survey; 2014	0.95
25	Ersoy G. et al.	2012	Why did the patient die? The relationship between ambulance accidents and death of patients: forensic medical issues (Ersoy et al., 2012)	Turkey	Descriptive analysis	1996–2005	0.55
26	Maguire B.J. et al.	2002	Occupational fatalities in emergency medical services: a hidden crisis (B. J. Maguire, Hunting, Smith, & Levick, 2002)	USA	Descriptive analysis	1992–1997	0.7

* Quality scores obtained by the average of two referees.

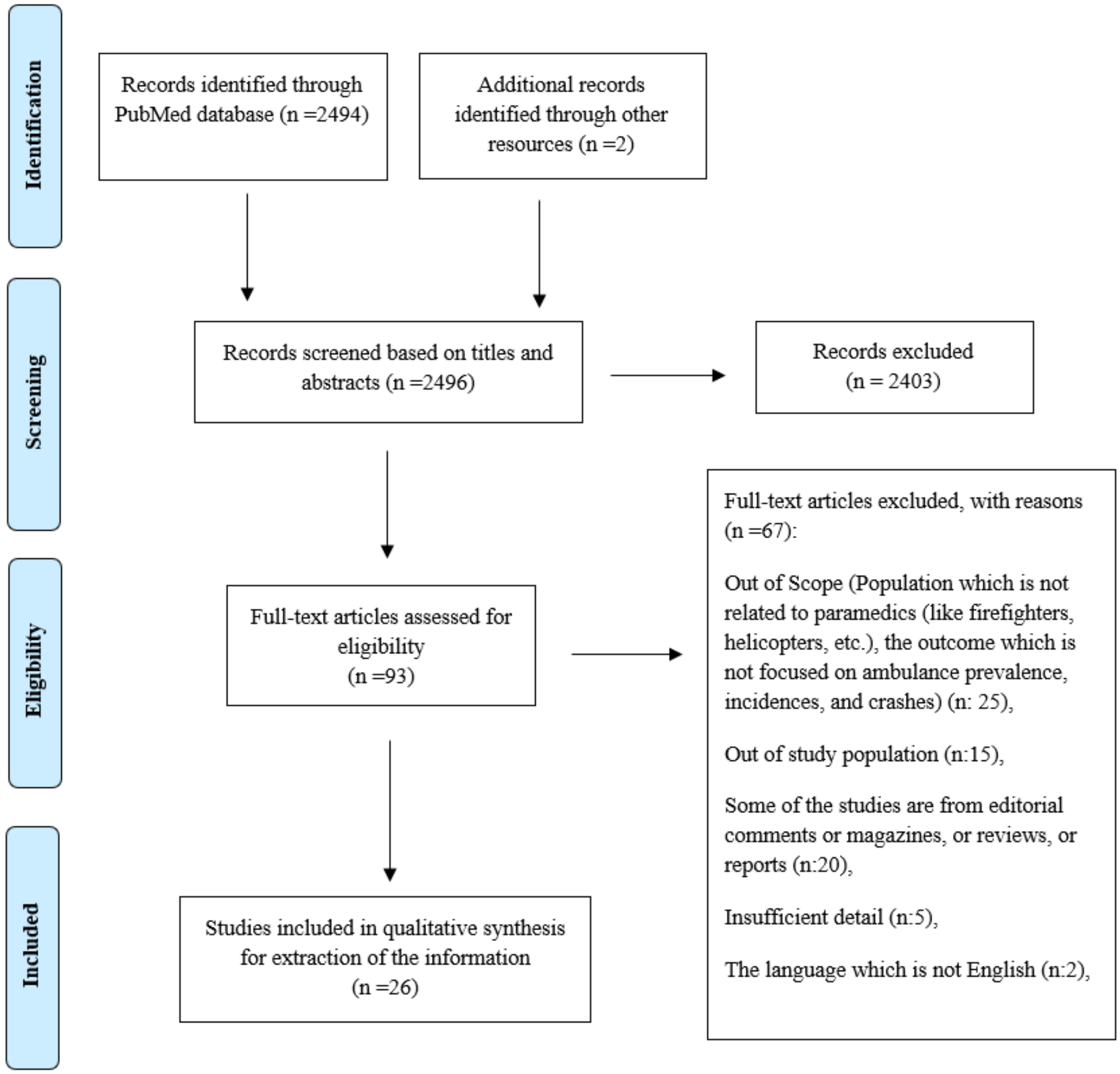


Figure 2.1 Flow diagram of the paper selection process based on PRISMA.

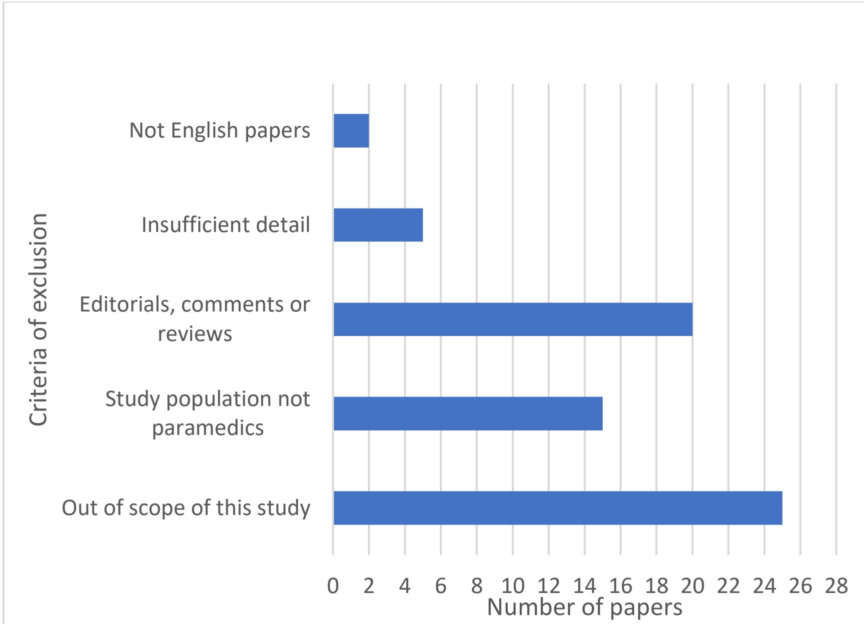


Figure 2.2 The criteria of exclusion of the papers at step four.

2.3 Results

The overall information of 26 papers included in the current study is shown in Table 2.1. This table summarizes these papers in different categories, consisting of authors' names, the year, the title of the paper, the studied country, the method, e.g., statistical tools, studied period, and QualSyst scores (ranging from 0.55 to 0.98). Sixty-nine percent of studies (n = 18) occurred in the USA and descriptive analysis or statistics, e.g., mean, was used in 58% of them (n = 15).

Table 2 shows the percentage of studies using data from governmental institutions, private institutions, or public access or survey or questionnaire results in presenting the prevalence of ambulance collisions or explanatory variables such as drivers' characteristics. It shows that most of our selected studies used data and, for instance, 58% of papers (out of 20) used datasets for showing the prevalence of collisions. This trend is also found for the independent variables.

Additionally, Table A1 in Appendix A provides additional details regarding the prevalence of ambulance collisions and the factors associated with them, as reported in the selected papers.

Table 2.2 Percentage of papers in desired categories.

Variables	**Sub-Category**	**Survey/Questionnaire (SQ)**	**Data (D) ***	**Total**
Outcomes n (%)	Collisions and/or Injury and/or Mortality	5 (19% **)	15 (58%)	20 (77%)
Independent	Drivers' Characteristics	4 (15%)	14 (54%)	18 (69%)

n (%)	(age, sex, experience, etc.)			
	Collision Characteristics	4 (15%)	9 (35%)	13 (50%)
	Vehicle Characteristics	0 (0%)	1 (4%)	1 (4%)
	Environment	3 (12%)	9 (35%)	12 (46%)
	Response mode	2 (8%)	9 (35%)	11 (42%)

* Data (D) come from governmental institutions, private institutions, or publicly available data. ** Percentage out of 26 papers in total.

2.3.1 Prevalence of Collisions

The number of reported collisions per year is shown in Figure 2.3. It shows that there is a yearly average of 144.6 collisions in the selected studies. The highest records are 509.5 and 436.25 from the studies of Ray and Kupas in 2005 and 2007 reported for ambulance collisions in the USA, respectively. In Taiwan (n = 14) and Poland (n = 18.5), there is the lowest reported prevalence of collisions (Galazkowski et al., 2015; Lai et al., 2018). In addition, Figure 2.4 shows the number of injury-causing collisions, injured persons, fatal collisions, and deaths per year. Among the selected studies, 387.3 injury-causing collisions (A. F. Ray & Kupas, 2005) and 368.8 injuries (P.-W. Chiu et al., 2018) are the highest records. In addition, the highest averages of 39.5 (49.5 deaths) and 36.3 (42 deaths) fatal collisions per year were presented by Sanddal et al. in 2010 and Pirrallo and Swor in 1994.

Two studies reported 1.7 injuries or fatalities and 0.94 injuries per 10,000 responses (see Figure 2.5) (Biggers et al., 1996; Custalow & Gravitz, 2004). Additionally, the highest records of 5 and 4.8 collisions per 10,000 ambulance responses are given by (Watanabe et al., 2019) and (Biggers et al., 1996), respectively. In addition, 13.3 ambulance collisions per 100,000 miles traveled occurred in the USA from June 1989 to August 1991 (C. E. Saunders & Heye, 1994). Seventy-three surveys found a mean of 0.82 per polled paramedic. Seventy-eight percent (57) of paramedics reported either being involved in a collision or witnessing at least one wake-effect collision (Clawson et al., 1997).

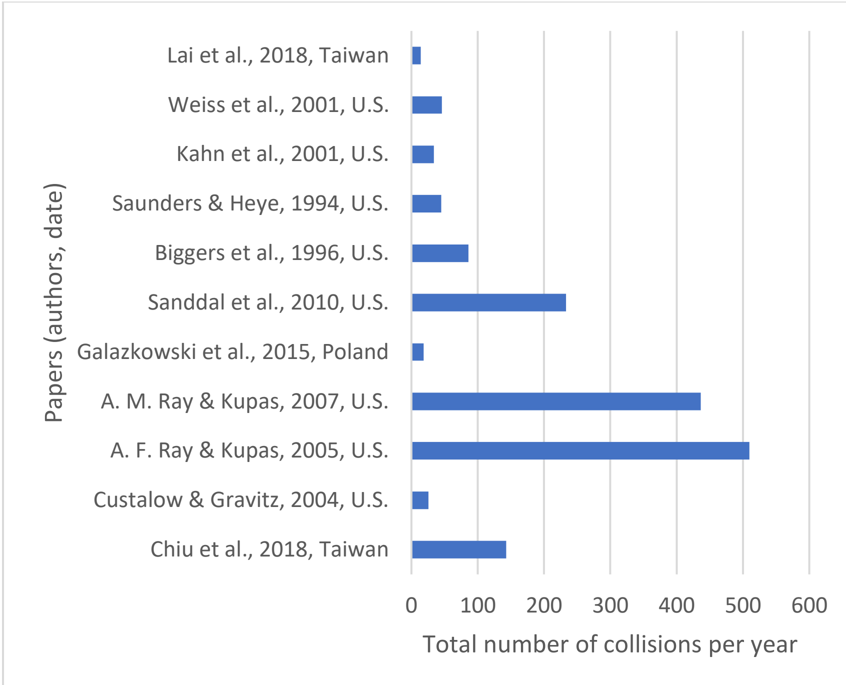


Figure 2.3 Total number of ambulance collisions recorded per year in different studies

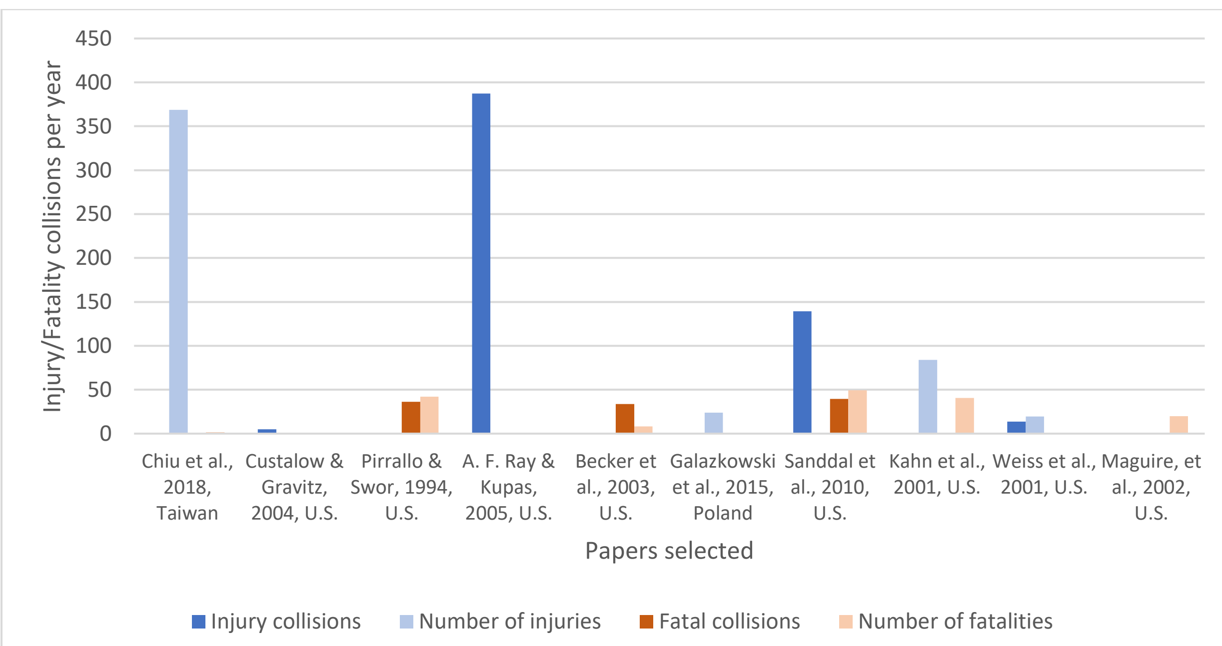


Figure 2.4 Number of injury-causing collisions, injured persons, fatal collisions, and deaths in different studies

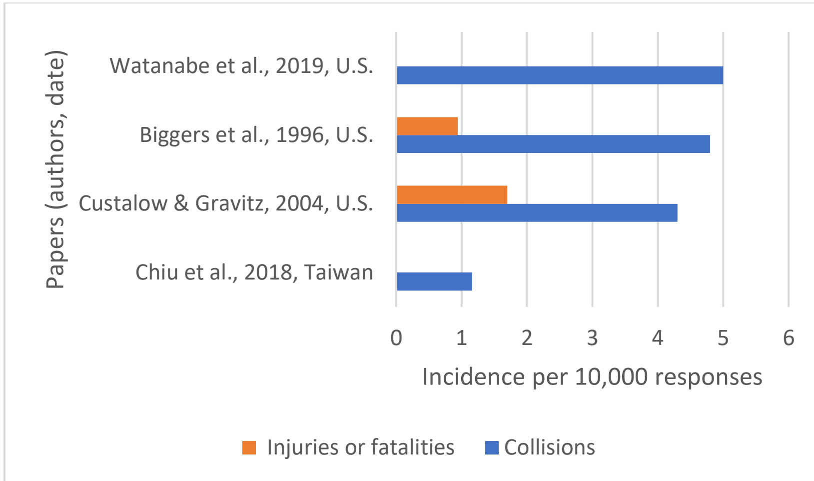


Figure 2.5 Incidence of collisions and injuries or fatalities per 10,0000 ambulance responses in different studies

2.3.2 Characteristics of Drivers

2.3.2.1 Age and Experience

In total, six papers reported the age characteristics of the study group. In three papers, the average age of ambulance drivers involved in collisions was between 30 and 35 years old (Custalow & Gravitz, 2004; Schwartz et al., 1993; Studnek & Fernandez, 2008). One of the studies had a younger population, with an average age of under 30 years old (Galazkowski et al., 2015), while another study had an average age of 47 for the group of paramedics they evaluated (Ersoy et al., 2012). One paper mentioned that 25% of the emergency medical service (EMS) injuries were in those less than 25 years old (Reichard & Jackson, 2010). A study by Studnek and Fernandez (2008) also highlights that the likelihood of being involved in a collision increases with a decrease in the ambulance driver's age. Only one study reported the experience of the ambulance drivers involved in the collisions with the minimal experience reported being 3 years and the maximum 12 years (average: 8.1 years) (Clawson et al., 1997).

2.3.2.2 Sex

Four papers had details on the injuries or fatalities regarding the sex of the paramedic who drove. Although all these papers mentioned that, in the vast majority of the collisions (either fatal or injury), more males were involved, the percentage of them involved differs from 71% to 100% (P.-W. Chiu et al., 2018; Custalow & Gravitz, 2004; Galazkowski et al., 2015; Schwartz et al., 1993). A study by Galazkowski et al. (2015) also mentioned that the trend of females involved in collisions increased from 2011 to 2012.

2.3.2.3 History of Collisions

Only three papers reviewed the history of collisions of the ambulance drivers. In one of these studies, the majority of the emergency drivers (more than 70%) had a history of multiple collisions (Custalow & Gravitz, 2004). Contrarily, in two other studies only 30% to 40% of the emergency drivers were involved in a collision more than once (Biggers et al., 1996; Kahn et al., 2001d).

2.3.2.4 Traffic Citation

Six studies investigated the traffic citations related to ambulance drivers' and civilian drivers' interactions with each other and with road regulations on the roads. While EMS drivers are expected to follow all traffic regulations, they are also granted certain legal exemptions in emergency situations, such as speeding. In this regard, a study examining the behavior of EMS drivers found that they were more likely to commit some traffic violations when responding to an emergency call than when driving in non-emergency modes (88.2% vs. 11.8%, respectively) (Pirrallo & Swor, 1994). However, another study mentions that there is no difference between fatal emergency and non-emergency crashes according to traffic citations (Kahn et al., 2001d). Two studies analyzed the percentage of ambulance collisions involving civilian drivers who received traffic citations. However, the studies reported different numbers (8% (n = 39) vs. 88.8% (n = 16)), possibly due to differences in data sources (Biggers et al., 1996; T. L. Sanddal et al., 2010). It is highlighted in another study that impaired civilian drivers increase the odds ratio of injury collisions by 6.1 (Custalow & Gravitz, 2004). Moreover, the study by S. J. Weiss et al. (2001) shows that both ambulance and civilian drivers are cited more often in urban areas than in rural areas.

2.3.2.5 Seat Belts

Six papers studied seat belt use of emergency drivers, as it is one of the most important surrogate measures of road safety. The results of four papers strongly confirm that while seat belt use is widely accepted by the occupants of the front seats of the ambulance, i.e., the drivers, in most cases, it is often neglected by the occupants of the rear seats, i.e., patients or EMS personnel (Bentley & Levine, 2016; Fournier et al., 2013; Larmon et al., 1993; Schwartz et al., 1993). This is mainly because the seat belt restricts the movements of the occupants and prevents them from doing their tasks, as mentioned in the study of Fournier et al. (2013). Furthermore, one study shows that the rear compartment has increased odds of incapacitating and fatal injuries of 2.7 (95% CI 2.0–3.7) compared to the front seat. Moreover, unrestrained occupants have increased odds of incapacitating and fatal injuries of 2.5 (95% CI 1.8–3.6) compared to those who are properly restrained. Unrestrained rear occupants have increased odds of incapacitating and fatal injuries of 2.8 (95% CI 1.8–4.2) compared to unrestrained front occupants (Kahn et al., 2001d). The study by S. J. Weiss et al. (2001) shows that those who did not use seat belts had more injuries in rural areas compared to urban areas. Fortunately, the frequency of using a seat belt for the front seat for work-related and non-work-related trips, from 2002 to 2008, increased by 15.1% and 10%, respectively (Bentley & Levine, 2016).

2.3.2.6 Liability of Collision

Four papers investigated the liability of ambulance collisions. Three papers confirmed that in the minority of the cases, ambulance drivers are responsible for the collisions. The percentage of ambulance drivers liable for collisions varies from 6% to 48.9% (Biggers et al., 1996; T. L. Sanddal et al., 2010; C. E. Saunders & Heye, 1994). However, the study by C. E. Saunders and Heye (1994) found that ambulance drivers were responsible for 67% of collisions during unsafe backing up or reversing due to limited visibility. Moreover, the use of lights and sirens is often cited as a reason for drivers colliding with ambulances. When these warning devices are activated, drivers more frequently fail to yield the right of way to the ambulance compared to cases of inattention. Surprisingly, when ambulances use lights and sirens, inattention increases while failure to yield decreases (C. E. Saunders & Heye, 1994).

2.3.3 Collision Characteristics

2.3.3.1 Time of Day/Day of the Week

The timeline of the collisions was a topic that was frequently discussed in the papers included in our study, since 10 papers worked on the daily, weekly, or monthly variances of the collisions. The most agreed upon result is the higher frequency of collisions in the afternoon (after 12 noon), rather than in other periods of the day, which is concluded in three studies (P.-W. Chiu et al., 2018; Kahn et al., 2001d; T. L. Sanddal et al., 2010). This is not in line with two studies in which the result shows that the frequency of the collisions is highest in the evening (Lai et al., 2018; A. F. Ray & Kupas, 2005).

Five papers also found no significant difference between weekdays and weekends, considering the frequency of the collisions (Biggers et al., 1996; Galazkowski et al., 2015; Kahn et al., 2001d; A. M. Ray & Kupas, 2007; S. J. Weiss et al., 2001). However, three papers had results showing significant variations in the week. The first one concluded that collisions are more frequent on the weekends (A. F. Ray & Kupas, 2005). The second one, though, found the highest frequency on Saturdays and Mondays (Pirrallo & Swor, 1994), while the last one found that the most collisions happen on Fridays (Biggers et al., 1996).

Only one study evaluated monthly variations in ambulance collisions. This study shows that although there is no statistical difference ($p = 0.201$) between monthly variations, January, May, and December had more collisions compared to other months (T. L. Sanddal et al., 2010).

2.3.3.2 Type of Collision

Eight studies analyzed the type of maneuvers that lead to the collisions. Although many of the studies had similar approaches in reviewing maneuvers and vehicles' movements before collisions, it is agreed by three papers that angle collisions are the most frequent in urban areas (Pirrallo & Swor, 1994; A. F. Ray & Kupas, 2005; A. M. Ray & Kupas, 2007). Another study showed that EMS vehicles experience 33% of their collisions while moving forward and only 17% while turning (C. E. Saunders & Heye, 1994). Given that angle crashes are the most common type of collision, the fact that ambulances are involved in only 17% of these incidents when turning suggests that they are not the primary cause of such collisions. The study of Biggers et al. (1996) showed that a frequent type of collision for ambulances is when they are hit in the back. Furthermore, there is evidence that ambulances were struck by another vehicle more frequently than they struck other vehicles (45% vs. 32%) (T. L. Sanddal et al., 2010). However, this study also mentions that 14% of ambulance collisions at intersections are rollovers, which implies the high speed of ambulances. Results from Ersoy et al. (2012) also showed that, after collisions between two vehicles, rollover is the most frequent type of ambulance collision (57.14% vs. 19.05%).

Two studies compared the differences between rural and urban EMS collisions; the first study shows that rural ambulances were significantly more likely to have an impact at the front while urban ambulances were more likely to have back-end collisions. There is an equal chance to be impacted on the side in rural and urban areas (S. J. Weiss et al., 2001). The second one stated that angle collisions are the most frequent collision type in urban areas (54%), whereas striking a fixed object is the most frequent one in rural areas (33%) (A. M. Ray & Kupas, 2007).

2.3.3.3 Transportation Mode

Six studies looked into the modes of transportation involved in ambulance collisions. Four studies' results confirm that non-motorized road users such as pedestrians and bicyclists are less likely to be involved in these collisions. The percentage of collisions between non-motorized road users and ambulances varies around 15.6% and 9% for bicyclists and pedestrians, respectively (Kahn et al., 2001d; Pirrallo & Swor, 1994). Two other studies have shown that less than 5% of collisions involve pedestrians

(A. F. Ray & Kupas, 2005; A. M. Ray & Kupas, 2007). Conversely, motorcycles have very concerning situations regarding their collisions with ambulances. There is evidence that motorcycles are involved in the majority of ambulance collisions (63.6%) and this becomes worse in terms of fatal collisions specifically (88.9%) (P.-W. Chiu et al., 2018). Another study also claims that in only half of ambulance collisions is another vehicle involved (Gülen et al., 2016). The study of A. M. Ray and Kupas (2007) compared the modes involved in rural and urban areas. The results say that a collision involving more than one vehicle (88% vs. 56%, $p < 0.0001$) and more than four people (35% vs. 23%, $p < 0.0001$) is more likely in urban compared to rural areas.

2.3.3.4 Type of Environment

Eleven papers (42%) considered the environments of the EMS collisions. Many studies' results in this section had a great consistency, and it increases the importance and reliability of the results on this subject. In four studies, it was concluded that EMS collisions are more likely to happen in urban areas than rural areas (P.-W. Chiu et al., 2018; Lai et al., 2018; T. L. Sanddal et al., 2010; S. J. Weiss et al., 2001) while there is weak evidence that more collisions happened outside of cities (Ersoy et al., 2012). In addition, it is found that operator errors in urban areas are more common than in rural areas (93% vs. 75%, respectively) (A. M. Ray & Kupas, 2007). It is worth mentioning that one study's result denies any difference between urban and rural EMS collisions in terms of their severity (A. M. Ray & Kupas, 2007). Seven papers also addressed intersections as the most dangerous part of urban areas for EMS vehicles (P.-W. Chiu et al., 2018; Custalow & Gravitz, 2004; Kahn et al., 2001d; Lai et al., 2018; A. F. Ray & Kupas, 2005; A. M. Ray & Kupas, 2007; T. L. Sanddal et al., 2010) while one paper disagreed with this (Biggers et al., 1996). Another study interestingly reveals that although the majority of ambulance collisions happened on urban streets, a considerable portion (i.e., 20.8%) of these collisions took place in parking lots or at hospitals. Conversely, freeway collisions show a negligible percentage in this study (0.7%) (C. E. Saunders & Heye, 1994). However, the study of Ersoy et al. (2012) disagrees with there being a negligible portion of ambulance collisions on highways (66%).

2.3.4 Weather Conditions

Five papers considered weather variables associated with the frequency of collisions. Four papers strongly confirmed that most of the collisions happen in clear weather (ranging from 68% to 77%). However, the percentages of collisions that happen in adverse conditions are also calculated. Snowy weather conditions cover 5% to 13% of the collisions in two different studies in the USA (Custalow & Gravitz, 2004; A. M. Ray & Kupas, 2007). Rain or light precipitation is associated with 3.7% of the collisions (C. E. Saunders & Heye, 1994). Two studies reported the percentage of collisions that happen at night and this is between 25% and 28.1% (A. M. Ray & Kupas, 2007; C. E. Saunders & Heye, 1994). There is weak evidence that weather conditions that lead to a slippery or icy surface (i.e., snow or rain in a certain range of temperatures) are more dangerous than those causing decreased visibility such as rain or fog (T. L. Sanddal et al., 2010).

2.3.5 Response Mode/Lights and Sirens

The variable most frequently investigated in all the papers identified is the use of lights and sirens. This shows the prominence and importance of this variable in the collisions of EMS vehicles. Several studies support the assumption that the majority of collisions involving emergency medical services (EMSs) occur when the ambulance is using lights and sirens (Custalow & Gravitz, 2004; T. L. Sanddal et al., 2010; Tennyson et al., 2015) or responding to a call, i.e., either going to the scene or caring for the patient on the way to hospital and during emergency use (Kahn et al., 2001d; Pirrallo & Swor, 1994; T. L. Sanddal et al., 2010; Schwartz et al., 1993). On the contrary, three papers found that there is no significant difference in the frequency or the severity of ambulance collisions in or out of emergency mode (L. R. Becker et al., 2003; Galazkowski et al., 2015; C. E. Saunders & Heye, 1994).

2.4 Discussion

Most (58.7%) fatal ambulance crashes resulted in the disabling of the ambulance, requiring towing of the vehicle (90.4%) (Pirrallo & Swor, 1994). Such major damage shows that the risk of being involved in collisions for paramedics and ambulance occupants cannot be ignored. Bentley and Levine (2016) found that the percentage of "excellent" health in paramedics decreased from 1999 to 2008 (38.5% vs. 32.2%, respectively). Moreover, it is found that the frequency of health problems among ambulance drivers is greater in comparison to that of the broader working population (Sterud, Ekeberg, & Hem, 2006). Sleeping problems (20–27%), back problems (20–24%), and hearing problems (7–10%) are among the top health issues. Regarding sleepiness, 8.0% of ambulance drivers faced difficulty in driving for short distances and 17.5% for long distances. Additionally, Studnek and Fernandez (2008) noticed that emergency medical service professionals with sleep problems were more likely to be involved in a crash than those who did not face this problem (14.9% vs. 7.5%, respectively). According to the importance of ambulance safety, the current study compares the prevalence of paramedics' crashes in different locations and times as well as investigates the factors surrounding such events.

Characteristics of drivers played an important role in the safety of emergency medical services. In this regard, male, younger (male and female around 30 years old), and paramedics with low experience in driving an ambulance may be more at risk of traffic collisions in comparison with their counterparts. The history of collisions and traffic violations, including failure to yield the right of way and not wearing a seat belt, was a significant factor in determining the probability of being responsible for a collision and predicting the severity of collisions for both paramedics and non-emergency drivers.

Regarding collision characteristics, angle collisions are the most common type of collision, particularly in urban areas. Additionally, the timing of collisions varies throughout the day and week, with most studies indicating a higher frequency in the afternoon, but some finding the highest frequency in the evening. While five papers found no significant difference between weekdays and weekends, three papers had conflicting results on which days had the most collisions (see Appendix A for further details). According to the type of environment, ambulance collisions are more likely to occur in urban areas, particularly at intersections, compared to rural areas. A study supports this finding and highlights the significant effect of intersections on ambulance crashes and delays (Wiwekananda, Hamukti, Yogananda, Calisto, & Utomo, 2020).

There is no statistical difference between the use of different response modes (emergency and non-emergency) among years of manufacture of the vehicles (Pirrallo & Swor, 1994). However, being in emergency mode and using warning lights and sirens (WLSs) in ambulances has been shown to increase the probability of being involved in crashes.

Exposure variables such as kilometers driven were not accessible for all the selected studies which made it difficult to compare and evaluate the prevalence of ambulance collisions. In addition, although several studies have indicated that civilian drivers are more often responsible for collisions than ambulance drivers (Biggers et al., 1996; T. L. Sanddal et al., 2010), no literature has evaluated human errors focusing specifically on such drivers in a simulated environment. To address this gap, future research could design scenarios to investigate the role of exposure variables or civilian drivers in ambulance collisions, such as driver distraction or non-compliance with traffic laws. This would help in enhancing our comprehension of factors involved in ambulance collisions and develop strategies to prevent them in the future.

This study faced difficulty in obtaining the data in all selected papers to run a quantitative analysis. As a result, it was not feasible to quantify the effect of explanatory variables (e.g., age or experience of drivers) on the number of ambulance collisions. Moreover, comparing the selected studies posed a challenge due to factors such as varying sample sizes across studies. To address these issues, we suggest that further investigation (e.g., quantitative analysis) is needed to analyze the data that come from studies chosen by the QualSyst method. This approach quantifies the effect of factors involved in ambulance collisions from selected studies.

The research underscores the importance of ensuring ambulance safety and highlights the risks faced by paramedics and other occupants. Specifically, the study highlights factors that contribute to ambulance collisions, including the use of WLSs and hazardous locations such as intersections in urban settings. It is recommended to determine the effect of other variables, such as driver distraction or failure to follow traffic laws, in ambulance collisions involving civilian drivers. The traffic regulations in urban areas, especially at intersections, should consider the potential hazards for ambulance operations. This could include measures such as giving ambulance vehicles the right of way or changing traffic signals to green during emergencies. Additionally, targeted training programs should be implemented for specific groups such as inexperienced young paramedics or those with a history of collisions or traffic violations, in order to decrease the occurrence of collisions. By identifying the risk factors, the study offers valuable insights that can be used to promote greater attention to ambulance safety and by policymakers to develop effective prevention strategies, thus making a significant contribution to the field.

2.5 Conclusions

Traffic collisions with ambulances are a major concern regarding the health and safety of paramedics, ambulance occupants, and other road users. There is a high incidence of collisions involving ambulances compared to other commercial or same-sized vehicles. In this regard, using WLSs for responding to calls is linked with an increase in the burden of collisions. In addition, in urban areas and especially at intersections, the risk of collision is greater than in other locations. Little driving experience, being younger, and having a history of collisions or traffic citations (e.g., not wearing a seat belt) can raise the chance of being involved in a traffic collision, collision severity, or liability of a collision. The results synthesized in this systematic literature review can help policymakers to implement educational programs focusing on target populations and the main variables involved in collisions of first responders.

Author Contributions Conceptualization, M.D. and M.L.; methodology, M.D., Z.G., and M.L.; formal analysis and investigation, M.D. and M.L.; data collection, M.D. and Z.G.; writing—original draft preparation, M.D. and M.L.; writing—review and editing, M.D., Z.G., and M.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was not funded.

Institutional Review Board Statement: Not applicable

Informed Consent Statement: Not applicable

Data Availability Statement: Not applicable

Acknowledgments: The authors would like to thank Ms. Sarah Simmons from the University of British Columbia for her substantial contributions in reviewing the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

CHAPITRE 3
PAPER2: WORK-RELATED COLLISIONS INVOLVING PARAMEDICS in QUEBEC (CANADA): AN ANALYSIS OF CONTRIBUTING FACTORS

Milad Delavary [1,2], Mathieu Tremblay [3] and Martin Lavallière [1,2,*]

[1] Department of Health Sciences, Université du Québec à Chicoutimi, Chicoutimi, QC, Canada, G7H 2B1; mdelavaryf@etu.uqac.ca (M.D.)
[2] Laboratoire BioNR and Centre Intersectoriel en Santé Durable (CISD), Université du Québec à Chicoutimi, Chicoutimi, QC, Canada
[3] Department of Health Sciences, Université du Québec à à Rimouski, Rimouski, Québec, Canada; mathieu_tremblay2@uqar.ca

***** Correspondence: Martin_Lavalliere@uqac.ca

Manuscript accepted with revisions in International Journal of Occupational Safety and Ergonomics

Acknowledgments

We would like to thank the research staff at the Société de l'assurance automobile du Québec (SAAQ) for making this research possible. Without their help and guidance through such a huge dataset, a study such as this one would not be possible.

Funding

There is no funding for this study.

Abstract

Purpose. This research aims to describe the distribution and occurrence of work-related collisions involving paramedics across Quebec and to compare these results with collisions of general vehicles. Method. This retrospective study spanned over 11 years of data (2010 to 2020) extracted from the Société de l'assurance automobile du Québec (SAAQ) road safety statistics. Statistical tests including paired t-test and Mann-Kendal were used for the temporal analysis of aggregated numbers of injury and non-injury collisions in 17 regions of Quebec. A descriptive analysis and logit regression were used to compare the various factors e.g., crash and environmental characteristics associated with ambulance and general vehicle collisions. Results. A higher percentage of ambulance collisions occurred at intersections (43.32%), in 50 km/h speed limit zones (48.05%), in commercial areas (48.29%) and on all types of two-way roads (62.05%). Logit models indicate that there is a significant association (p-values <0.05) between collision severity and a variety of factors, including asphalt conditions, collision types and locations. Conclusion. Our results are consistent with prior research, showing that Quebec paramedics have comparable incidents and collision causes related to environmental, weather, and road factors. Our findings suggest several specific areas for policymakers to focus on regarding ambulance collision reduction.

Keywords

Ambulance Personnel, Crashes, Environment, Road, Weather, Logit Regression.

3.1 Introduction

According to the literature, the risk of occupational death and injury due to traffic collisions is high for emergency medical services because of work-related factors such as long working hours, insufficient sleep, stress and fatigue (AJ. Heightman, 2006; AJ Heightman, 2009; James & Vila, 2015; Nordberg, 2006a, 2006b; Sagarra, 2015; Sedlár, 2022; Vila, 2006).

National crash fatality rates in the United States (U.S.), for emergency vehicle (EV) personnel are 2.5 to 4.8 times higher than the national average for all occupations (Savolainen et al., 2009). Compared to overall traffic collisions, ambulance traffic collisions are 1.7 times more likely to result in death and 1.9 times more likely to produce injuries (P.-W. Chiu et al., 2018). A literature review on rural ambulance crashes showed that the frequency and severity of ambulance collisions are higher than those involving vehicles of similar size and weight (N. D. Sanddal et al., 2008). Moreover, if an ambulance is involved in a road crash, it poses a threat to the patient it carries (American Medical Association, 1903).

More specifically, collisions are the leading cause of death among work-related collisions of emergency respondents (Fetto Law Group, 2018). In this sense, 6,500 crashes per year were recorded between 1998 and 2002 in the U.S., which is quite high compared to Sweden with 16 crashes per year (resulting in 218 injured people in total) between 2003 and 2013 (Elvik et al., 2007) or Great Britain with 338 per year (including 38 fatal, 204 serious injury and 1784 slight injury crashes in total), from 1999 to 2004 (Lutman, Montgomery, Ramnarayan, & Petros, 2008a).

It is imperative to underline that environmental conditions constitute a prevalent factor in ambulance collisions, as evidenced by numerous studies dedicated to investigating the impact of such conditions on emergency drivers (Custalow & Gravitz, 2004; M. Delavary, Ghayeninezhad, & Lavallière, 2023; Drucker, 2013; Pirrallo & Swor, 1994; A. F. Ray & Kupas, 2005). A pertinent study indicates that ambulance collisions occurring at intersections, with an odds ratio of 4.3 ($p<0.05$), represent a significant proportion of overall injury collisions involving ambulances (Custalow & Gravitz, 2004). This supports the statement that driving on urban roads, straight through four-way (or above) intersections with traffic signals can increase the risk of ambulance collisions (Drucker, 2013; Pirrallo & Swor, 1994; A. F. Ray & Kupas, 2005). This aligns with findings that show that most fatalities happen in zones with speed limits lower than 80 km/h, i.e. urban areas (Pirrallo & Swor, 1994). Reported speeds at the time of ambulance collisions were found to generally be below 65 km/h (Biggers et al., 1996). A retrospective, cross-sectional, and largely descriptive study noted that all 8 fatal and 529 (out of 707) nonfatal ambulance collisions happened on urban roads (P.-W. Chiu et al., 2018). Furthermore, 5 fatal and 463 (out of 707) nonfatal collisions happened at four-point intersections.

Regarding temporal factors, an association can be made between the time of day(s) of the week and the incidence of emergency vehicle collisions, most studies found that a significant number of collisions take place in the evening (16:00 to 20:00) and during daytime (08:00 to 12:00) (P.-W. Chiu et al., 2018; Drucker, 2013; Lai et al., 2018). Also, it is reported that almost 33% of all collisions occurred on a Friday (Biggers et al., 1996).

When examining the significance of collision types, collisions frequently occur at an angled position at intersections: a pattern observed in both non-emergency and emergency medical vehicles, with a higher frequency noted for the latter (Kahn, Pirrallo, & Kuhn, 2001c). In this regard, forward (33.3%), stationary (20.7%), turning (17.7%), and going in reverse (11.1%) are the first four types of movement for ambulances at the time of the collisions (C. E. Saunders & Heye, 1994). In addition, the T-bone mechanism (OR of 29.7, $p<0.05$), responsible for a significant number of intersection collisions is a highly frequent type of ambulance crash (Custalow & Gravitz, 2004).

Medical conditions, mental health, and the psychosocial work environment are associated with the safety of professional drivers (e.g., emergency drivers) (Noonan, Ryan, Whelan, & O’Neill, 2023; Useche, Ortiz, & Cendales, 2017). While limited information exists regarding connections between medical conditions, health status, and the potential contribution to heightened crash risks for emergency drivers, a narrative review suggests mandating specific levels of medical fitness to drive, mirroring the emphasis on the significance of medical fitness for these vehicles (Noonan et al., 2023). Studies focusing on bus rapid transport (BRT) and long-haul truck drivers have extensively investigated stress-related psychosocial factors, including stress-related work conditions, and their correlation with risky driving behaviors (Useche, Alonso, Cendales, & Llamazares, 2021; Useche et al., 2017). These studies also examine whether fatigue acts as a mediating mechanism between stress-related factors and risky driving behaviors. The findings of these investigations have shown the association between stress-related working conditions, fatigue related to work conditions and risky driving behaviors. Moreover, the intersection of work stress, health issues, and safety outcomes for professional drivers has been identified as a hazardous combination (Useche, Cendales, Montoro, & Esteban, 2018). The results underscore that stress is linked to professional drivers' mental health, traffic accidents and fines.

The current study highlights an understanding of work-related motor collisions among paramedics, particularly highlighting the substantial occupational risk associated with driving. The examination of ambulance collisions, both injury and non-injury, across 17 administrative regions in the province of Quebec, along with an analysis of explanatory variables influencing odds ratios of collision severity in regions including Montréal and Montérégie, provides unique insights. This includes an assessment of geographical distribution based on population density in this province.

Moreover, while previous studies have delved into factors contributing to fatal and serious injuries in work-related crashes at the municipal or regional level (Pirrallo & Swor, 1994; T. L. Sanddal et al., 2010; C. E. Saunders & Heye, 1994), our study provides a nuanced perspective from previous literature by studying new variables including surface and weather conditions, work zone, and asphalt conditions. This study focuses on the different impact of environmental, road, and collision characteristics specifically on the collisions' severity between ambulances and general vehicles at a provincial level in Canada.

3.2 Method

3.2.1 Data Collection

For the current project, ambulance, and general vehicle collision data from the Société de l'assurance Automobile du Québec (SAAQ) were used, covering a period from 2010 to 2020 for 17 administrative Quebec regions. A general vehicle is defined as any type of motor vehicle, except for emergency vehicles. In Quebec, the SAAQ is responsible for issuing driver's licenses and vehicle registrations (Société de l'assurance automobile du Québec, 2020a). It is a source of detailed crash data for all surface transportation modes in the province through its role of administering Québec's public automobile insurance plan by compensating road collision victims and setting insurance contributions.

The dataset provided by the SAAQ includes three primary factors: collision, environment, and weather characteristics (refer to Table 1.1). Collision severity is categorized into three classes: fatal, injury, and damage or non-injury (Chapman & Underwood, 1998; C. Chen et al., 2015; Chiou & Fu, 2015; Garber & Ehrhart, 2000). In the present study, this distinction was made during the descriptive analysis. However, when it came to statistical modeling, all fatalities and injuries (regardless of severity) were combined into a single category. This decision was influenced by the fact that there were only five instances of traffic fatalities resulting from ambulance collisions throughout the 11 years of available data. The term injury/fatality refers to a collision where either civilians or paramedics are injured/killed.

Table 3.3 Crash, environment, and road and traffic characteristics

Collision Characteristic	Environmental Characteristic	Weather Characteristic
Time of day	Type of environment	Weather conditions
Days of week	Lighting conditions	
Number of vehicles involved in collision	Traffic conditions	
Collision Type	Work zone	
Mode of transportation involved in collision	Location of collision	
	Asphalt conditions	
	Speed limit zones	
	Road configuration	
	Surface state	

3.2.2 Statistical Analysis

3.2.2.1 Trend Analysis

In this study, a paired t-test was employed to assess the disparities in averages between the first, middle, and last three years of ambulance and general vehicle collisions. This approach aimed to examine the trends and fluctuations throughout the study period. It is not possible to split the data into periods of 4 years due to an 11-year time span. The null hypothesis of the paired t-test showed no significant difference in the mean, with a 95% confidence interval of 2 sets of data (Boston University of Public Health, 2016). Furthermore, the Mann-Kendall (MK) test and regression with a piecewise linear function for the time were utilized as a nonparametric approach to determine the presence of a statistically significant monotonic trend in the time series data at a 5% significance level. (McLeod, 2005; Yannis, Antoniou, Papadimitriou, & Katsochis, 2011).

3.2.2.2 Logit model

A multiple logit model was developed to explore the impact of factors and relevant levels in the odds ratio of paramedic collision severity (injury vs. non-injury) in Quebec. A literature review (C. Chen et al., 2015) and the cumulative scatter plot of the data were used to determine the appropriate boundary to classify

the dependent variable. In this case, a binary response variable, including injury and non-injury collisions, was used in the logit model. The fatality collision will be explained only in descriptive tables and is not included in the logit regression, since the number of these cases (5 collisions) was concluded to being non-sufficient in the multiple logit model.
The current logit model is utilized to model the effect of explanatory variables on the odds ratio of ambulance injury collisions. The odds ratio can be interpreted as the probability of an event occurring when the factor of interest is present, divided by the probability when the factor is not present. In addition, the logit model can be a statistical methodology to investigate crash severity. For instance, Dong et al. investigated the differences in single-vehicle and multi-vehicle collision probability using a mixed logit model (Dong, Ma, Chen, & Chen, 2018). In addition, Chen et al. studied collision data involving trucks on a rural highway to evaluate the difference in driver-injury severity between single- and multi-vehicle collisions by using mixed logit models (C. Chen et al., 2015). The linear relationship between the explanatory variables and a binary response variable, including injury and non-injury collision, can be written in the following equation where ℓ refers to log-odds, X_i refers to independent variables and βare coefficients of the parameters of the logit model (Ma, Shao, Yue, & Ma, 2009):

$$\ell = Log\frac{P}{1-P} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \qquad (1)$$

The model is prepared using the training dataset, which includes 70% of the total data, leaving the remaining 30% for testing. One of the main steps is the variable selection to use in logit regression. The current study used cross-correlation and a variance inflation factor (VIF) to check the multicollinearity. VIF values above 5 indicate severe multicollinearity. So, if none of the explanatory variables in our models have a VIF over 5, it is assumed that multicollinearity is not an issue in our model. The existence of collinearity between variables rejects the assumption of independence. In the context of regression models, the estimation of parameters plays a key role in interpreting the model. This process is fundamental for understanding the relationships within the model. In these models, it is possible to estimate the parameters despite collinearity, but the standard error will be inflated. Consequently, small changes in the data will cause significant changes in the results (unstable model), making it impossible to understand the importance and impact of each variable (Dormann et al., 2013).
The performance of the final model, after building a logit model, was evaluated by using the number of true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN), as four common statistical measurements for classification tests. For this purpose, TP and TN measure the number of actual positives and negatives that are correctly classified for the injury severity. On the other hand, FP defines the number of the estimated instances that are incorrectly classified as positive when negative, or FN defines the number of the estimated instances that are incorrectly classified as negative when positive. From these measurements, we can estimate the model's accuracy, sensitivity, and specificity (Ma et al., 2009).
A Receiver Operating Characteristic (ROC) curve is a graph that shows the performance of a classification model at all response thresholds. This graph is produced by plotting the TP-rates (y-axis) versus the FP-rates (x-axis) (Markham, 2014). The ROC curve is an important indicator of the overall performance of the logit regression, which generally shows whether the true positive rate is higher than the false-positive rate. Area Under Curve of ROC Curve (AUC-ROC) shows the relationship between sensitivity and specificity. This value is used to describe the overall performance of a classification model, in a range between 0 and 1,

where values close to 1 represent an accurate classification and values less than 0.5 are not acceptable (Mujalli, López, & Garach, 2016; Provost & Domingos, 2000).

3.3 Results

3.3.1 Data Descriptive

The data provided by the SAAQ contains 1,228 ambulance collisions (including 5 fatalities, 365 injuries, and 858 non-injury collisions) spanning from 2010 to 2020. The overall trends of injury and non-injury collisions (black and blue colors) are visible in Figure 3.1. This figure shows the ambulance and general vehicle injury and non-injury collisions over 11 years (2010-2020). The overall trend for all collision types is decreasing, while there are some fluctuations, particularly for ambulance collisions over the studied period.

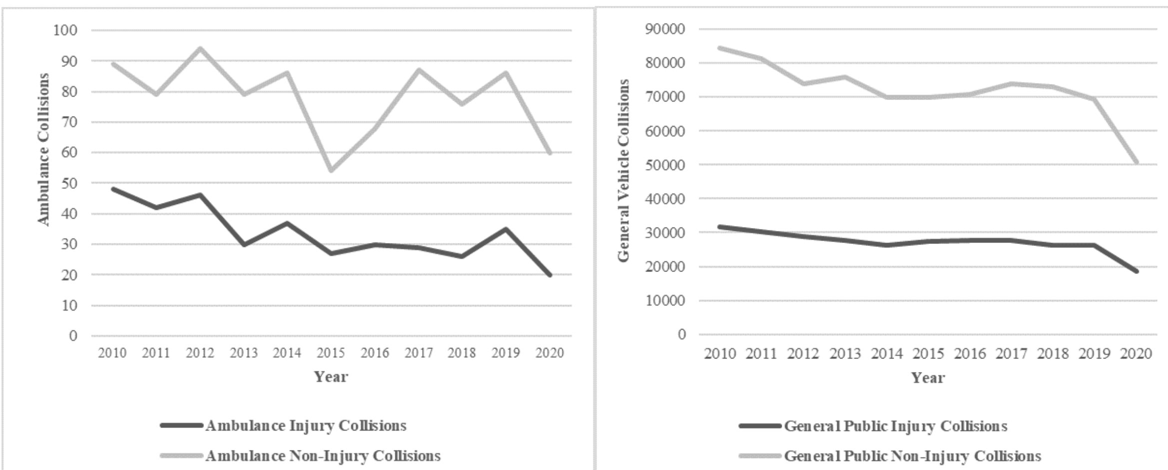


Figure 3.6a. The overall trend of injury and non-injury collisions for ambulances (left) and figure 1b. the overall trend of injury and non-injury collisions for general vehicles (right) in Quebec

The results of the Mann-Kendall test show that all collision types have a decreasing trend (p-value: <0.05) except non-injury ambulance collisions (p-value: 0.21). The findings from the piecewise linear regression analysis substantiate the significance of the coefficients associated with reducing slopes (p-values < 0.01), except for non-injury ambulance collisions (p-value: 0.206). Furthermore, the paired t-test results for the difference in collision mean of the first and middle three years (p-value: 0.14) as well as the middle and last 3 years of non-collisions for ambulances (p-value: 0.77) confirm the non-decreasing trend.

Figures 3.2 and 3.3 show the distribution of fatality, injury, and non-injury collisions according to the days of the week and hours of the day. There is a higher number of collisions for all transportation modes recorded on Fridays compared to other days, except for ambulance fatality collisions where 40% (n=2) of them happened on Tuesdays. The number of collisions is higher for both ambulances and general vehicles between 12:00 and 15:59 compared to other periods of the day, except for fatality collisions in ambulances and injury collisions in general vehicles. In this regard, the highest record of injury collisions for general vehicles happened from 16:00 to 19:59. Furthermore, two fatal collisions accounting for 40% of the total occurred between 04:00 and 07:59, and an additional two fatal collisions (also representing 40% of the total) occurred between 16:00 and 19:59. Note that the full-color version of the following figures is available online.

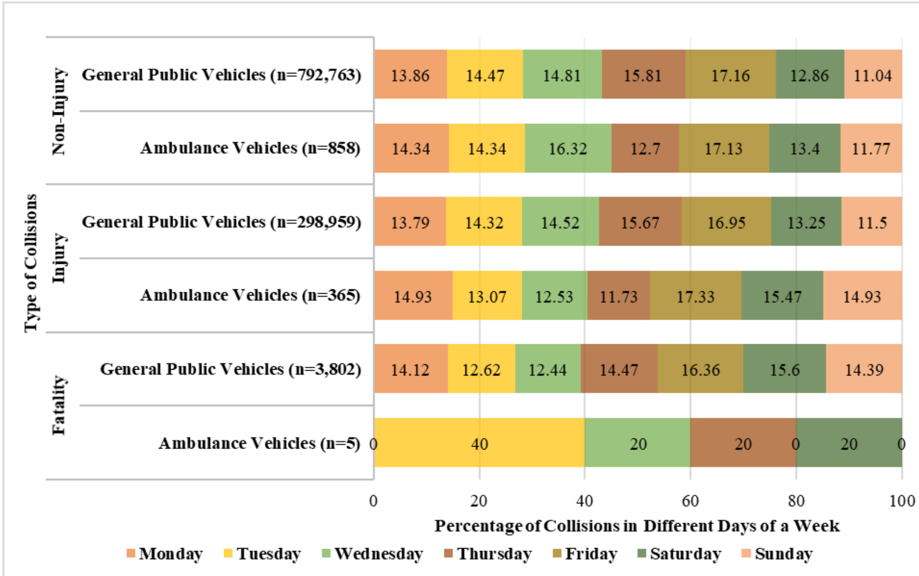


Figure 3.7. Day of the collisions with non-injury, injury, and fatality

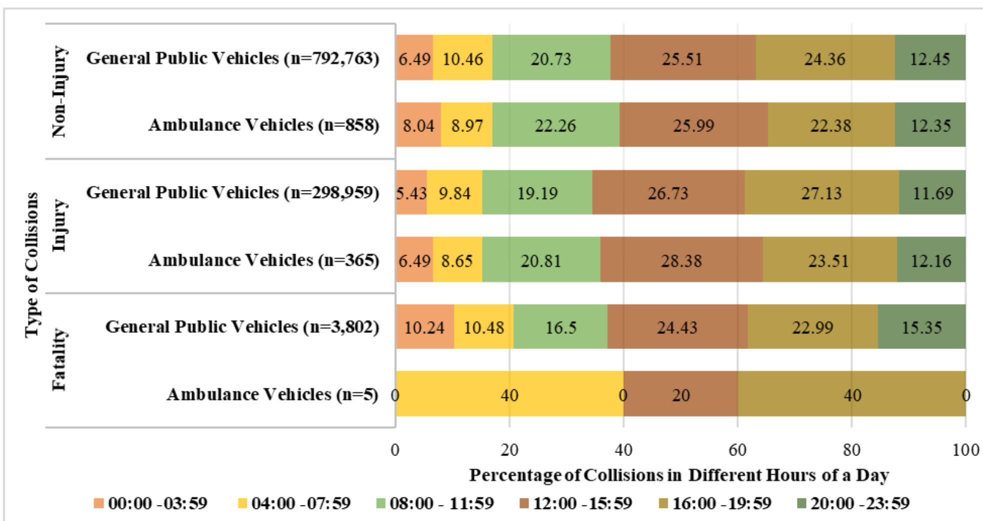
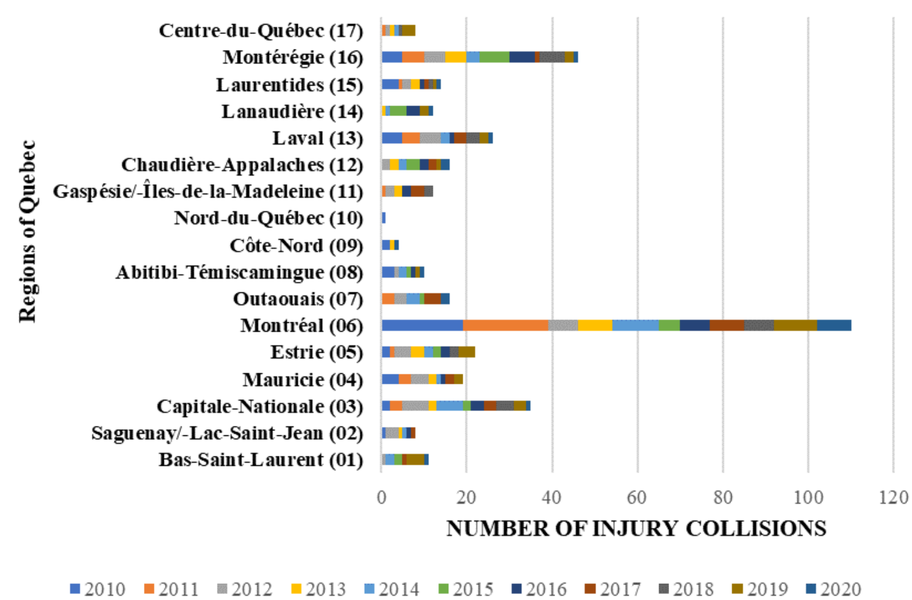


Figure 3.8. Hour of the collisions with non-injury, injury, and fatality

Figures 3.4 (a) and 3.4 (b) show the absolute number of injury/non-injury ambulance collisions in 17 regions of Quebec between 2010 and 2020. Regarding ambulance collision frequency, Montréal (injury:110, non-injury:323), Montérégie (injury:46, non-injury:107), and Capitale-Nationale (injury:35, non-injury:72) are the top 3 regions. Considering the incidence of collisions per 100,000 population, Montréal ranks 6th and has 5.66 injury collisions per 100,000 population, based on Figure 3.5 (a). To that extent, Gaspésie-Îles-de-la-Madeleine (13.29) and Nord du Québec (2.24) have the highest and lowest incidence of injury collisions, respectively. Also, Figure 3.5 (b) shows that Montréal (16.58) and Côte-Nord (16.22) have the highest incidence of non-injury collisions per 100,000 people, while Nord du Québec (0) and Laval (6.15) have the lowest rates. Note that the full-color version of the following figures is available online.



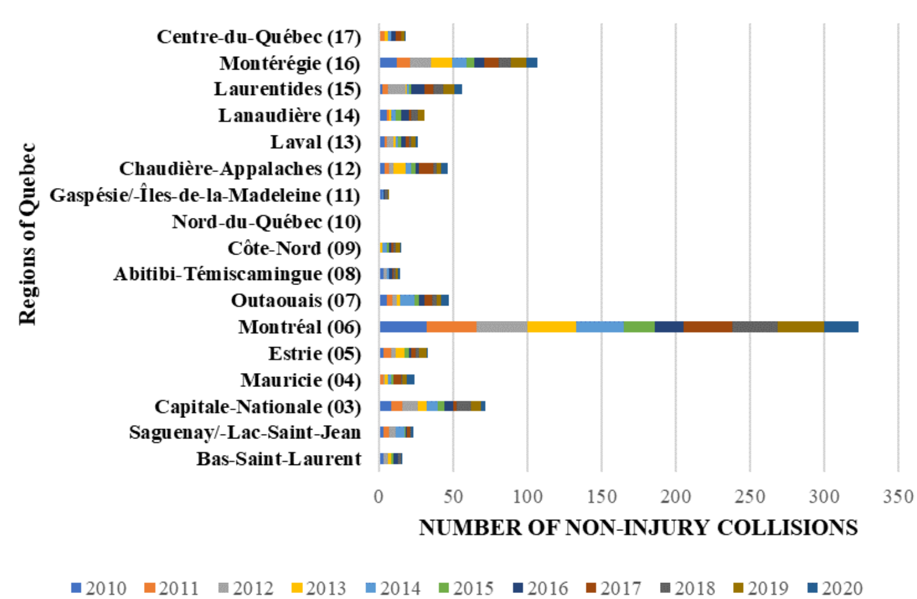


Figure 3.9. Number of injury (upper) and non-injury (lower) paramedics' collisions in Quebec between 2010 and 2020 per administrative region

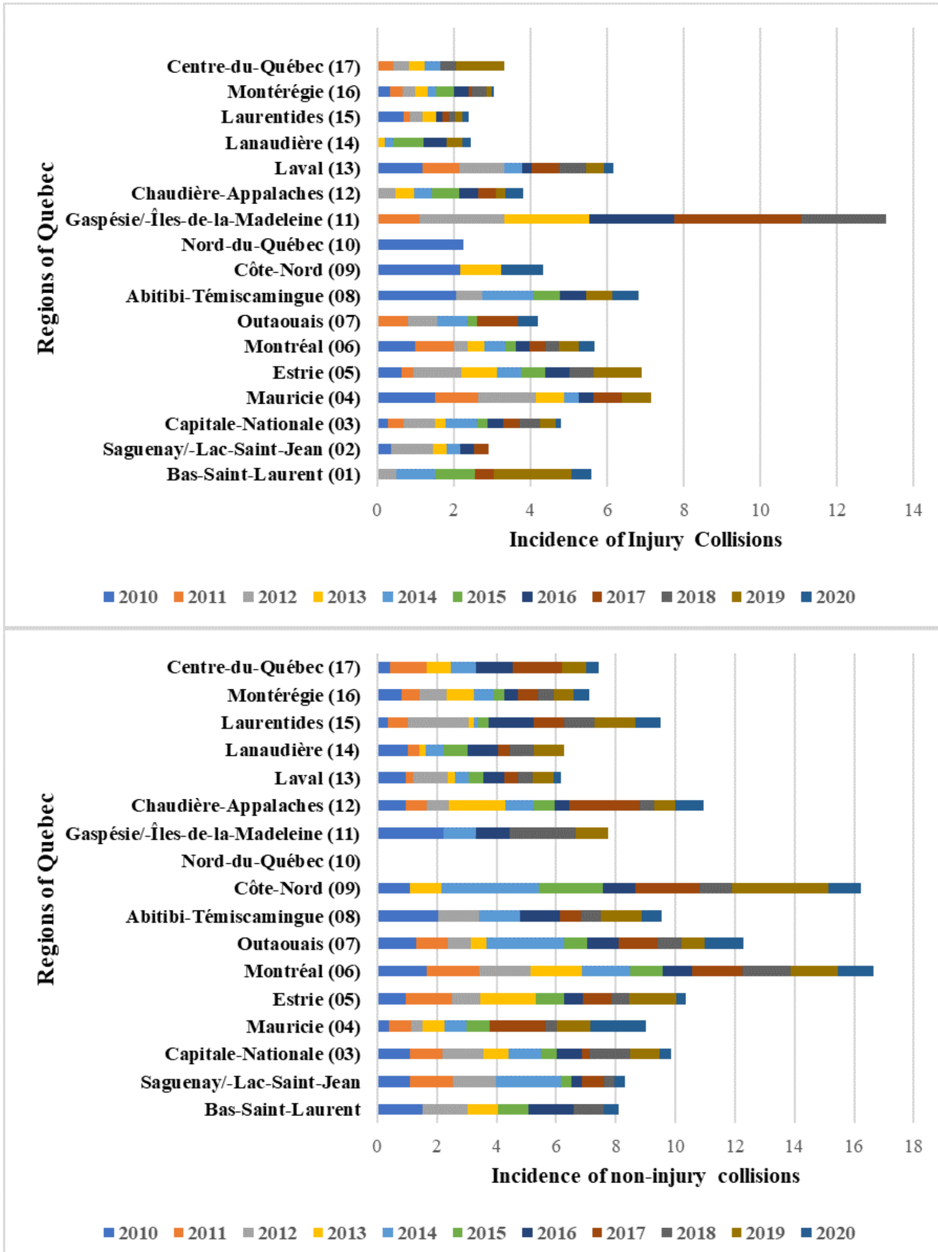


Figure 3.10. Incidents of injury (upper) and non-injury (lower) collisions for paramedics' collisions in Quebec between 2010 and 2020 per administrative region

The results of the paired t-test on injury and non-injury ambulance collisions are presented in Tables 3.2 and 3.3. These tables also show the difference in collision means between the first and last three years of the studied period with a 95% confidence interval. Accordingly, no region in Quebec experienced a significant change in collisions, except Saguenay-Lac-Saint-Jean with three fewer non-injury collisions (P-value: 0.035, CI: [-0.52, -5.48]). In addition, a paired t-test shows that differences in the injury collisions for ambulances (P-values: 0.087, CI: [6.55, -43.22]) and the general vehicles (P-values: 0.076, CI: [1.65, -14.51]) are not significant across the province of Quebec. The same is observed for the means of non-injury ambulance collisions (P-values: 0.3770, CI: [37.60, -64.26]) and general vehicle collisions (P-values: 0.056, CI: [0.99, -31.94]).

Figure 3.6 also shows the difference in the average of ambulance injury collisions, with 95% CI for 17 regions. None of the regions had a negative value for both the upper and lower bounds of 95% CI.

Table 3.4. Statistical Analysis of the difference in injury collisions mean, between the first (2010-12) and last three years (2018-2020)

Region	t-value	P-value	The difference between Injury Collisions mean	95% confidence interval
Bas-Saint-Laurent (01)	1.512	0.270	1.33	[5.13, -2.46]
Saguenay/-Lac-Saint-Jean (02)	1.512	0.270	-1.33	[2.46, -5.13]
Capitale-Nationale (03)	0.480	0.679	-1	[7.96, -9.96]
Mauricie (04)	3.000	0.095	-3	[1.30, -7.30]
Estrie (05)	0.164	0.884	-0.33	[8.39, -9.06]
Montréal (06)	1.732	0.225	-7	[10.39, -24.39]
Outaouais (07)	1.512	0.270	-1.33	[2.46, -5.13]
Abitibi-Témiscamingue (08)	0.555	0.635	-0.67	[4.50, -5.84]
Côte-Nord (09)	1.000	0.423	-0.33	[1.10, -1.77]
Gaspésie/-Îles-de-la-Madeleine (11)	0.277	0.808	-0.33	[4.84, -5.50]
Chaudière-Appalaches (12)	1.000	0.423	0.33	[1.77, -1.10]
Laval (13)	4.000	0.058	-2.67	[0.20, -5.54]
Lanaudière (14)	1.732	0.225	1	[3.48, -1.48]
Laurentides (15)	1.512	0.270	-1.33	[2.46, -5.13]

Montérégie (16)	1.309	0.321	-2	[4.57, -8.57]
Centre-du-Québec (17)	0.756	0.529	0.67	[4.46, -3.13]
Quebec Province	3.170	0.087	-18.33	[6.55, -43.22]

Table 3.5. Statistical Analysis of the difference in non-injury collisions means, between the first and last three years

Region	t-value	P-value	The difference between non-Injury Collisions mean	95% confidence interval
Bas-Saint-Laurent (01)	1.732	0.225	-1	[1.48, -3.48]
Saguenay/-Lac-Saint-Jean (02)	5.196	0.035	-3	[-0.52, -5.48]
Capitale-Nationale (03)	0.756	0.529	-2	[9.38, -13.38]
Mauricie (04)	1.387	0.3000	1.67	[6.84, -3.50]
Estrie (05)	1.732	0.225	-1	[1.48, -3.48]
Montréal (06)	1.637	0.243	-5	[8.14, -18.14]
Outaouais (07)	0.277	0.807	-0.33	[4.84, -5.50]
Abitibi-Témiscamingue (08)	0.277	0.807	-0.33	[4.84, -5.50]
Côte-Nord (09)	1.512	0.270	1.33	[5.13, -2.46]
Gaspésie/-Îles-de-la-Madeleine (11)	1.000	0.427	0.33	[1.77, -1.10]
Chaudière-Appalaches (12)	0.378	0.742	-0.33	[3.46, -4.13]
Laval (13)	0.756	0.529	-1.33	[6.26, -8.92]
Lanaudière (14)	0.555	0.635	0.67	[5.84, -4.50]
Laurentides (15)	0.091	0.936	0.33	[16.11, -15.44]

Montérégie (16)	1.443	0.286	-3	[5.96, -11.96]
Centre-du-Québec (17)	0.500	0.667	-0.33	[2.54, -3.20]
Quebec Province	1.126	0.377	-13.33	[37.60, 64.26]

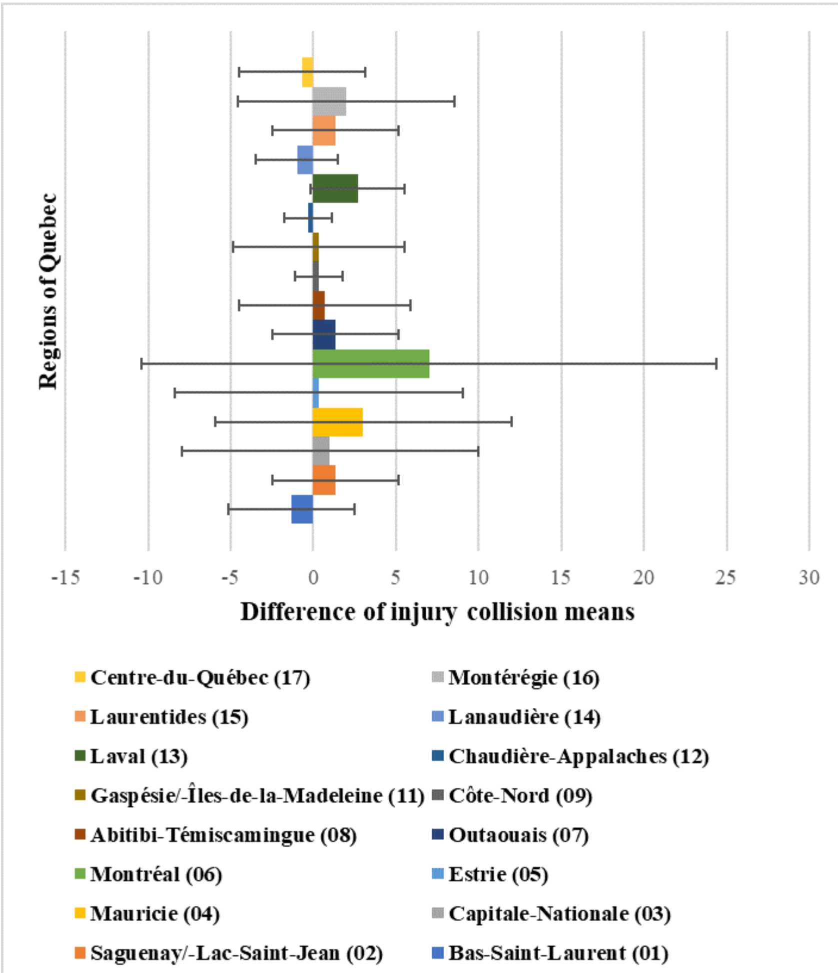


Figure 3.11. Statistical Analysis of the difference in injury collisions mean, between the first and last three years

Figures 3.5 and 3.6 show the distribution of fatality, injury, and non-injury collisions according to the days of the week and hours of the day. There is a higher number of collisions for all transportation modes recorded on Fridays compared to other days, except for ambulance fatality collisions where 40% (n=2) of them happened on Tuesdays. The number of collisions for all modes is higher between 12:00 and 15:59 compared to the rest of the day, except for fatality collisions in ambulances and injury collisions in general vehicles. In this regard, the highest record of injury collisions for general vehicles happened from 16:00 to 19:59. Furthermore, 80% of ambulance fatality collisions (n=4) happened between 04:00 and 07:59 and 16:00 and 19:59. Note that the full colour version of the following figures is available online.

Table 3.6 presents the distribution of non-injury and injury collisions for both ambulance and general vehicles among collisions, environmental, and weather characteristics. Fatality collisions are only addressed for general vehicles since there is no record of traffic fatalities for ambulances in the studied period.

There is a high frequency of ambulance and general vehicle injury collisions with light vehicles (75.62%, 79.34%, respectively) and two-wheelers (i.e. bicycles and motorcycles) (17.53%, 12.54%, respectively). This trend is also found for non-injury ambulance collisions (light vehicles (78.79%) as well as bicycles and motorcycles (15.38%)) but not for non-injury collisions involving general vehicles (light vehicles (79.74%) and heavy vehicles (11.75%)). Furthermore, light vehicles are involved in 80% (n=4), and 66.01% (n=2509) of fatality collisions for ambulances and general vehicles, respectively.

Concerning environmental factors (see to Table 3.4 for additional details), collisions involving ambulances were most prevalent in commercial areas, accounting for 48% of non-injury collisions and 49.86% of injury collisions, as well as in residential areas, where they constituted 25.94% of non-injury collisions and 22.19% of injury collisions. Similarly, collisions involving general vehicles were prominently observed in commercial areas, representing 40% of non-injury collisions and 39.13% of injury collisions, and in rural areas, comprising 26.63% of non-injury collisions and 29.05% of injury collisions. These locations stand out as the primary settings for collisions in Quebec. Furthermore, most of the fatal collisions involving ambulances (60% of the total) and general vehicles (57% of the total) happened in rural areas.

Moreover, the highest percentage of ambulance injury (55.62%) and non-injury (38.34%) collisions occurred less than five meters from an intersection. This happens for injury collisions (38.35%) of general vehicles, whereas more non-injury collisions are recorded between intersections (100 meters and above) compared to other locations. In addition, 60% of fatal collisions for ambulances and 51.32% for general vehicles are recorded between intersections (100 meters and above).

The posted speed limit variable shows that there is a high number of collisions in zones of 50 km/h speed limit zones (48.05%) compared to other zones. Almost 60% (n=3) and 46% (n=1,748) of all traffic fatalities for ambulances and general vehicles, respectively, happened in 90 or 100 km/h speed limit zones.

Road configuration data shows that one-way roads have fewer collisions than two-way roads without a median divider. Focusing on two-way roads, having at least one extra lane can lead to a decrease in non-injury and injury collisions by 26.08% and 23.18%, respectively, for general vehicles, and a 6.41% reduction in non-injury collisions for ambulances. Fatal collisions for both ambulances and general vehicles occur more commonly on two-way roads with one lane per direction (4 and 2,436 cases, respectively). Regarding light conditions, more than 63% of all collisions happened in daylight and clear conditions, and approximately 20% happened at night on well-lit roads.

Eight hundred and fifty-one (851) ambulance collisions occurred on roads with poor asphalt conditions, accounting for 69.3% of the ambulance collisions, such as construction zones. In this regard, 94.99% of this number belongs to non-injury collisions, while only 9.86% of injury and all fatality collisions happened during such asphalt conditions. Furthermore, 93.21% of injuries and 92.79% of fatal general vehicle collisions happened during good asphalt conditions.

Most ambulance collisions occurred on dry (53.42%) and wet (18.49%) surfaces, while snowy (11.32%) and icy (6.68%) surfaces represented a minor proportion. The percentage of total ambulance collisions that occurred in clear (56.35%) and cloudy (15.64%) weather is higher than in other conditions. These trends are similar for general vehicles.

Table 3.6. Characteristics of Ambulance vs. General Vehicle Collisions

Variable	Category	Level	Non-injury		Injury		Mortality	
			Ambulance Vehicles	General Vehicles	Ambulance Vehicles	General Vehicles*	Ambulance Vehicles	General Vehicles
			(n=858)	(n=792,763)	(n=365)	(n=298,959)	(n=5)	(n=3,802)
Collision Characteristics	Number of vehicles	1	107 (12.47%)	245250 (30.94%)	62 (16.99%)	112419 (37.6%)	0 (0%)	1818 (47.82%)
		2	685 (79.84%)	493341 (62.23%)	260 (71.23%)	157090 (52.55%)	3 (60%)	1587 (41.74%)
		3	53 (6.18%)	40379 (5.09%)	30 (8.22%)	23116 (7.73%)	2 (40%)	284 (7.47%)
		4 or more	13 (1.52%)	13793 (1.74%)	13 (3.56%)	6334 (2.12%)	0 (0%)	113 (2.97%)
	Mode of transportation	Light vehicles	676 (78.79%)	632,149 (79.74%)	276 (75.62%)	237,194 (79.34%)	4 (80%)	2509 (66.01%)
		Heavy vehicles	0 (0%)	93,150 (11.75%)	12 (3.29%)	22,243 (7.44%)	0 (0%)	662 (17.42%)
		Bicycle and Motorcycle	132 (15.38%)	4,836 (0.61%)	64 (17.53%)	37,489 (12.54%)	1 (20%)	584 (15.35%)
		Others and unknown	50 (5.83%)	62,628 (7.9%)	13 (3.56%)	2,063 (0.69%)	0 (0%)	46 (1.22%)
	Collision type	Collision with road vehicle	700 (81.59%)	504,435 (63.63%)	276 (75.62%)	159,764 (53.44%)	5 (100%)	1636 (43.06%)
		Fixed object collisions	48 (5.59%)	123,592 (15.59%)	16 (4.38%)	39,253 (13.13%)	0 (0%)	643 (16.93%)

		Collisions with animals	43 (5.01%)	62,073 (7.83%)	1 (0.27%)	4,036 (1.35%)	0 (0%)	45 (1.18%)
		Without collisions (fire etc.)	19 (2.21%)	66,116 (8.34%)	38 (10.41%)	45,502 (15.22%)	0 (0%)	640 (16.85%)
		Collisions with pedestrians, bicycles, and trains	0 (0%)	1,110 (0.14%)	18 (4.93%)	44,395 (14.85%)	0 (0%)	764 (20.11%)
		Others and unknown	48 (5.59%)	35,437 (4.47%)	16 (4.38%)	5,979 (2%)	0 (0%)	71 (1.87%)
Environment (road and traffic) Characteristics	Environment	School	5 (0.59%)	10783 (1.36%)	3 (0.82%)	4633 (1.55%)	0 (0%)	24 (0.63%)
		Residential	221 (25.94%)	187152 (23.61%)	81 (22.19%)	74033 (24.76%)	0 (0%)	671 (17.65%)
		Commercial	409 (48%)	317103 (40%)	182 (49.86%)	116983 (39.13%)	2 (40%)	669 (17.6%)
		Industrial	28 (3.29%)	24169 (3.05%)	6 (1.64%)	8754 (2.93%)	0 (0%)	75 (1.97%)
		Rural	146 (17.14%)	211120 (26.63%)	78 (21.37%)	86845 (29.05%)	3 (60%)	2168 (57.02%)
		Recreational, and unknown	43 (5.05%)	42436 (5.35%)	13 (3.56%)	7711 (2.58%)	0 (0%)	195 (5.13%)
	Speed limit zones	40 km/h and bellow	64 (7.47%)	41526 (5.24%)	17 (4.66%)	16558 (5.54%)	0 (0%)	112 (2.95%)
		50 km/h	386 (45.04%)	290173 (36.6%)	203 (55.62%)	131676 (44.04%)	1 (20%)	786 (20.67%)
		60,70, and 80 km/h	108 (12.6%)	117604 (14.83%)	51 (13.97%)	52726 (17.64%)	0 (0%)	855 (22.49%)
		90, and 100 km/h	128 (14.94%)	182167 (22.98%)	62 (16.99%)	66203 (22.14%)	3 (60%)	1748 (45.98%)

	unknown	171 (19.95%)	161293 (20.35%)	32 (8.77%)	31796 (10.64%)	1 (20%)	301 (7.92%)
Road Configuration	One-way	144 (16.78%)	89929 (11.34%)	30 (8.22%)	27703 (9.27%)	0 (0%)	191 (5.02%)
	Two-way, one lane per direction	276 (32.17%)	333168 (42.03%)	129 (35.34%)	139532 (46.67%)	4 (80%)	2436 (64.07%)
	Two-way, more than one lane per direction	221 (25.76%)	126428 (15.95%)	131 (35.89%)	70237 (23.49%)	1 (20%)	530 (13.94%)
	Separated by passable layout	40 (4.66%)	37253 (4.7%)	17 (4.66%)	15701 (5.25%)	0 (0%)	186 (4.89%)
	Separated by impassable layout	83 (9.67%)	86721 (10.94%)	33 (9.04%)	27706 (9.27%)	0 (0%)	204 (5.37%)
	Others (ex.: two-way left turn lane) and unknown	94 (10.96%)	119264 (15.04%)	25 (6.85%)	18080 (6.05%)	0 (0%)	255 (6.71%)
Traffic Position	Traffic way	35 (3.98%)	36638 (4.62%)	275 (75.34%)	221119 (73.96%)	3 (60%)	2729 (71.78%)
	Others (ex.: reserved lane, slow lane/passing lane, left turn lane in both directions)	3 (0.34%)	6936 (0.87%)	18 (4.93%)	33629 (11.25%)	2 (40%)	472 (12.41%)
	unknown	841 (95.68%)	749189 (94.5%)	51 (13.97%)	44211 (14.79%)	0 (0%)	601 (15.81%)
Work Zone	Near work zone	8 (0.93%)	6107 (0.77%)	4 (1.1%)	2498 (0.84%)	0 (0%)	26 (0.68%)
	Work zone	20 (2.33%)	13617 (1.72%)	8 (2.19%)	4719 (1.58%)	0 (0%)	51 (1.34%)

	Without work zone and unknown	830 (96.74%)	773039 (97.51%)	353 (96.71%)	291742 (97.59%)	5 (100%)	3725 (97.97%)
Lighting Condition	Daylight and clear (clarity)	548 (63.87%)	503570 (63.52%)	247 (67.67%)	205475 (68.73%)	5 (100%)	2284 (60.07%)
	Day and semi-darkness	40 (4.66%)	41030 (5.18%)	12 (3.29%)	14591 (4.88%)	0 (0%)	165 (4.34%)
	Night and lighted Path	205 (23.89%)	162041 (20.44%)	88 (24.11%)	56108 (18.77%)	0 (0%)	628 (16.52%)
	Night and unlighted path	55 (6.41%)	68985 (8.7%)	15 (4.11%)	20969 (7.01%)	0 (0%)	700 (18.41%)
	Unknown	10 (1.17%)	17137 (2.16%)	3 (0.82%)	1816 (0.61%)	0 (0%)	25 (0.66%)
Collision Location	Between intersections (100 meters and more)	239 (27.86%)	285886 (36.06%)	86 (23.56%)	101061 (33.8%)	3 (60%)	1951 (51.32%)
	At an Intersection (less than 5 meters)	329 (38.34%)	194201 (24.5%)	203 (55.62%)	114649 (38.35%)	0 (0%)	809 (21.28%)
	Near an intersection, roundabout	129 (15.03%)	108079 (13.63%)	30 (8.22%)	39637 (13.26%)	1 (20%)	375 (9.86%)
	Others (railway crossing, bridge, tunnel, shopping center and unknown	161 (18.76%)	204597 (25.81%)	46 (12.6%)	43612 (14.59%)	1 (20%)	667 (17.54%)
Asphalt Condition	Good condition	43 (5.01%)	47994 (6.05%)	329 (90.14%)	278669 (93.21%)	5 (100%)	3528 (92.79%)

		Poor condition and unknown	815 (94.99%)	744769 (93.95%)	36 (9.86%)	20290 (6.79%)	0 (0%)	274 (7.21%)
Weather Characteristics	Surface Condition	Dry	465 (54.2%)	435125 (54.89%)	188 (51.51%)	188230 (62.96%)	3 (60%)	2511 (66.04%)
		Wet	149 (17.37%)	133606 (16.85%)	77 (21.1%)	51082 (17.09%)	1 (20%)	550 (14.47%)
		Slush	22 (2.56)	19362 (2.44%)	13 (3.56%)	6698 (2.24%)	0 (0%)	100 (2.63%)
		Snowy	109 (12.7%)	93242 (11.76%)	30 (8.22%)	21694 (7.26%)	0 (0%)	194 (5.1%)
		Hard snow	12 (1.4%)	18714 (2.36%)	8 (2.19%)	4021 (1.35%)	0 (0%)	55 (1.45%)
		Ice	51 (5.94%)	47006 (5.93%)	30 (8.22%)	15944 (5.33%)	1 (20%)	205 (5.39%)
		Others and unknown	50 (5.83%)	45708 (5.77%)	19 (5.21%)	11290 (3.78%)	0 (0%)	187 (4.92%)
	Weather Condition	Clear	497 (57.93%)	426644 (53.82%)	192 (52.6%)	179621 (60.08%)	3 (60%)	2257 (59.36%)
		Cloudy and dark	132 (15.38%)	166060 (20.95%)	59 (16.16%)	55971 (18.72%)	1 (20%)	786 (20.67%)
		Rain/drizzle and heavy rain	61 (7.11%)	63316 (7.99%)	42 (11.51%)	26774 (8.96%)	0 (0%)	290 (7.63%)
		Snow	85 (9.91%)	68485 (8.64%)	32 (8.77%)	19661 (6.58%)	0 (0%)	213 (5.6%)
		Snowstorm	27 (3.15%)	17875 (2.25%)	14 (3.84%)	5498 (1.84%)	0 (0%)	74 (1.95%)
		Black ice	5 (0.58%)	4895 (0.62%)	7 (1.92%)	1622 (0.54%)	1 (20%)	19 (0.5%)
		Fog, strong wind, others, and unknown	51 (5.94%)	45488 (5.74%)	19 (5.21%)	9812 (3.28%)	0 (0%)	163 (4.29%)

*All transportation modes except emergency vehicles

3.3.2 Results of Logit Models

The effect of explanatory factors and their corresponding levels on the odds of collision severity was analyzed with logit regression. Table 3.5 shows the result of multivariate binary logistic regression which is used to estimate the effect of different levels of explanatory variables on the odds of collision severity in the province of Quebec. The model reveals that non-traffic incidents, such as involvement in a fire, are associated with a 1.53-fold increase in the odds of collision severity (p-value < 0.01). Additionally, in locations such as railway crossings, bridges, tunnels, and shopping centers, there is a notable increase in the odds ratio of collision severity by 3.64 (p-value: 0.047). The mean error (ME) and mean absolute error (MAE) are 1.02e-09 and 0.11 for the training set, respectively. With a McFadden's R2 value of 0.67, ranging from 0 to just under 1, the indication is that the logit model fits the actual data very well (in practice, values > 0.40 show a good model/data fit) (Jackman, 2020; Le, 2018). Variance inflation factor (VIF) values for this model are no more than 5, which means that there is no multicollinearity in the logit model.

Table 3.7. The effect of the levels of variables on the odds ratio of collision severity, Quebec

Variable	Exp* (Estimate (Log* OR))	SE	z value	p-value	GVIF*
Intercept	9.27	0.46	4.81	1.49e-06*	
Collision type (Ref. Collision with road vehicle)					1.49
Fixed object collisions	2.37	0.62	1.4	0.16	
Collisions with animals	3.61	1.74	-0.59	0.56	
Without collisions (fire etc.)	1.53	0.58	4.69	2.67e-06*	
Collisions with pedestrians, bicycles, and trains	8.11	648.39	0.03	0.98	
Others and unknown	4.95	0.7	-1.00	0.32	
Asphalt condition (Ref. Good condition)					1.27
Poor condition and unknown	4.24	0.33	-16.5	<2e-16*	
Collision location (Ref. Between intersections (100 meters and more))					1.49
At an Intersection (less than 5 meters)	1.32	0.45	0.61	0.55	

Near an intersection, roundabout	4.82	0.58	-1.27	0.21
Others (railway crossing, bridge, tunnel, shopping center and unknown	3.64	0.51	-1.99	0.047*

*Log: Logarithm function, GVIF: generalized variance-inflation factor

*It is statistically significant (p-value <0.05)

The results of logistic regression for modeling the ambulance collisions in Montréal and Montérégie, the two most populated regions in the province of Quebec, are shown in Tables 3.6 and 3.7. It is found that having collisions with fixed objects and non-traffic incidents such as being involved in a fire can increase the odds of having an injury by 23.8 and 137.88 (p-value <0.01), respectively, in Montréal. Collisions at intersections can lead to a 4.48 increase in the odds of having injuries in Montréal (p-value: 0.06). Highway construction or other asphalt-paving operations that create obstacles leading to bottlenecks for road users (which may reduce the overall speed of drivers) can decrease the odds ratio of severe collisions for both the Montréal (0.01) and Montérégie regions (0.003). The results of the model for the Montérégie region show that a slushy surface can result in a 4.24 increase in the odds ratio of collision severity (p-value: 0.06). Moreover, the ME and MAE for these models (Montréal; 3.91e-10, and 0.12, respectively, and Montérégie; -9.91e-10, and 0.10, respectively) show that the predicted values are well fitted to the actual data. Also, there are no VIFs over 5, which means there is no multicollinearity among independent variables in the logit models.

Table 3.8. The effect of the levels of variables on the odds ratio of collision severity, Montreal region

Variable	Exp* (Estimate (Log* OR))	SE	z value	P-value	GVIF*
Intercept	1.73	0.76	0.72	0.47	
Collision type (Ref. Collision with road vehicle)					2.94
Fixed object collisions	23.80	1.00	3.16	0.00*	
Without collisions (fire etc.)	137.88	1.12	4.41	1.02e-05*	
Collisions with pedestrians, bicycles, and trains	3.1e+6	1605.67	0.01	0.99	
Others and unknown	5.47	1.21	1.40	0.16	
Asphalt condition (Ref. Good condition)					1.47

Poor condition and unknown	0.01	0.58	-9.15	<2e-16*	
Collision location (Ref. Between intersections (100 meters and more))					1.67
At an Intersection (less than 5 meters)	4.48	0.78	1.91	0.06	
Near an intersection, roundabout	1.78	0.95	0.61	0.54	
Others (railway crossing, bridge, tunnel, shopping center and unknown	1.14	1.05	0.13	0.9	
Weather condition (Ref. Clear)					2.29
Cloudy and dark	1.06	0.77	0.08	0.94	
Rain/drizzle and heavy rain	2.04	0.91	0.78	0.43	
Snow	0.16	1.05	-1.77	0.08	
Snowstorm	0.13	1.47	-1.41	0.16	
Black ice	2.79E-06	3956.18	-0.00	0.99	
Fog, strong wind, others, and unknown	1.19	1.50	0.11	0.91	

*OR: Odds Ratio, Exp: Exponential function, Log: Logarithm function, GVIF: generalized variance-inflation factor

*It is statistically significant (p-value <0.05)

Table 3.9. The effect of the levels of variables on the odds ratio of collision severity, Montérégie region

Variable	Exp* (Estimate (Log* OR))	SE	z value	P-value	GVIF*
Intercept	13.40	0.77	3.36	0.00*	
Surface condition (Ref. Dry)					1.45

Wet	0.40	1.10	-0.83	0.41	
Slush	14.23	1.42	1.87	0.06	
Snowy	0.20	1.29	-1.24	0.22	
Hard snow	1.78e-06	1697	-0.01	0.99	
Ice	0.21	1.32	-1.18	0.24	
Others and unknown	1.00	2.04	0.00	1.00	
Asphalt condition (Ref. Good condition)					1.45
Poor condition and unknown	0.003	9.55	-6.2	5.74e-10*	

*OR: Odds Ratio, Exp: Exponential function, Log: Logarithm function, GVIF: generalized variance-inflation factor

*It is statistically significant (p-value <0.05)

3.4 Discussion

Although the overall trend of collisions in Quebec decreased from 2010 to 2020, no significant reduction regarding ambulance collisions was found according to literature reporting on the variation of incidence by year (Kahn et al., 2001c). This could be associated with an increase in the number of emergency service calls during the COVID-19 pandemic in Canada, starting in January of 2020 (Canadian institute for health Information, 2022; Ferron, Agarwal, Cooper, & Munkley, 2021). During the studied period, 365 injury cases and 858 non-injury ambulance collisions happened in Quebec, compared to 298,959 injury and 792,763 non-injury collisions for the general vehicles. The number of paramedics' collisions and their incidence per population varied greatly between regions in Quebec. For instance, Montréal and Montérégie, with 5.66 and 3.05 injury collisions per 100,000 population, respectively, were not among the top regions despite them being the two regions with the highest absolute number of injury collisions over the studied period. The results suggest a higher number of collisions for all transportation modes on Fridays, aligning with Biggers et al.'s finding in their research on collisions involving vehicles from the emergency medical services division of the Houston fire department in the U.S. (Biggers et al., 1996). Moreover, ambulance injury and non-injury collisions exhibit a higher frequency during the afternoon hours (12:00 p.m. to 03:59 p.m.), aligning with findings from other studies (P.-W. Chiu et al., 2018; Drucker, 2013; Lai et al., 2018), whereas injury collisions involving general vehicles are more prevalent in the evening (04:00 p.m. to 07:59 p.m.).

The results showed that the percentage of collisions involving another vehicle (81.59% of non-injury and 75.95% of injury collisions) is higher for ambulances than for general vehicles (63.63% of non-injury and 53.44% of injury collisions). Consequently, general vehicles collide with fixed objects more often than ambulances. Kahn et al. (Kahn et al., 2001c) observed the same trend when they studied the characteristics of ambulance collisions occurring on U.S. public roadways and reported to the Fatality Analysis Reporting System (FARS) database from 1987 to 1997. In addition, the mode of transportation of other road users can also impact the prevalence of ambulance collisions (P.-W. Chiu et al., 2018; Pirrallo & Swor, 1994). Among current results, a higher frequency of collisions was observed regarding light vehicles, bicycles, and motorcycles with ambulances in comparison to other transportation modes such as heavy vehicles (which rank second in collisions with general vehicles). This may be due to the elevated occurrence of interactions between light vehicles, bicycles, and motorcycles on the roads, especially in urban areas. Paramedics, serving as first responders, navigate among these transportation modes in urban areas, potentially contributing to the observed disparities in collision involvement.

Moreover, commercial, and residential areas in urban settings are among top locations in which ambulance collisions happen in Quebec. In this context, some studies confirm the observed effect of environmental factors on road safety. For instance, Sanddal et al. (T. L. Sanddal et al., 2010) found that ambulance crash happened in urban areas more than in rural environments (82% vs. 18%, respectively). Similarly, it has been reported that ambulances and other vehicle drivers are more often involved in collisions in urban, rather than in rural settings (S. J. Weiss et al., 2001). This may be due to a notably larger number of vehicles resulting in reduced road space, and therefore, an increased risk of collisions. Nonetheless, it is important to acknowledge the unavailability of data on traffic volume and call numbers in this study.

Intersections were riskier locations for ambulances than for general vehicles. Kahn et al. (Kahn et al., 2001c) concluded that more crashes happened at intersections for ambulances, compared to general vehicles. In addition, intersections can increase the odds of ambulance collision severity due to the nature of the impact in which vehicles coming from two different (or perpendicular) directions cross paths, creating a 'T-bone' effect (Custalow & Gravitz, 2004). It is important to acknowledge the potential contribution of frequent activation of emergency lights and sirens for ambulance vehicles when bypassing of red lights during emergency responses, which may significantly increase the occurrence of severe collisions at intersections (M. Delavary et al., 2023; M. Delavary, Tremblay, & Lavallière, 2024). Areas between intersections were shown to have significantly lower odds of collision severity but a high frequency of collisions involving injuries. This is also supported through a descriptive analysis of both ambulance and general-vehicle collisions which could be associated with the speed variance of vehicles between intersections leading to an increase in the frequency of crashes (Virginia Transportation Research Council, 2008).

Zones with lower speed limits can result in higher numbers of injuries and non-injury collisions, especially for ambulances. This study found that the 50 km/h speed limit zone led to 590 collisions (48.05% of the total) while over 50 km/h zones include 18.69% of total collisions. This can be associated to lower speed limits, indicating an increased presence of vulnerable road users (e.g., pedestrian or bicyclist) particularly in residential and commercial areas that pose higher risks for ambulances. Literature confirms this trend by recording that 89.6% of collisions occurred in zones with speed limits lower than 32.2 km/h (C. E. Saunders & Heye, 1994), and that most fatal collisions happened on roads with speed limits lower than 80.5 km/h (Custalow & Gravitz, 2004).

Among variables identified during this study, asphalt conditions and types as well as collision locations seemed to be important predictors due to low p-values (i.e., <0.05), while other variables were much less significant. The coefficients in the output indicate the average change in log odds. In this case, poor conditions of asphalt and areas between intersections (100 meters and more) result in 4.24, and 3.64 increments in the odds ratio, respectively. It should be noted that almost all the roads in Quebec are made from asphalt. It is therefore normal to focus on the condition of asphalt on the roads in this study.

The ambulance collision data of the Montréal and Montégérie regions show that asphalt-paving operations can lead to a reduction in the odds of injury crashes. This may be due to ambulances and other vehicles reducing their speed when passing road construction (Coleman, 1996; Committee for Guidance on Setting and Enforcing Speed Limits, 1998; Lin, Kang, & Chang, 2004; P. Lyu, Lin, Wang, & Yang, 2017).

Also, the logit models show that accidents such as those involving fire can result in increasing the odds of being injured for ambulance occupants, which is a new finding for their safety.

Numerous studies are available regarding effects of weather such as precipitation, visibility distance, and wind speed on different road users (Grande et al., 2017; Huang et al., 2008; Król, 2014b; Pino et al., 2014; Rezapour et al., 2019; Zeng et al., 2017). Traffic collision researchers have considered wind directions to be linked with increased injury from collisions (C. Chen et al., 2015) despite the fact that considering surface and weather conditions in this study shows that most collisions happened in clear weather and on a dry or wet surface. This can be related to a study revealing that the most of collisions happened under clear atmospheric conditions (79.8%) and on dry roadways (67.9%), and only a few of them occurred on snow or ice (5.5%) (Pirrallo & Swor, 1994). However, slushy surfaces increased the number of injury collisions for ambulance vehicles in Montérégie.

3.5 Limitations

This study focused on vehicle and environmental factors as the two main variables in the Haddon matrix (Haddon Jr, 1972). This matrix shows the factors involved in collisions and their effect in the periods before, during, and after the collision. The 'human factor' component of the Haddon matrix had to be excluded in the current results, as the paramedics' demographics such an age, gender, experience, and history of prior crashes of drivers were not available. Also, our current dataset does not have information on the model of vehicles (such as brand and year) and the weight of vehicles involved in collisions, both for ambulances and civilian vehicles. These factors should be considered for the safety of ambulance occupants in future studies. Previous research has revealed that investigating the effect of vehicle type and weight on vehicle occupant protection, as increased weight does not consistently improve safety (Tavakoli Kashani, Rakhshani Moghadam, Taheri, Müller, & Dissanayake, 2023).

Information regarding the paramedics' working conditions (i.e. responding to a critical call, patient's condition, and use or not of lights and sirens) was not available in the current dataset. Moreover, there is no specific data distinguishing whether a moving or parked vehicle was involved in the collisions. There is no information regarding seatbelt usage for the paramedic who was driving, the patients in the back of the ambulance, and the paramedic who was providing care to them. This information was not available for the general vehicles either, so it cannot be determined whether wearing a seatbelt influenced the severity of the collisions based on the current data.

When examining the discourse surrounding psychosocial work environments, it is noteworthy that as stress-related psychosocial levels increase, existing literature suggests a corresponding escalation in the risk of fatigue and, subsequently, an elevated risk of collisions among professional drivers (Useche et al., 2021; Useche et al., 2017). The current study lacks access to psychosocial-related information about paramedics. It is recommended that future research endeavors focus on evaluating the association between these psychosocial factors and collision risks among paramedics. Such investigations would contribute valuable insights into the intricate interplay of psychosocial dynamics and their potential impact on paramedic safety outcomes.

In addition, this study did not focus on available internal data regarding ambulance collisions for each region of the province of Quebec. Our research has shown that differences might exist between the total number of collisions reported internally for minor events and less severe collisions (M. Lavallière, Delavary, de Montigny, Tremblay, & Ignacio Castellucci, 2021; Urgences-Sante, 2020). It would be interesting to compare the result of each region to the entire province of Quebec to know whether the same factors are involved in collisions, based on geographical location. Also, having a control group, such as trips without collisions, would enable us to identify characteristics that significantly differ between trips with collisions and control scenarios.

A future study should analyze distraction (for both civilian and ambulance drivers), fatigue (working long hours and shift changing), and the impact of distractions on the safety of ambulance drivers and other road users, especially near intersections. Also, this study did not focus on the impact of factors related to civilian drivers, such as traffic offenses (e.g., not yielding the right of way to ambulances) on ambulance collisions, since it was concluded that certain variables (e.g., alcohol intoxication of the civilian driver) play a significant role in ambulance collisions, especially when emergency medical vehicles use their warning lights and sirens (Custalow & Gravitz, 2004).

3.6 Conclusion

The current study shows the prevalence of ambulance and general vehicle collisions and how they are distributed according to different environments, transportation modes, etc. and is the first study of this type, to our knowledge, in Quebec. It highlights that collision type, location, and pavement conditions significantly impact the odds ratio of collision severity in Quebec. The areas near intersections, which can increase the frequency and severity of collisions, should be addressed as top priorities with countermeasures to reduce the risk of collision in urban areas. Also, descriptive analysis shows that speed limit zone, mode of transportation, and type of environment can play an important role in the severity of collisions.

A comprehensive post-crash database could be used to identify factors that are likely to be involved in future collisions and could contribute to better-comprehensive decisions on awareness and recommendations for targeted preventive actions among paramedics (M. Delavary, de Montigny, L., Castellucci, H. I., Tremblay, M., & Lavallière, M. , 2021; Hongwei Hsiao et al., 2018). Our study underscores the significance of targeted training programs focused on safe intersection navigation, emphasizing the importance of visual scanning. Furthermore, it stresses the need for heightened awareness regarding pedestrians and cyclists in densely populated areas, particularly in residential and commercial zones. Additionally, the study suggests the potential efficacy of utilizing driver assistance technologies, like in-vehicle monitoring systems, and telematics for real-time feedback as a proactive approach to enhance safe driving practices. This may need standard procedures for introducing such technologies in emergency vehicles and the adaptation of policies and regulations for advanced safety and driver-assist technologies, which could be combined with driver training. Future research endeavors should explore the effectiveness of these proposed countermeasures and delve into factors such as the use of lights and sirens, seat belt adherence, the education of civilian drivers when they navigate in the vicinity of emergency vehicles, and psychosocial-related information in ambulance collisions that offer valuable insight for policy development and educational interventions.

Disclosure Statement

No potential competing interest was reported by the authors.

Data Availability Statement

The data that supports this study’s findings are available upon request from the corresponding author, ML. Data is not publicly available, due to ethical and privacy restrictions.

Ethical Approval

The study protocol received approval from the Ethics Committee (#2019-131, 602.545.04) at the University of Quebec at Chicoutimi (UQAC).

ORCID

Milad Delavary[a] https://orcid.org/0000-0003-0540-4437

Mathieu Tremblay[b] https://orcid.org/0000-0002-9507-9051

Martin Lavallière[a*] https://orcid.org/0000-0003-0247-0308

CHAPITRE 4
PAPER 3: NAVIGATING PARAMEDICS' SAFETY: UNRAVELING FACTORS in EMERGENCY SERVICE VEHICLE INCIDENTS

Milad Delavary [1,2], Mathieu Tremblay [3] and Martin Lavallière [1,2,*]

[1] Department of Health Sciences, Université du Québec à Chicoutimi, Chicoutimi, QC, Canada, G7H 2B1; mdelavaryf@etu.uqac.ca (M.D.)
[2] Laboratoire BioNR and Centre Intersectoriel en Santé Durable (CISD), Université du Québec à Chicoutimi, Chicoutimi, QC, Canada
[3] Department of Health Sciences, Université du Québec à à Rimouski, Rimouski, Québec, Canada; mathieu_tremblay2@uqar.ca

***** Correspondence: Martin_Lavalliere@uqac.ca

Manuscript published in International Journal of Paramedicine

DOI: 10.56068/MHCE4982

Abstract

Problem: First responders form a critical cornerstone of public health, providing rapid and lifesaving medical assistance in times of urgent need. However, paramedics are at a persistent elevated rate of fatal and injury collisions while in displacement to or from a call compared to workers who drive vehicles of similar size and other professional drivers. This highlights a pressing concern for these healthcare providers that necessitates investigation and targeted intervention.
Study Objective: This study is a retrospective study aimed to describe factors involved in paramedics' collisions.
Method: Spanning over 10 years of data (2010-2019) from a paramedic agency covering Montreal (Qc, Canada), links between the number of ambulance injuries and non-injury collisions and diverse characteristics like experience, sex, and age of paramedics, day and time of the collision, weather and surface conditions, type of environment, and type of driving activity. The distribution of characteristics involved in the severity of collisions is presented with descriptive analysis. The evaluation of trends of monthly and yearly ambulance collisions is conducted using the Mann-Kendal test. The logit model is also used to examine the effect of such factors on the odds of collision severity.
Results: The results indicate that there is no noteworthy decline in the trend of monthly ambulance collisions. However, calculating the yearly occurrence of non-injury collisions per 10 paramedics shows a statistically significant decline. Also, young paramedics with less ambulance driving experience are more involved in multiple collisions compared to their experienced colleagues. Furthermore, 62% of injury collisions happen when paramedics are responding to an emergency call. The logit model confirms a decrease in the odds of injury collisions (odds ratio: 0.48) during non-emergency activities. Also, intersections and traffic lights are the riskiest locations regarding injury collisions (43.5%, and 51%, respectively). In this case, collisions occurring at traffic lights can increase the odds of severity by nearly six times.
Conclusion: This study exemplifies that preventive policy regarding paramedics (e.g., training programs) should focus on younger paramedics, paramedics less experienced in operating the vehicles, and risky

locations, especially while driving on emergency calls. More oriented awareness and training programs for emergency respondents are required to reduce the number of work-related collisions.

Keywords

ambulance crashes; drivers’ characteristics; environment; emergency/non-emergency activities; work-related collisions

Disclosure of Interest

The authors report there are no competing interests to declare.

4.1 Introduction

Center for Disease Control and Prevention (CDC) (United States of America) and the World Health Organization (WHO) (Switzerland) declared that traffic collisions lead to the death of approximately 1.35 million people per year (Centers for Disease Control Prevention, 2005, 2020; World Health Organization, 2020) from which 33% of drivers involved in these collisions are mostly considered as work-related collisions (European Agency for Safety and Health at Work (EU-OSHA), 2019). More specifically, work-related collisions among emergency respondents have been identified as the leading cause of mortality (Fetto Law Group, 2018; M. Lavallière, Duguay, P., & Bellavance, F. , 2015). As per the American Ambulance Association data, there are an estimated 10,000 or more ambulance-related collisions annually, with many of these resulting in injury or death (US Fire Administration, 2014). More specifically, compared to overall traffic collisions, ambulance vehicles are 1.7 times more likely to be involved in fatal collisions and 1.9 times more likely to be involved in injury collisions (P.-W. Chiu et al., 2018).

Each year, emergency medical responders in the United States (US) experience an average of ten transportation-related fatalities (Maguire, 2015). Between 2006 and 2008, paramedics in the US encountered a traffic collision risk that was five times greater than the national average (B. J. Maguire, 2011). Additionally, their rate of occupational fatalities and injuries related to transportation collisions exceed the national average (Maguire, 2015; Maguire, 2013). Most of the fatalities in this sector result from collisions related to transportation. Traffic collisions accounted for 74% of paramedics' fatalities, with medical emergency responders driving in 69% of these incidents (Maguire et al., 2002). Furthermore, compared to other vehicles of similar size and weight, ambulances are more frequently involved in collisions (A. F. Ray & Kupas, 2005).

As per the usage of lights and sirens, there were 7.0 collisions without lights and sirens and 17.1 with lights and sirens per 100,000 trips in 2016 in the US (Watanabe et al., 2019). Jarvis et al. (2021) found that the utilization of lights and sirens is linked to a rise in collisions and injuries among paramedics. Consequently, there is a pressing need for a structured approach to emergency medical responders in developing specific strategies for responding with lights and sirens. This is because only a small percentage (6.9%) of responses involving lights and sirens need potentially life-saving interventions.

Furthermore, 99,400 injuries and 65 mortalities were recorded between 2003 and 2007 for paramedics and emergency respondents from the Bureau of Labor Statistics (BLS)(USA), which shows a higher rate compared to other kinds of workers (Reichard et al., 2011). In Quebec (Canada), there are 1228 ambulance collisions (including 5 fatalities, 344 injuries, and 859 non-injury) covering from 2010 to 2020 (Société de l'assurance automobile du Québec, 2020a). In Turkey, 81.4% of paramedics (n=733) declared being in at least one collision while on duty in an ambulance (Gülen et al., 2016). In Poland, there were five deaths and 153 injured people from January 2008 to December 2012 (Galazkowski et al., 2015). It is clear that work-related collisions happen worldwide and that they are of utmost importance to address.

Some studies reviewed the characteristics of paramedics involved in collisions. For example, it is found that males are involved more than females in ambulance collisions (almost 80% vs. 20%) (P.-W. Chiu et al., 2018; Custalow & Gravitz, 2004) but there has been an increasing trend in the proportion of females recently (Galazkowski et al., 2015). Also, younger drivers (under 30 years old) are more involved in ambulance collisions (Galazkowski et al., 2015) and a study stated that ambulance drivers, the mean age of 32 years old, who are responsible for collisions had a previous history of multiple collisions in 71% of the cases (Custalow & Gravitz, 2004).

There is a wide range of literature looking at ambulance collisions' characteristics like environmental factors or time of collisions. For instance, the probability of a collision happening is higher during daytime hours (0800 to 1200) and evening hours (1600 to 2000) compared to other periods throughout the day (P.-W. Chiu et al., 2018; Drucker, 2013; Lai et al., 2018). Also, it is reported that almost 33 % of all ambulance collisions happened on Friday (Biggers et al., 1996). Looking at the location of collisions shows that there is a significant number of collisions happening at intersections; for instance, a T-bone mechanism or striking a vehicle with an angle is found to be a highly frequent type of ambulance crash (Custalow & Gravitz, 2004; Kahn et al., 2001c). A descriptive study showed five fatal collisions (out of eight) and 463 nonfatal collisions (out of 707) happened at four-point intersections in Taiwan from January 2011 to October 2016 (P.-W. Chiu et al., 2018). Collisions are statistically more prone to happen at intersections (67% vs. 26%) or at stop signs or signals (53% vs. 14%) in urban environments compared to rural areas (Ray and Kupas, 2007). There are other studies supporting the fact that four way or more intersections, and with traffic signals can increase the risk of ambulance injury and non-injury collisions (Drucker, 2013; Pirrallo & Swor, 1994; A. F. Ray & Kupas, 2005). As per weather conditions, a study shows that most collisions happened when the atmospheric conditions are clear (79.8%) and roadways are dry (67.9%), and only a few of them occurred on snow or ice (5.5%) (Pirrallo & Swor, 1994). Overall, one can appreciate that there are numerous factors influencing the implication of paramedics in collisions and their effects on the severity of collisions.

4.1.1 Purpose and Objectives

The purpose of the current study is to descriptively and statistically analyze the key characteristics surrounding ambulance collisions in Montreal, Canada, that are not typically documented on a formal road safety data set. In this case, most collisions in locations like parking lots, hospitals, etc. were provided by Corporation d'urgences-santé (CUS) and not available in the Société de l'assurance automobile du Québec (SAAQ) data set. To our knowledge, this study is the first of its kind to focus on collision characteristics, with a specific focus on paramedics' factors such as age, experience, sex, and collision history in Canada.

4.2 Methods

4.2.1 Data Collection

This research is based on paramedics' collision data collected in a corporation of a metropolitan city (Montréal, Canada) coming from CUS dataset including 4577 non-injury and 136 injury collisions from January 2010 to December 2019. The CUS serves as the official public emergency medical service for Montreal and Laval islands in the province of Quebec (Canada), providing a comprehensive repository of detailed collision data involving medical emergency vehicles in these areas (CUS, 2023). Also, the SAAQ administers driver's licenses, vehicle registration, and Quebec's public automobile insurance plan, making it a comprehensive source of detailed collisions data for the province (SAAQ, 2020).

4.2.2 Statistical Analysis

This study aimed to understand the effect of contributing factors on the severity of ambulance collisions. To quantify the odds ratio of being involved in an injury collision for each unit increase in an explanatory variable, such as the age or experience of paramedics, a multivariable logit model was employed using Stata software (StataCorp LLC, USA). The interpretation of the odds ratio is the probability of an event happening when the factor of interest is present, divided by the probability of the event occurring when the factor is absent. To illustrate, consider the odds ratio for the involvement of drivers over 25 in crashes compared to those aged 25 and below. If the younger drivers are on the baseline and the odds ratio for the older drivers is 0.70, the older drivers are 30% less likely to be involved in a crash. The linear relationship between the explanatory variables and a binary response variable, including injury and non-injury collisions can be written in the following equation. Note that p-values less than 0.05 shows the effect of explanatory variables is statistically significant at the 95th percentile confidence limit.

$$\ell = \mathrm{Log}\frac{\mathrm{P}}{1-\mathrm{P}} = \beta_0 + \beta_i X_i \qquad (1)$$

Where ℓ is the log-odds, X_i is the independent variables and β are the coefficients of the parameters of the model (Ma et al., 2009).

One of the main steps is a variable selection to use in logit regression. This study used the variance inflation factor (VIF) to check multicollinearity. VIF values above 5 indicate severe multicollinearity. So, if none of the explanatory variables in our models have a VIF over 5, it is assumed that multicollinearity is not an issue in our model. The existence of collinearity between variables rejects the assumption of independence. So, in such models, it is possible to estimate the parameters despite the collinearity, but the standard error will be inflated and, make it impossible to understand the importance and impact of each variable (Dormann et al., 2013).

The next step is examining the performance of the model by using measures such as a Receiver Operating Characteristic (ROC) curve. This is a graph that shows the performance of a classification model at all response thresholds. This graph is produced by plotting the true positive rates (y-axis) with the false positive rates (x-axis) (Markham, 2014). The ROC curve is an important indicator for evaluating the overall performance of the logit regression, which generally shows whether the true positive rate is higher than the false-positive rates. Area Under Curve of ROC Curve (AUC-ROC) shows the relationship between sensitivity and specificity. The value of this number is used to describe the overall performance of a classification model in which values close to 1 represent an accurate classification and values less than 0.5 are considered not acceptable (Mujalli et al., 2016; Provost & Domingos, 2000). Furthermore, the other measurements to assess the goodness of fit is Pseudo R2 and correctly classified (%) values which measure the number of actual positives and negatives which are correctly classified. This study chooses the best-fitted model based on the maximum Pseudo R2, the area under the ROC curve, and correctly classified (%) values.

Additionally, Shewhart's control charts help us figure out if the variation in data is normal or caused by specific circumstances (Nolan et al., 2016; Perla et al., 2011). There are two types of reasons for such variations: common causes that happen naturally over time, and special causes that are not part of a system and happen because of specific circumstances. Shewhart's chart has three lines including the central line and upper and lower control limit lines and points plotted on a graph. If the points are plotted outside of control limit lines, there is a sign of special causes of variation in data. Control limits are typically set at a certain number of standard deviations from the process mean or centerline.

To assess the trend and changes within the studied datasets, the Mann-Kendall and Wilcoxon rank sum tests were employed, respectively. The null hypothesis for Mann Kendal test is that there is no decreasing/increasing trend and the null hypothesis for the Wilcoxon rank sum test is true location shift is equal to zero.

4.3 Results

4.3.1 Descriptive Analysis

We cross-referenced the CUS data presented in Table 4.1 with the collision dataset from the SAAQ for the corresponding time frame and geographical region. This table shows the percentage of overlap for the same data (injury or non-injury collisions) in different source databases including CUS and SAAQ. For instance, in 2019, only 6.83% of all non-injury collisions were matched in both CUS and SAAQ and 88.78 were only available in the CUS dataset. This is because SAAQ primarily records severe collisions that result in injuries or fatalities.

There were 2.11% injury and 5.41% non-injury cases (out of total collisions) matched for both sources during the period from January 2010 to December 2019. Of these, 90.27% of non-injury collisions are only available in CUS datasets which means these are minor collisions that were only recorded internally. Additionally, the SAAQ dataset includes 0.6% injury and 1.4% non-injury collisions that were not present in the CUS dataset. These collisions were incorporated into the CUS data to create a comprehensive dataset for this study.

Table 4.1. Similarity among U-s and SAAQ sources (in percentage)

Year	Injury collisions			Non-Injury collisions		
	U-s and SAAQ	only in U-s	only in SAAQ	U-s and SAAQ	only in U-s	only in SAAQ
2010	4.19	0.44	1.10	4.86	86.31	3.09
2011	3.22	0.00	1.61	4.63	88.13	2.41
2012	1.94	0.39	0.39	5.81	89.73	1.74
2013	1.59	0.2	0.00	5.17	92.05	0.99
2014	2.07	0.00	0.62	6.22	90.25	0.83
2015	0.88	0.44	0.22	4.16	93.44	0.88
2016	1.24	0.00	0.41	3.91	93.83	0.62
2017	1.79	0.22	0.67	6.71	89.49	1.12
2018	1.95	0.00	0.22	5.84	90.69	1.30
2019	2.2	0.24	0.73	6.83	88.78	1.22
Mean	2.11	0.19	0.60	5.41	90.27	1.42

Figure 4.1 shows a Shewhart chart that tracks the monthly collisions involving ambulances from January 2010 to December 2020. The chart has a centerline at 37.5076, and there are lower and upper control limit lines, which are set at 14.9723 and 60.0429, respectively. Most of the data points on the chart cluster around the centerline, showing that the ambulance collisions are typically within a certain range. However,

there are only three points that go beyond these control limits, indicating the possibility of outliers or special causes for these particular points. For analyzing the trend of ambulance monthly collisions visible in this Figure, the Mann Kendal test was also used. The result shows that no trend is found for this time series (p-value= 0.2746).

Also Figure 4.2 shows the incidence of yearly injury collisions per 10 paramedics and non-injury collisions per 10 paramedics covering from 2010 to 2019. The reason for presenting the incidence of injury collisions per 10 paramedics in Figure 4.2 is to aid visualization, as these types of collisions occur significantly less frequently than non-injury collisions. Although there is a significant drop (Wilcoxon rank test; p-value= 0.0495) after 2011 in the incidence of injury, there is no significant decrease in the overall trend (Mann Kendal test; p-value= 0.0736). Furthermore, there is a significant reduction trend (Mann Kendal test; p-value= 0.0123) for the incidence of non-injury collisions.

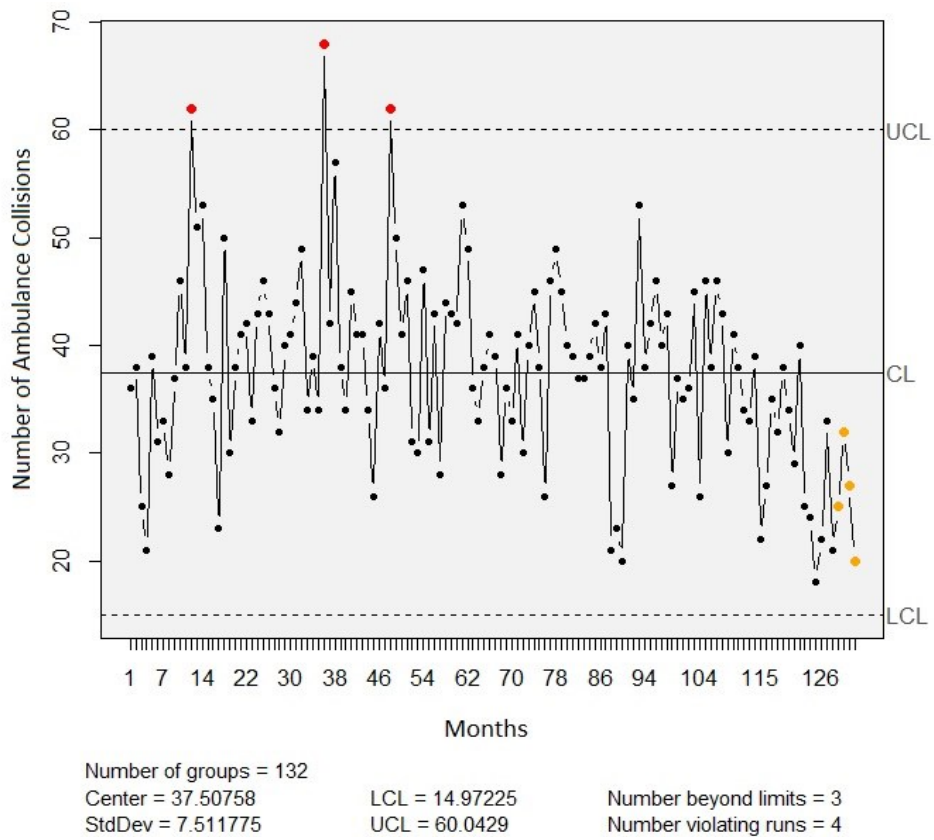
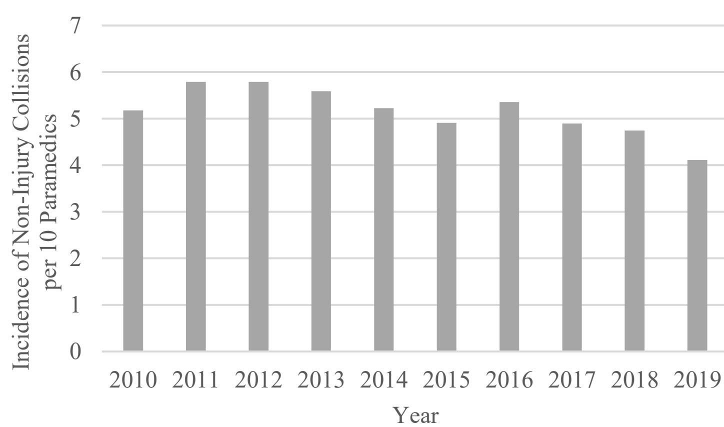


Figure 4.12 Shewhart Chart of Ambulance Monthly Collisions between January 2010 and December 2020 in Montreal, Quebec



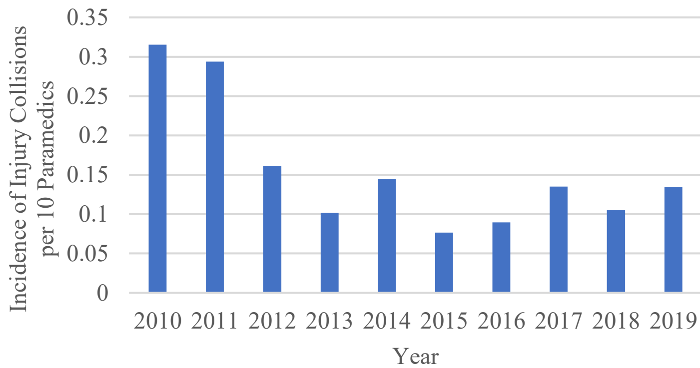


Figure 4.13. Incidence of Yearly Non-Injury (upper panel) and Injury (lower panel) Collisions between January 2010 and December 2020 in Montreal, Quebec

Distribution of injury and non-injury collisions during a week and along a day are shown in Figures 4.3 and 4. In this regard, the time-of-day variable was divided into 12 periods of 2 hours bins. The percentage of injury collisions from 20:00 to 21:59 and non-injury collisions from 16:00 to 17:59 are higher than other periods with 16.67% and 13.60%, respectively. And paramedic drivers were less involved in injury collisions (0.93%), and non-injury collisions (2.48%) from 4:00 a.m. to 5:59 a.m. Furthermore, the pattern of non-injury collisions remains relatively constant throughout the week; however, injury collisions exhibit two spikes on Friday (23.15%) and Tuesday (18.52%). Friday has the highest number for both injury and non-injury collisions, counting 23.15% and 16.99% of the total, respectively.

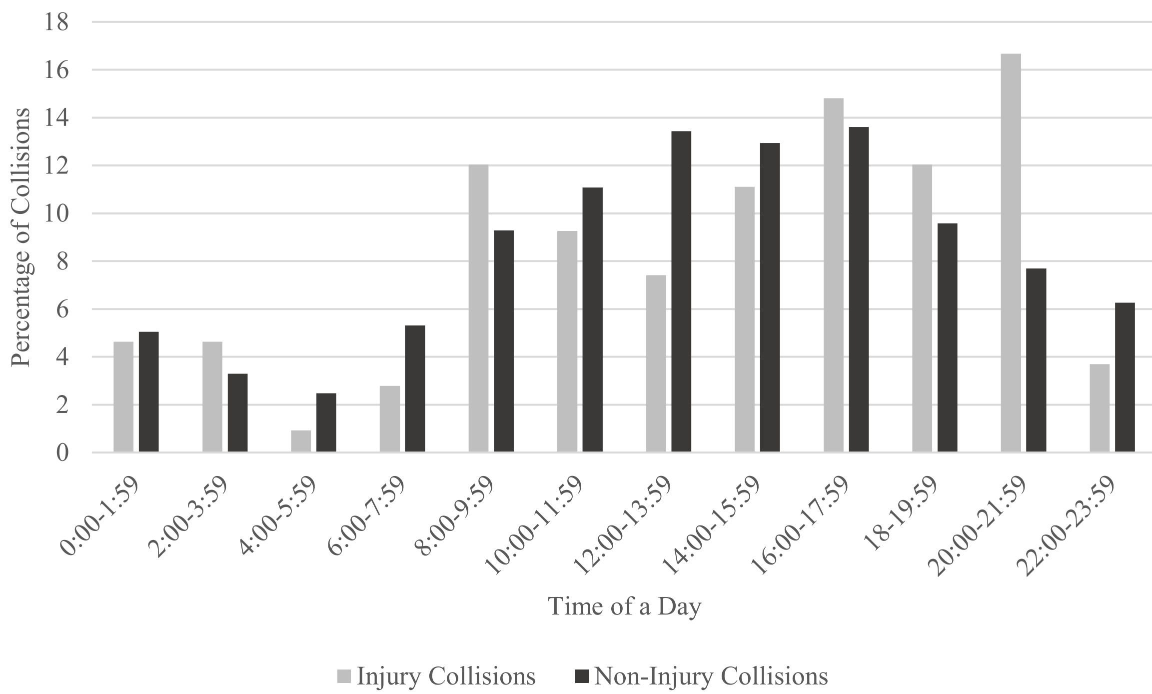


Figure 4.14. Distribution of collisions along a day

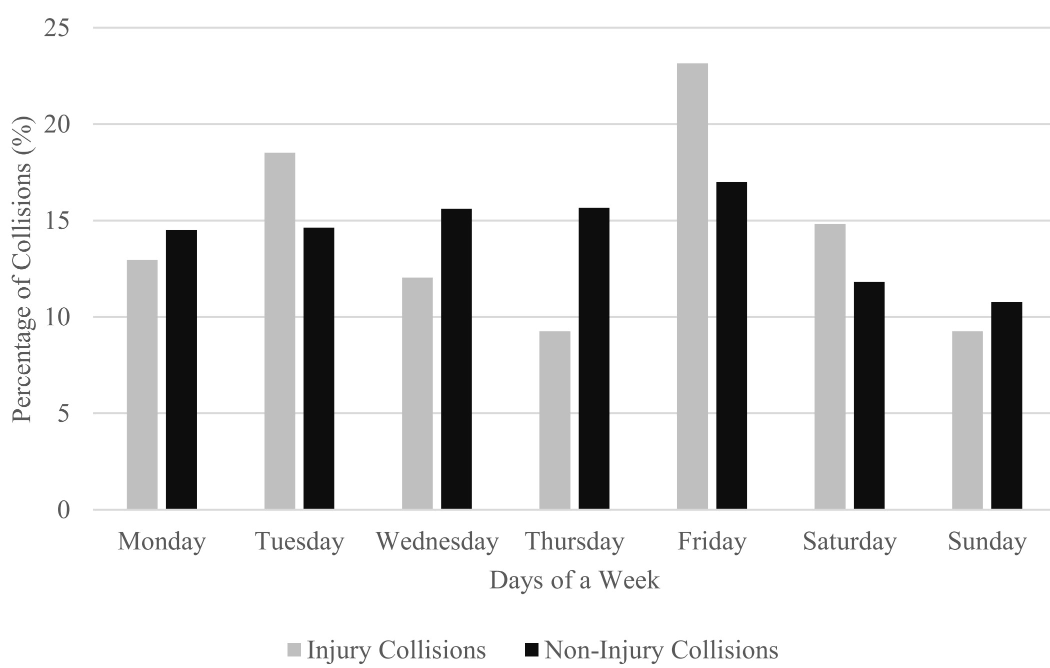


Figure 4.15. Distribution of collisions during a week

Furthermore, the distribution of collisions severity (including injury and non-injury) among other variables like paramedic factors (e.g., experience, sex, and age of drivers), weather and surface conditions, environmental factors (e.g., type of environment, road topography, and signal type), day and time of the collision, and type of driving activity are shown in Table 4.2.

The number of male and female drivers involved in crashes is 3672 and 961 cases, respectively. In detail, the number of injury collisions where males are involved is 78 more than females (93 vs. 15, respectively). The workforce consists of 27% females and 73% males in terms of gender distribution. In addition, there is no notable difference between male and female paramedics' involvement in non-injury collisions (0.50 vs. 0.53 collisions per paramedic, respectively). Also, the number of injury collisions per 10 paramedics is more for males compared to females (0.13 vs. 0.08, respectively).

Ambulance drivers between ages 25-45 are more involved in injury/non-injury collisions with 2490 (out of 4633) cases when compared to those outside this bracket. Moreover, paramedics aged 45 or older show a higher percentage of involvement in injury collisions (30.56%) compared to their younger counterparts aged 25 or less (12.04%). This might be due to a smaller number of staff aged less than 25 years old. Figure 4.5 shows a 3D distribution of the number of collisions per paramedic among different ages and experiences for both males and females. It shows that the number of young paramedics with low experience involved in multiple collisions is more than others. Additionally, there is a slight increase in the number of collisions among male paramedics over the age of 45.

Paramedic drivers with less than seven years of experience, most of them being younger, were involved in 2437 collisions (2384 non-injury and 53 injuries). Figure 4.5 shows a 3D plot to understand the intricate interplay between age, experience, and collision occurrences. By representing age and experience on the X and Y axes respectively, and collisions on the Z-axis, it aims to provide a comprehensive visual representation that not only showcases how collisions change with varying levels of experience and age but also highlights the joint impact of these variables on collision outcomes. According to this Figure, the number of collisions that involved paramedics ranging from seven to 20 years of experience reached 990 cases (963 non-injury and 27 injuries) and after that, it increased to 1206 collisions (1176 non-injury and 28 injuries) for paramedics with more than 20 years of experience, especially for male drivers.

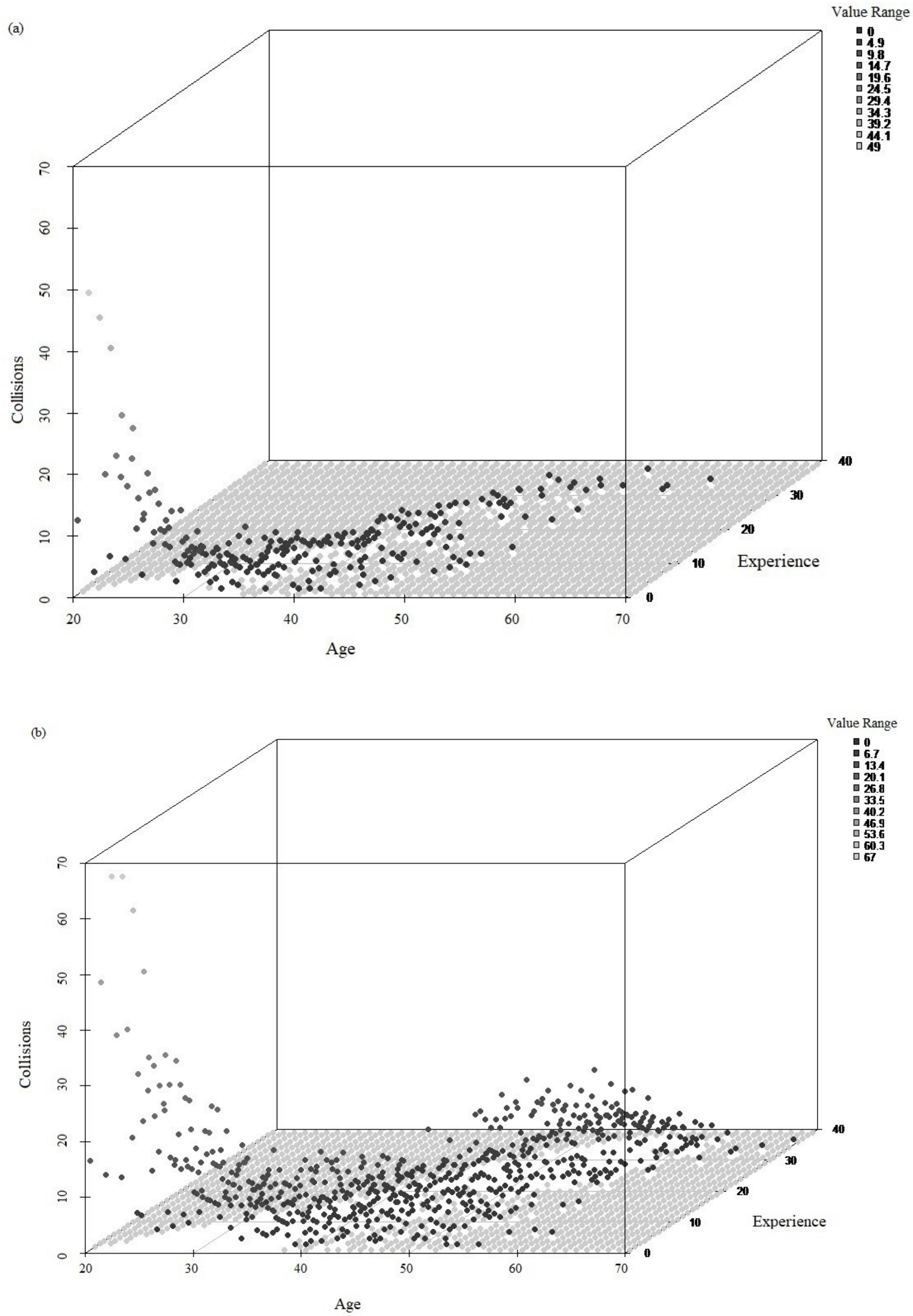


Figure 4.16. A 3D plot of collisions based on age and experience (a: female, b: male)

In 23.82% (n: 1078) of non-injury and 19.44% (n: 21) of injury collisions, ambulance drivers were considered responsible for the collisions. And there is no clear answer for 66% of collisions on knowing who (civilian or ambulance drivers) is responsible for collisions. Furthermore, paramedic drivers with unknown use of seatbelts represent 2843 non-injury (62.83%) and 62 injuries (57.41%) crashes. The number of non-injury and injury collisions when they wear seatbelts is 1328 (29.35% of the total) and 41 (37.96% of the total), respectively.

In 37 injury cases (34.26%), the airbags were not deployed during the collisions, and for 67 cases, there is no answer on our database. This trend is observed for non-injury collisions with 1863 (41.17%) and 2645 (58.45%) cases for "not used" and "not answered" categories, respectively.

The driving activity was categorized into four groups: emergency driving (also known as the 10-30 code), non-emergency driving (also known as the 10-16 code), on-site, and others. In most of the cases in which the ambulance drivers were involved in the collision (especially for injury with 62.04% of total injury collisions), the crew was engaged in "emergency driving" with a total of 1461 cases. Meanwhile, other levels of activity, including non-emergency driving, on-site, and others, had a total of 1400, 582, and 1190 cases, respectively. Also, there is no patient in the ambulance in 66.67% (n: 3017) of non-injury and 55.56% (n: 60) of injury collisions.

In this study, four regions were used based on the Montréal Island: the north region, east region, west region, and other regions. The highest frequency of collisions can be seen in the east and the west regions of the territory with 2063 and 1868 cases, respectively. The north region exhibited 606 cases. Furthermore, there were more collisions reported in commercial and residential areas compared to other locations. Specifically, 1294 collisions occurred in commercial areas, 1257 in residential areas, and 688 in hospital areas. More precisely, intersections have the highest percentage of injury collisions (43.52%) compared to other areas like roadways between intersections (21.3%).

According to the weather conditions variables, the highest number of non-injuries (n: 2649) and injury (n: 66) collisions happened when the sky was clear. In addition, 2776, 633, and 493 (out of 4633) collisions happened on a dry, wet, and snowy surface, respectively.

Flat/Straight areas exhibited 3525 crashes, by far the largest number of cases of all areas, followed by Hill/Straight areas, which showed 331 cases. In addition, cases with no signalization showed 2950 (65.19%) cases, the largest number of cases in non-injury collisions, followed by cases with an obstacle sign, showing 716 (15.82%) cases. Traffic lights (n: 55) and no signalization (n: 33) are ranked in the top risky locations concerning injury collisions.

It should be mentioned that most collisions (n: 3891) happened on asphalt pavement. Almost 81% of collisions happened when the pavement is in good condition. Only 336 crashes (7.25%) happened when the pavement is under construction, repair, or there are potholes on the pavement.

Table 4.2. Descriptive analysis of ambulance collisions in Montreal from 2010 to 2019

Variable	Category	Sub-Category	Non-Injury	Injury	Total
Paramedic level factors	Sex	Female	946 (20.91%)	15 (13.89%)	961
		Male	3579 (79.09%)	93 (86.11%)	3672
	Age	Less than 25	785 (17.35%)	13 (12.04%)	798

		Between 25 and 45	2428 (53.66%)	62 (57.41%)	2490
		More than 45	1312 (28.99%)	33 (30.56%)	1345
	Experience	Less than 7 year	2384 (52.69%)	53 (49.07%)	2437
		Between 7 and 20	963 (21.28%)	27 (25%)	990
		More than 20	1178 (26.03%)	28 (25.93%)	1206
	Responsibility	Yes	1078 (23.82%)	21 (19.44%)	1099
		No	406 (8.97%)	12 (11.11%)	418
		Shared	55 (1.22%)	2 (1.85%)	57
		Not answered	2986 (65.99%)	73 (67.59%)	3059
	Seatbelt	Yes	1328 (29.35%)	41 (37.96%)	1369
		No	354 (7.82%)	5 (4.63%)	359
		Not answered	2843 (62.83%)	62 (57.41%)	2905
Environmental factors	Localization	Rural	32 (0.71%)	0 (0.00%)	32
		Waiting area	38 (0.84%)	0 (0.00%)	38
		Operational Center	155 (3.43%)	0 (0.00%)	155
		Hospital	414 (9.15%)	0 (0.00%)	414
		Intersection	635 (14.03%)	47 (43.52%)	682
		Roadway between intersections	825 (18.23%)	23 (21.3%)	848
		Median strip	24 (0.53%)	1 (0.93%)	25
		Commercial Center	57 (1.26%)	0 (0.00%)	57
		Shoulder	67 (1.48%)	0 (0.00%)	67

	Land or private road	103 (2.28%)	0 (0.00%)	103
	Tunnel/Bridge	34 (0.75%)	0 (0.00%)	34
	Others and not answered	2141 (47.31%)	37 (34.26%)	2178
Environment	Hospital	688 (15.2%)	0 (0.00%)	688
	Operation center	235 (5.19%)	0 (0.00%)	235
	Waiting area	65 (1.44%)	0 (0.00%)	65
	Residential	1224 (27.05%)	33 (30.56%)	1257
	Commercial	1243 (27.47%)	51 (47.22%)	1294
	Industrial	197 (4.35%)	5 (4.63%)	202
	Rural	239 (5.28%)	10 (9.26%)	249
	Others (e.g. school, park and parking lots) and not answered	634 (14.01%)	9 (8.33%)	643
Road topography	Flat/Straight	3431 (75.82%)	94 (87.04%)	3525
	Flat/Curve	213 (4.71%)	0 (0.00%)	213
	Hill/Straight	324 (7.16%)	7 (6.48%)	331
	Hill/Cruve	128 (2.83%)	3 (2.78%)	131
	Not answered	429 (9.48%)	4 (3.7%)	433
Pavement type	Asphalt	3789 (83.73%)	102 (94.44%)	3891
	Concrete	277 (6.12%)	1 (0.93%)	278
	Others (e.g. gravel)	459 (10.14%)	5 (4.63%)	464
Signalization	No Traffic light	2950 (65.19%)	33 (30.56%)	2983

		Traffic light	650 (14.36%)	55 (50.93%)	705
		Flashing red light	63 (1.39%)	2 (1.85%)	65
		Green light with priority	70 (1.55%)	2 (1.85%)	72
		Stop sign	57 (1.26%)	1 (0.93%)	58
		Obstacle(s) sign	716 (15.82%)	12 (11.11%)	728
		Others (e.g. pedestrian lights and flashing yellow light) and not answered	19 (0.42%)	3 (2.78%)	22
	Region	West	1829 (40.42%)	39 (36.11%)	1868
		East	2025 (44.75%)	38 (35.19%)	2063
		North	576 (12.73%)	30 (27.78%)	606
		Others	95 (2.1%)	1 (0.93%)	96
	Pavement conditions	Good condition	3633 (80.29%)	97 (89.81%)	3730
		In Construction	148 (3.27%)	3 (2.78%)	151
		Under reparation	39 (0.86%)	1 (0.93%)	40
		Pot hole	143 (3.16%)	2 (1.85%)	145
		Others	562 (12.42%)	5 (4.63%)	567
Weather condition	Surface State	Dry	2710 (59.89%)	66 (61.11%)	2776
		Wet	609 (13.46%)	24 (22.22%)	633
		Snowy	488 (10.78%)	5 (4.63%)	493
		Icy	174 (3.85%)	4 (3.70%)	178

		Muddy & humid	67 (1.48%)	3 (2.78%)	70
		Others and not answered	477 (10.54%)	6 (5.56%)	483
	Weather conditions	Black Ice	40 (0.88%)	0 (0.00%)	40
		Clear	2649 (58.54%)	66 (61.11%)	2715
		Covered	546 (12.07%)	13 (12.04%)	559
		Raining	256 (5.66%)	13 (12.04%)	269
		Snow/hail	231 (5.1%)	7 (6.48%)	238
		Gust of rain	87 (1.92%)	1 (0.93%)	88
		Strong winds	25 (0.55%)	1 (0.93%)	26
		Snowstorm	85 (1.88%)	0 (0.00%)	85
		Others (e.g. fog) and unknown	606 (13.39%)	7 (6.48%)	613
Vehicle	airbag used?	Yes	17 (0.38%)	4 (3.70%)	21
		No	1863 (41.17%)	37 (34.26%)	1900
		Not answered	2645 (58.45%)	67 (62.04%)	2712
Type of task	Driving activity	Emergency	1394 (30.81%)	67 (62.04%)	1461
		Non-emergency	1378 (30.45%)	22 (20.37%)	1400
		On site	581 (12.84%)	1 (0.93%)	582
		Others	1172 (25.9%)	18 (16.67%)	1190
	Is there a patient in an ambulance?	Yes	1020 (22.54%)	33 (30.56%)	1053
		No	3017 (66.67%)	60 (55.56%)	3077

	Not answered	488 (10.78%)	15 (13.89%)	503

The effect of collision history on the total number of collisions for ambulance drivers during the studied period was examined with Pearson's product-moment correlation test. The null hypothesis of this test is that the true correlation is equal to zero. According to the results, there is a significant correlation (-0.383, 95%CI [-0.435, -0.327]; p-value< 0.0001) between the minimum interval separating individual paramedic's collisions and the overall number of collisions per ambulance driver. This means that by increasing the minimum interval of collisions, the total number of collisions per paramedic is expected to decrease. This trend is observed for the mean of intervals between collisions (-0.255, 95%CI [-0.313, -0.195]; p-value< 0.0001). In Table 4.3, the total number of collisions is presented for various interval cut-points, including the first to the fourth quartile of the minimum interval, as well as the mean of intervals between collisions for each ambulance driver. The results show that 36.5% and 24.91% of collisions are associated with drivers involved in collisions with a minimum interval of 28 days or less and a mean of intervals of 234 days or less.

Table 4.3 Mean and Minimum of Intervals between collisions per ambulance driver

Percentage	Minimum interval				Mean interval			
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Cut-point of interval	28	85	283.5	2979	234.9	382	627.375	2979
Total number of collisions	1700	3042	4008	4657	1160	2651	3866	4657
Percentage (out of total collisions)	36.5	65.32	86.06	100	24.91	56.93	83.01	100

4.3.2 Logit Regression

The logit regression results for the collision severity of ambulances are presented in Table 4.4. The VIF value for all variables used in this table is less than 5 which means there is no collinearity between variables. These tables provide the estimated odds ratios, standard error, z-value, p-values, and 95% confidence interval (CI) for each of the independent variables included in the models. The logit model demonstrated good performance as indicated by various goodness-of-fit measures such as Pseudo R2, the area under the ROC curve, and the percentage of correctly classified.

The models indicate that changing from emergency (baseline) to non-emergency, and on-site activities can lead to a reduction of 52% (95%CI; [75%, 6%]) and 92% (95%CI; [99%, 35%]) in odds of collision severity. "On-site activities" include tasks or operations that paramedics engage in at locations where the mission does not involve an emergency response. For example, collisions might occur in a hospital parking lot during non-emergency actions or at the CUS's vehicle depot.

Furthermore, trips in the north of Montreal lead to a high odds ratio (4.58, 95%CI; [2.12, 9.90]) compared to the other regions. The snowy surface is associated with a 73% (95%CI; [92%, 2%]) reduction in the odds of having an injury collision. Intersections with traffic lights can increase the odds of having a collision severity by 5.97 times (95%CI; [2.58, 12.60]) compared to no traffic light locations. The visual representation of the effect of these significant contributing factors on injury collisions is evident in Figure 4.6.

Table 4.4 Results of logit regression

Variables	Levels	Odds Ratio	Standard error	z-value	p-value	95% Confidence Interval	Pseudo R2	Area under ROC curve	Correctly classified
Activity	2	0.48	0.16	-2.15	0.03	[0.25, 0.94]	0.25	0.82	77.84%
	3	0.08	0.09	-2.36	0.02	[0.01, 0.65]			
	4	0.47	0.17	-2.03	0.04	[0.23, 0.97]			
Region	2	0.98	0.32	-0.07	0.94	[0.52, 1.85]			
	3	4.58	1.80	3.86	0.00	[2.12, 9.90]			
	4	0.21	0.26	-1.29	0.20	[0.02, 2.24]			
Surface Condition	2	1.47	0.55	1.03	0.30	[0.71, 3.05]			
	3	0.27	0.18	-1.99	0.05	[0.08, 0 .98]			
	4	1.13	0.83	0.17	0.87	[0.27, 4.78]			
	5	3.99	4.11	1.34	0.18	[0.53, 30.07]			
	6	0.66	0.46	-0.59	0.56	[0.17, 2.62]			
Signalisation	2	6.97	2.30	5.70	0.00	[3.58, 13.60]			
	3	0.87	0.82	-0.15	0.88	[0.14, 5.56]			
	4	3.08	3.10	1.11	0.27	[0.43, 22.24]			
	5	1.20	1.65	0.13	0.90	[0.08, 17.91]			
	6	2.10	1.17	1.33	0.19	[0.70, 6.27]			

7	22.33	26.22	2.65	0.01	[2.24, 223.01]

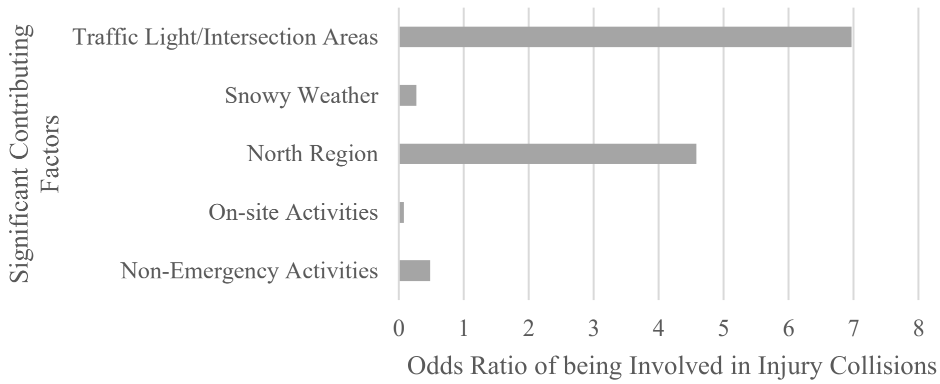


Figure 4.17 Summary of the effect of significant contributing factors on injury collisions

4.4 Discussion

The primary focus of this study was to ascertain the factors contributing to the severity of work-related collisions within a paramedic corporation operating in the Montreal area (Quebec, Canada). The present results show that most ambulance collisions happen in urban environment areas such as commercial and residential. A study looking at ambulance collisions concluded that 82% of collisions occurred in an urban environment (T. L. Sanddal et al., 2010). Looking in detail, intersections have been identified as particularly risky locations, and the presence of traffic lights may increase the likelihood of injury collisions occurring. This is in line with multiple studies that worked on the location of collisions regarding emergency responders (P.-W. Chiu et al., 2018; Custalow & Gravitz, 2004; Kahn, Pirrallo, & Kuhn, 2001a; Lai et al., 2018; Pirrallo & Swor, 1994; A. F. Ray & Kupas, 2005). They confirmed that such locations are significant predictors of collisions and ambulances were more likely to be involved in them compared to others.

The date and time of collisions are associated with the frequency of ambulance collisions which is in line with the finding of Ray and Kupas (2005). Furthermore, the prevalence of non-injury and injury collisions is higher in the afternoon (23.82%; 12:00 to 15:59) and evening (26.85%; 16:00 to 19:59), respectively, which is consistent with other studies on the topic (P.-W. Chiu et al., 2018; Drucker, 2013; Lai et al., 2018). This may be attributed to a variety of factors, such as the increased volume of emergency calls received during those times, as well as the heavier traffic on the roads, which can increase the likelihood of occurring a collision.

In more than 50% of collisions, ambulances did not have patients on board at the time of the collisions which is found in other literature (T. L. Sanddal et al., 2010). In addition, this study found that emergency activities can result in increasing the odds of collision's severity. Notably, the models indicate that changing from emergency to non-emergency, and on-site activities can substantially reduce the odds of collision severity. There are significant studies that concluded using lights and sirens or emergency mode can increase both frequency and severity of collisions. In this regard, there is a study that shows half of the collisions happened while using lights and sirens but did not find an association between emergency activities and an increase in the severity of the collisions (Biggers et al., 1996). This study shows most collisions happened in clear weather conditions and on dry surfaces. This fact is in line with previous literature about the effect of weather variables on ambulance collisions (Kahn et al., 2001a; Pirrallo & Swor, 1994). However, it is found that the snow surface is associated with a reduction in the odds of having an injury collision. This might be due to a small proportion of calls or fewer crashes occurring in such kind of weather (Pirrallo & Swor, 1994). This could also be associated with an increased level of vigilance and preventive actions from paramedics while driving in such conditions, and thus to an overall reduction of collisions in such weather (Wilde, 1989).

Furthermore, it is found that cases with unknown seatbelt usage have a higher number of collisions for paramedics with 2905 cases (out of 4633), followed by those who wear it with 1369 cases. This founding was reported in another study (Bentley & Levine, 2016). It is declared that 65.1% of paramedics were wearing seat belts when sitting in the front seat of the ambulance while 75.8% of their organizations have a written seat belt policy. And, almost no one (3.1%) during emergency mode reported using seat belts when in the patient compartment (Bentley & Levine, 2016). It is found that the chance of being killed or injured is significantly reduced by 3.77 times and 6.49 times, respectively, for ambulance occupants who are properly restrained (Becker et al., 2003). Therefore, specific interventions should be tailored to address this issue among paramedics since using seatbelts can improve the safety of both paramedics and civilian drivers. Moreover, one might assume that if the status of the seatbelt is identified as "unknown" while reporting the event, it is probably because it was not worn at the time of the collision.

Males were more involved in collisions compared to females (3672 vs. 961, respectively) which differs from a study with Maguire (B. J. Maguire, 2011) in terms of sex in paramedics' collisions (female: 53%). Or another study concluded that although females consist up 27% of employment, they were involved in 53% of collisions (B. J. Maguire, 2011). But the results of the study conducted by Boufous et al. (Boufous & Williamson, 2006) and Bellavance et al. (Bellavance, 2016) in terms of prevalence by sex in work-related collisions and other general kinds of literature on traffic safety confirm our findings (Choi, 2010; Claret et al., 2003; Durak, Fedakar, Türkmen, Akgöz, & Baduroğlu, 2008; Mascarenhas et al., 2016). These results differ from the ones observed by Bellavance et al. (Bellavance, 2016) in terms of prevalence by sex in work-related collisions.

Furthermore, paramedics are more involved in collisions when they are young and have a lower level of experience, consistent with the general literature on road safety (Lloyd, Wilson, Mais, Deda, & Bhagat, 2015; N. Lyu, Cao, Wu, Xu, & Xie, 2018; Toroyan & Peden, 2007). Studies focused on ambulance drivers confirmed that the probability of being involved in collisions for such age categories is higher than others (Custalow & Gravitz, 2004; Galazkowski et al., 2015). Noting that the reason behind more involvement in collisions for ambulance drivers aged between 25 and 45 can be due to a higher staff count in this age group.

When an ambulance is involved in a collision while transporting a patient, it rapidly increases the risk of having injuries/deaths compared to other types of collisions, especially when the person being transported is already being taken care of for a particular health condition. To address this, we need to develop comprehensive proactive measures such as training programs designed specifically for less experienced drivers, or provide training on ambulance operators to focus on inadequate skills and abilities or operator errors (Elling et al., 2018; Boone et al., 2015). Use of emerging technology e.g., telematics devices (Levick & Swanson, 2005) can improve driver behavior. To achieve this goal, it's important to enhance the policies and standards for recruiting paramedics. By setting up clear and adaptable standards that consider the specific challenges of ambulance driving, and by integrating focused training and education plans, we can create a proactive strategy within the emergency medical services framework. This combined effort not only tackles the immediate issue of reducing collisions but also demonstrates a dedication to the ongoing safety and welfare of emergency personnel and the communities they serve.

4.5 Limitation

Exposure variables like the number of emergencies and non-emergency calls or miles driven in different regions, e.g., west and east regions of Montréal, are not available to see the possible reason behind the different distribution of collisions in such times and locations. The distribution of these exposure variables for different ranges of age, experience, and sex or in different weather conditions and activities including emergency and non-emergency are not accessible. In addition, this study is faced with a limitation regarding the number of paramedics with different experiences and age groups.

4.6 Conclusion

First responders' work-related collisions, especially among paramedics, are a major concern regarding road safety and health and safety. Also, the trend of ambulance collisions is not decreasing in Montreal during the studied period. It is concluded that male and young drivers with low experience (less than seven years) have a history of multiple collisions more than others. In addition, among risky locations, e.g., commercial and residential areas, crossing the intersections with traffic lights can increase the odds of collision severity significantly. Interventions aimed at reducing non-emergency and on-site activities could reduce significantly the odds of being involved in injury collisions compared to emergency calls. These key factors can help paramedics' organizations to focus on target populations like young drivers or those who are involved in multiple collisions in a short timeline. Then, they could tailor either educational content for all or implement specific driving maneuvers programs that have been identified as problematic for their organizations and that have been shown promising in other clientele of drivers to reduce the burden of collisions (Tiesman et al., 2019) or inappropriate visual search as an example (Castellucci et al., 2020).

Data Availability Statement

The data that supports this study's findings are available upon request from the corresponding author, ML. Data are not publicly available, due to ethical and privacy restrictions.

Ethics Review

The study received ethical approval from both the University of Quebec at Chicoutimi (2019-131, 602.545.04) and CUS scientific review committees, ensuring adherence to the necessary ethical standards for research.

CHAPITRE 5: DISCUSSION and CONCLUSION

5.1 Discussion:

5.1.1 Assessment of advances :

This study highlights the higher risk of injury and fatalities associated with ambulance collisions compared to other professional drivers. The primary objective is to comprehensively analyze the prevalence, characteristics, and factors associated with ambulance collisions, drawing comparisons with collisions involving similar-sized and general vehicles across different regions of Quebec, Canada. The research also seeks to provide recommendations for preventive policies and training programs to enhance the safety of paramedics. Particularly, the focus is on addressing the specific needs of younger and less experienced paramedics while addressing the challenges posed by risky locations and emergency response modes. The current study emphasizes the importance of age, experience, and driving history in determining the likelihood of such collisions. It utilizes retrospective and statistical analysis of ambulance collisions and compares them with general vehicle collisions.

The findings from the systematic literature review underscore the pressing concern regarding traffic collisions involving ambulances, as they pose significant risks to the health and safety of paramedics, ambulance occupants, and other road users. Compared to other commercial or same-sized vehicles, ambulances exhibit a disproportionately high incidence of collisions, with the use of warning light systems during emergency responses exacerbating this burden. Particularly in urban areas and at intersections, where collision risks are heightened, the likelihood of ambulance-involved collisions is notably elevated. The review found that factors such as limited driving experience, youthfulness, and a history of collisions or traffic violations, such as not wearing seat belts, further compound the risk of being involved in and the severity of collisions.

Despite an overall decreasing trend in collisions across Quebec from 2010 to 2020, the study reveals a concerning lack of significant reduction in ambulance collisions during this period, particularly in Montreal. The analysis underscores the critical impact of collision type, location, and pavement conditions on collision severity, with intersections emerging as focal points for heightened collision risks across Quebec. Addressing these areas with targeted countermeasures emerges as a top priority for mitigating collision risks in urban settings. Furthermore, descriptive analysis underscores the influential role of speed limit zones, transportation modes, and environmental factors in shaping collision severity outcomes across Quebec.

The findings reveal specific characteristics associated with ambulance collisions, such as their frequency near intersections, in commercial areas, and when responding to emergency calls which is align with previous studies worked on the mode of responding to a call (Custalow & Gravitz, 2004; Kahn et al., 2001d; Pirrallo & Swor, 1994; T. L. Sanddal et al., 2010; Schwartz et al., 1993; Tennyson et al., 2015) or the location of collisions including urban vs rural areas (P.-W. Chiu et al., 2018; Lai et al., 2018; T. L. Sanddal et al., 2010; S. J. Weiss et al., 2001) or intersection vs non-intersection areas (P.-W. Chiu et al., 2018; Custalow & Gravitz, 2004; Kahn et al., 2001d; Lai et al., 2018; A. F. Ray & Kupas, 2005; A. M. Ray & Kupas, 2007; T. L. Sanddal et al., 2010).

Moreover, the study shed light on key demographic and situational factors associated with increased collision risks among ambulance drivers in Montreal. Male drivers with limited experience, particularly those with less than seven years of driving history, and a track record of multiple collisions emerge as high-risk cohorts. Intersections with traffic lights in both commercial and residential areas significantly elevate the odds of collision severity in Montreal. Conversely, non-emergency and on-site activities are associated with significantly reduced odds of injury collisions compared to emergency responses.

There is limited access to know the usage of seatbelt for the paramedic who was driving, the patients in the back of the ambulance, and the paramedic who was providing care to them. This study found that in most of the occuasion where the collision ahppneed, there is no information to see whether they waered seatbelt or not. However, there are several reseaons that paramedics could not wear seatbelts in the back of the ambulance. One of the main reasons is discomfort, as 82.8% of paramedics reported that they do not wear safety belts due to this reason (Thorvaldsen et al., 2022). Additionally, paramedics feel that wearing seatbelts restricts their ability to fully access and care for patients during transport (Lindridge et al., 2022). Another factor is the layout and design of the ambulance, as the seats and restraints are often inadequate and impractical for paramedic work (George, 2017). Another reason could be the lack of unification of equipment in different ambulances, which may result in discomfort or difficulty in wearing seatbelts (Thomas et al., 2020). These issues highlight the need for specially designed belts, ergonomic seats, and improved equipment and communication systems to ensure paramedic safety and efficient work.

Similarly, a study investigating driving perceptions and behaviors among police officers, as a first responders, in Quebec indicates that the propensity of wearing seat belts among them varies depending on the time of day and the nature of their driving tasks (M Lavallière & Bellavance, 2020). During daytime driving, a majority of police officers report wearing their seat belts regularly or always, but the percentage is lower compared to the general population. Interestingly, less experienced police officers tend to wear seat belts less frequently than their more experienced colleagues. Several reasons are cited for not wearing seat belts among paramedics. Some perceive seat belts as too restrictive, uncomfortable, or hindering rapid exit from the vehicle. Additionally, there's a fear of getting stuck in the vehicle cabin, particularly during emergency situations. Some of them also mention the short distance to travel or concerns about equipment getting stuck in the belt as reasons for not wearing seat belts. However, lack of awareness about the importance of wearing seat belts seems to be less of a factor among first responders compared to the general population. When responding to a call, police officers often remove their seat belts upon arriving at the scene or just before the vehicle is stopped. Some may detach their seat belts upon arriving in the vicinity of the call or when traveling to the location of the call if it's more than 500 meters away. Some of them said “Sometimes when arriving at a street corner of the call if it is for sweeping and you expect to have to run/catch someone on foot, you will have to react quickly” or “If the call is not urgent and there is no imminent threat, I detach myself when the vehicle is immobilized. If we are looking for a dangerous person who is traveling on foot, I detach myself when we arrive in the area and we are no longer in emergency driving”. This specific differentiation at the moment when the police officer unfastens the belt suggests a moderation of this behavior depending on the work context and the type of conduct required for the exercise of duties. Furthermore, there's a variation in behavior based on experience, with less experienced drivers tending to remove their seat belts just before the vehicle is immobilized, while more experienced ones may detach them earlier depending on the urgency of the situation and the type of conduct required for their duties.

A recent research, aimed to analyze ambulance crash incidences, seating arrangements, and seatbelt usage among casualties, found the majority of rear cabin occupants involved in these crashes were found to have not been wearing seatbelts (Norii et al., 2024). The study conducted a nationwide survey of all fire departments, spanning from January 1, 2017, to December 31, 2019 in Japan. Two-thirds of the surveyed fire departments reported at least one ambulance crash during this period. Seatbelt usage among EMS professionals and patients/companions in the rear cabin was notably low, at 10.3% and 11.5% respectively. Furthermore, the study revealed that only 46.7% of fire departments had established internal policies regarding seatbelt usage.

These identified factors provide valuable insights for paramedic organizations to tailor interventions aimed at enhancing road safety for paramedics and the broader population they serve. The implementation of stringent seatbelt policies within ambulance operations to mitigate the risks associated with crashes and reduce the severity of injuries sustained by occupants. Also, targeting high-risk demographics, such as young and inexperienced drivers, and implementing tailored training programs can serve as effective strategies to mitigate collision risks and safeguard the well-being of ambulance personnel and the communities they serve.

5.1.2 Transfer of knowledge to emergency professions and road users:

This study provided better insights into the details and effects of collisions which will enable organizations to make recommendations for targeted preventive actions on the organizational level to reduce the injuries and non-injuries as well. It is recommended that policymakers prioritize ambulance safety by considering measures such as giving ambulance vehicles the right of way or implementing changes in traffic signals during emergencies. Additionally, interventions like training programs, awareness campaigns, organizational changes, and monitoring the ambulance vehicles with cameras, etc. should be developed and implemented for specific groups such as inexperienced young paramedics or those with a history of collisions or traffic violations.

Ambulance drivers face numerous manual distractions during operation, especially when utilizing lights and sirens (Grundgeiger et al., 2014). To mitigate the necessity for drivers to divert their attention from the steering wheel controls for common light-and-siren functions could be placed onto the steering wheel itself. Research suggests that this adaptation could potentially halve the duration of one-handed driving. Implementing such a modification is cost-effective, and its efficacy could be evaluated through driving simulations (Grundgeiger et al., 2014).

Ambulance drivers face numerous manual distractions during operation, especially when utilizing lights and sirens (Grundgeiger et al., 2014). Integrating controls directly onto the steering wheel can significantly reduce these distractions (Kun, Wachtel, Miller, Son, & Lavallière, 2015; Miller & Kun, 2013). The Project54 system, used by law enforcement, with its touchscreen and voice command interface for device control, exemplifies an innovative approach that could serve as a model for emergency vehicles (Miller & Kun, 2013). This adaptation not only potentially halves the duration of one-handed driving but also enhances safety through ergonomic improvements. Implementing such modifications, which are cost-effective and whose efficacy can be evaluated through driving simulations, underscores the potential for reduced distractions and improved operational safety (Grundgeiger et al., 2014).

Studies have investigated the impact of fitness and health on occupational hazards. Studnek and Crawford discovered that emergency medical responders who rated their fitness as good or fair were three times as likely to experience back issues compared to those with excellent fitness (Studnek & Crawford, 2007). Another study prior back problems, self-reported health, and job satisfaction were identified as the most influential factors associated with recent back pain and its severity (Studnek, Crawford, Wilkins III, & Pennell, 2010). Therefore, paying attention to the fitness and healths of emergency medical responders can lead to reduction of paramedics involved in collisions in their workplace.

Moreover, various studies have explored alternative strategies to enhance the safety of medical emergency transportation. In 1997, Maguire and Porco implemented a comprehensive program of training and policy adjustments aimed at reducing ambulance collisions, resulting in a notable 50% decrease in such incidents (B. Maguire & Porco, 1997). Levick and Swanson introduced onboard computers in test ambulances to provide real-time auditory feedback to drivers regarding risky behaviors like driving without seat belts and speeding (Levick & Swanson, 2005). Their findings indicated a substantial reduction in violations, accompanied by significant cost savings in vehicle maintenance. Furthermore, Myers et al. utilized video recording devices coupled with post-event reviews to analyze and mitigate negative driving events, leading to a demonstrable decrease in such occurrences (Myers et al., 2012). These studies underscore the importance of innovative approaches in bolstering the safety of medical emergency transportation.

Haddon’s matrix serves as a useful tool for identifying the potential factors contributing to ambulance crashes. This tool enables us to target various aspects, including engineering enhancements such as reducing diesel emissions, enhancing seatbelt effectiveness, improving brake systems, and implementing rigorous maintenance protocols such as regular inspection of rear tire pressure. Moreover, it guides us in enhancing the safety of the patient compartment by addressing issues like eliminating protrusions and sharp corners, while also incorporating measures such as adding padding and restraint systems for equipment (B. J. Maguire, 2003).

Encouraging paramedics to wear seatbelts could be achieved through the implementation of safer ambulance designs and fostering cultural and attitude changes. Studies have revealed that existing ambulance designs often lack adequate restraints and seating configurations, resulting in paramedics not using seatbelts due to restricted access to patients (George, 2017). To enhance safety, the development of specially designed seatbelt systems can be pursued to prioritize both paramedic safety and efficient work practices (Clarkson, 1986). Communication systems between the driver seat and paramedics can be improved to enhance safety (Alrazeeni, 2021). Furthermore, Optimizing the equipment layout in the ambulance compartment can lead to reduce the risk exposure (Gilad & Byran, 2007). By making these modifications, paramedics will have a safer working environment, allowing them to perform their job effectively while also protecting their own lives.

This study suggests that individuals with a history of multiple collisions or traffic violations could be suitable candidates for implementing the program. This is in line with a study that found 41% of EMS drivers involved in collisions had poor driving records (Kahn et al., 2001b). It is therefore advisable and crucial for ambulance agencies to conduct a thorough screening of potential employees' driving records and obtain annual updates on motor vehicle citation reports for all personnel authorized to drive emergency vehicles.

Addressing the challenges posed by distraction and fatigue is paramount in ensuring the safety and effectiveness of EMS personnel. Distraction, particularly visual distraction, can significantly impair ambulance drivers' focus on the road and their ability to respond promptly to emergencies. Research has shown that operating emergency vehicles with light-and-siren systems introduces additional manual distractions, increasing the risk of accidents (Grundgeiger et al., 2014). Moreover, addressing fatigue is essential, as it can lead to cognitive impairment and reduced vigilance, akin to driving under the influence of alcohol (Arnedt et al., 2001; Dawson & Reid, 1997). EMS organizations should reevaluate their scheduling practices to minimize the potential hazards associated with long shifts, ensuring adequate rest periods for personnel. Additionally, coaching programs led by supervisors, utilizing techniques such as video recording to identify and address risky behaviors, can play a vital role in promoting safe driving practices among paramedics. By taking proactive measures to address distraction and fatigue, EMS agencies can safeguard the well-being of their personnel and enhance road safety for both first responders and the community they serve by implementing effective training programs and awareness initiatives targeting distraction management.

It is evident that training plays a crucial role in mitigating the risks associated with ambulance operations. Employers should prioritize regular training sessions for emergency vehicle drivers to instill essential safety protocols and practices. As an example, it is found that the emphasis should be placed on the importance of visually clearing intersections before proceeding and establishing eye contact with other drivers to enhance situational awareness (Custalow & Gravitz, 2004). Also, training programs should underscore the judicious use of emergency response modes, highlighting the necessity of activating them only when absolutely necessary. By integrating these recommendations into training initiatives, employers can better equip their personnel with the knowledge and skills essential for safe and effective ambulance operations, ultimately contributing to enhanced overall safety for both ambulance crews and the public.

5.1.3 Future Studies:

Conducting investigations into civilian driver behavior is a crucial aspect of understanding ambulance collisions and developing effective prevention strategies (Custalow & Gravitz, 2004; T. L. Sanddal et al., 2010; S. J. Weiss et al., 2001). By designing scenarios that simulate real-world situations, researchers can examine the role of various exposure variables and the behavior of civilian drivers in ambulance collisions. This includes investigating factors such as driver distraction, non-compliance with traffic laws, failure to yield the right of way, or improper response to emergency vehicles. By analyzing these specific errors made by civilian drivers and their impact on ambulance collisions, valuable insights can be gained. Researchers can identify common patterns and behaviors that contribute to collisions, helping to inform the development of targeted educational programs and initiatives. These initiatives can focus on raising awareness among civilian drivers about the importance of yielding to emergency vehicles, respecting traffic laws, and minimizing distractions while driving.

In order to advance our knowledge and enhance safety measures regarding ambulance collisions, it is important for future research to focus on the analysis of driver distraction and fatigue.

There are few studies on emergency vehicle on distraction specifically on police officers that shows mobile computer terminals by police officers while driving, as in-vehicle distractions, can be found to reduce awareness and increased cognitive workload (Zahabi & Kaber, 2018a). But, investigating the effects of this factor on the safety of ambulance drivers is still unclear, particularly in the vicinity of intersections, can provide valuable insights. One area of research could involve examining the impact of distractions on ambulance drivers, including behaviors such as mobile phone use or interaction with in-vehicle technology. By studying how these distractions affect driver performance and response times, researchers can gain a better understanding of the potential hazards they pose.

Fatigue is another crucial aspect that should be considered for the safety of medical emergency vehciles. For instance, a scoping review of literature showed associations between cognitive fatigue and physical fatigue with adverse health and performance outcomes among first responders, underscoring the necessity for a comprehensive fatigue risk management standard tailored to their needs (Yung, Du, Gruber, & Yazdani, 2021). Also, Law enforcement officers exhibit higher levels of lane deviation and collisions after long shifts during driving simulation (James & Vila, 2015).

Research focusing on the effects of fatigue resulting from long working hours and shift changes can provide valuable insights into the risks associated with tired ambulance drivers. By examining the impact of fatigue on driver alertness, reaction times, and decision-making abilities, researchers can identify potential dangers and develop guidelines and policies to mitigate these risks. Furthermore, exploring the effectiveness of interventions and training programs aimed at reducing distractions and managing fatigue among ambulance drivers would be beneficial. This could involve evaluating the impact of implementing technology restrictions or providing fatigue management education and resources to ambulance personnel. By assessing the effectiveness of these interventions, researchers can contribute to the development of evidence-based guidelines and practices that promote safer ambulance operations.

The high prevalence of health problems among ambulance drivers, including sleeping problems, back problems, and hearing problems and their impact on the safety of ambulance occupants, highlights the critical need for prioritizing the well-being of paramedics (Bentley & Levine, 2016; Studnek & Fernandez, 2008). These health issues can have significant implications for both the individual paramedics and the overall effectiveness of emergency medical services. Sleeping problems are of particular concern due to the demanding nature of ambulance work, which often involves long shifts and irregular working hours. Sleep deprivation and disrupted sleep patterns can negatively impact cognitive function, reaction times, and decision-making abilities, increasing the risk of collisions.

The impact of exposure variables, such as the number of kilometers driven, on the odds of ambulance collisions remains unclear due to limited data availability. It is proved that the prevalence of Emergency

Use (EU) crashes during daylight hours can be attributed to the increased volume of daytime ambulance calls for cardiac arrests (Pirrallo & Swor, 1994). By collecting and analyzing comprehensive data on the number of kilometers driven by ambulance vehicles, researchers can gain insights into the relationship between exposure and collision rates. This analysis can help determine if there is a correlation between increased exposure and a higher probability of ambulance collisions. To conduct this study, researchers would need access to detailed records of ambulance mileage, preferably over an extended period of time. By combining this data with information on collision occurrences, it would be possible to perform a robust analysis and establish the potential impact of exposure variables on ambulance collisions.

Given the lack of concrete data on Quebec drivers' adherence to laws regarding emergency vehicles, there is a significant opportunity for future research in this area. A potential study could systematically investigate drivers' compliance with regulations when encountering ambulances and other emergency vehicles. By employing observational methods, surveys, and analyzing traffic camera footage or traffic violations, researchers could assess the effectiveness of current laws and the level of public awareness. This research could provide valuable insights for policymakers, potentially leading to enhanced safety protocols and educational campaigns aimed at improving road safety for emergency responders and the general public road users.

In addressing the vital role of organizational levels in influencing road safety among paramedics, it is essential to consider the systems-based perspective inspired by Hollnagel's framework (Hollnagel, 2002, 2004), which delineates a hierarchical structure where both proximal and distant factors interact to affect collision risks and injury severity involving first responders. While this framework is robust in illustrating the multiple layers (from individual human factors to broader legislative influences) it becomes evident that each level can profoundly impact the outcomes of road safety of emergency responses. However, the thesis could not explore these dynamics in depth due to data limitations, particularly in capturing the intricate, often hidden variables within the organizational level that significantly influence road safety. This gap underscores the necessity for future research to incorporate a more extensive collection of qualitative and quantitative data. Future studies should aim to holistically evaluate how organizational practices as well as the socio-economic context influence road safety. This will not only enrich the understanding of systemic interactions but also enhance the formulation of more targeted and effective safety interventions. Thus, it is recommended that subsequent research considers these dimensions to further the recommendations on improving road safety for first responders.

To gain a comprehensive understanding of ambulance collisions and develop region-specific prevention strategies, conducting spatial analysis using internal collision data for each region is recommended. This involves examining the relationship between geography and collision events by overlaying collision data on regional maps to identify hotspots and variations in collision patterns. By comparing collision patterns and factors among regions, valuable insights can be gained, such as region-specific road hazards or traffic patterns that contribute to higher collision rates (Kim, Jang, & Choi, 2022; Lizarazo & Valencia, 2018). Understanding these factors is crucial for developing targeted prevention strategies. Additionally, spatial analysis can identify areas with fewer collisions, allowing researchers to identify successful measures and share them among regions for knowledge exchange and adoption.

Systematic literature reviews on ambulance collisions face challenges due to the availability of comprehensive data and varying sample sizes across studies. These limitations hinder quantitative analysis and meaningful comparisons. future research should aim to overcome challenges related to data availability and sample size variation in systematic literature reviews on ambulance collisions. Quantitative analyses and comparative studies using appropriate methodologies can facilitate a deeper understanding of the factors that contribute to ambulance collisions and aid in the development of effective prevention strategies.

To further deepen our understanding of ambulance collisions and devise more effective prevention strategies, future studies could prioritize investigation in the above areas. By focusing research efforts in these areas, e.g., fatigue, and distraction of drivers, we can enhance our understanding of ambulance collisions and develop evidence-based prevention strategies to ensure the safety of paramedics, ambulance occupants, and other road users. These programs can help decrease the occurrence of collisions by enhancing their driving skills and promoting adherence to traffic laws. By identifying the risk factors associated with ambulance collisions, the study offers valuable insights that policymakers can utilize to develop effective prevention strategies, ultimately contributing to improve the safety of ambulance operations and promote a safer environment for emergency response activities.

5.2 Conclusion

The research conducted emphasizes the crucial need to prioritize ambulance safety and sheds light on the various risks faced by both paramedics and occupants of ambulances, as well as other road users. The study specifically examines the contributing factors to ambulance collisions, such as the utilization of warning lights and sirens (WLSs) and the presence of hazardous locations, particularly at intersections in urban areas.

To accomplish this, the study employed a comprehensive approach that involved descriptive analysis and statistical tools, such as logit regression. The data utilized spanned a period of 11 years, from 2010 to 2020, and was obtained from the Société de l'assurance Automobile du Québec (SAAQ) for the analysis. Additionally, ten years of data, from 2010 to 2019, provided by Corporation Urgences-santé (CUS) were also incorporated.

The findings of the research reveal several significant factors that contribute to both injury and non-injury collisions. These include the age, experience, and gender of paramedics, weather conditions, residential areas, road function, traffic control, road surface conditions, and other relevant variables. The study finds out how these factors influence the increase in the number of collisions.

Furthermore, the research investigates the impact of collision location and time on the occurrence of collisions. Additionally, the study explores methods for effectively monitoring drivers based on the frequency of traffic collisions, yielding valuable insights through statistical analysis.

The risk associated with ambulance collisions is a matter of great concern, given the potential for severe injuries and even fatalities. Understanding the characteristics of drivers involved in such incidents is essential for promoting ambulance safety. Recent studies have shown that certain driver demographics are more susceptible to traffic collisions in ambulance settings. Specifically, male drivers, younger individuals, and those with less experience are found to be at higher risk.

Furthermore, a driver's previous collision history and traffic violations prove to be significant factors in predicting both the probability and severity of ambulance collisions. For civilian drivers, failure to yield the right of way are commonly observed contributing factors. These findings highlight the importance of addressing these risk factors through targeted training programs and educational initiatives.

In addition to driver characteristics, the timing and location of ambulance collisions offer valuable insights into enhancing ambulance safety. The research reveals that collisions are more prevalent during the afternoon hours and in urban areas, particularly at intersections. These findings highlight the importance of implementing targeted traffic regulations and measures that take into account the specific hazards faced by ambulances during emergency operations. The higher frequency of collisions during the afternoon hours suggests that additional precautions should be taken during this time period. This might involve increasing awareness among drivers about the presence of ambulances on the road and the need for yielding the right of way. Furthermore, traffic management systems could be adjusted to prioritize and facilitate the smooth passage of ambulances during peak hours.

Urban areas, with their complex traffic patterns and intersections, pose a heightened risk for ambulance collisions. Recognizing this, it becomes crucial to develop comprehensive strategies that address these specific challenges. One approach could involve granting ambulances the right of way at intersections or providing them with dedicated lanes to expedite their response time and minimize the potential for collisions. Additionally, incorporating intelligent traffic signal systems that can detect the presence of an approaching ambulance and adjust the timing of signals accordingly can significantly improve safety for both the ambulance and other road users.

When it comes to ambulance safety, the use of warning lights and sirens (WLSs) is a factor that has garnered significant attention. The utilization of WLSs is intended to alert other drivers on the road to the presence of an approaching ambulance, allowing them to yield the right of way and make way for the emergency vehicle. However, the increased speed and maneuverability associated with emergency response can introduce additional risks and challenges, potentially leading to collisions. Interestingly, studies examining the correlation between response modes and crash rates have produced varied results. While some studies have observed a higher incidence of crashes during emergency responses compared to non-emergency situations, other studies have failed to establish a statistically significant difference between the two response modes. A study focused on analyzing the work context of ambulance technicians during prehospital interventions, particularly concerning the duration of transport and the biomechanical aspects of loading the hydraulic stretcher (Prairie, 2017). The findings revealed that the duration of transport varied depending on the urgency of the situation, with emergency situations having a shorter average transport time compared to non-urgent cases. Also, the sequence of operations during care protocols differed between emergency and non-emergency situations, with more flexibility observed in non-emergency scenarios. These findings highlight the complex nature of ambulance collisions and suggest that additional factors beyond response mode may come into play. It is important to consider variables such as road conditions, driver behavior, traffic patterns, and situational awareness to gain a more comprehensive understanding of the factors contributing to ambulance crashes.

In summary, the safety implications of traffic collisions involving ambulances are a matter of significant concern for the well-being of paramedics, ambulance occupants, and other road users. Ambulances face a higher incidence of collisions compared to other commercial vehicles, and the use of warning lights and sirens further amplifies the risks involved. Various factors contribute to the probability and severity of these collisions, including the activation of warning lights and sirens, the presence of intersections in urban areas, and driver characteristics such as experience and past involvement in collisions or traffic violations. The higher frequency of collisions in urban areas, particularly at intersections, underscores the urgent need for targeted traffic regulations and measures that specifically address the unique challenges faced by ambulances. The current thesis represents a significant leap forward in the field of road safety by offering a comprehensive and in-depth understanding of ambulance safety and the various factors that influence ambulance collisions. Through meticulous analysis of extensive data spanning over a decade, the research has illuminated the risks faced not only by paramedics and ambulance occupants but also by other road users. The findings underscore the critical importance of prioritizing ambulance safety to safeguard lives during emergency response operations.

It is essential to develop comprehensive strategies aimed at preventing collisions and ensuring the safety of ambulances. This requires considering a range of factors, including driver characteristics, collision characteristics, the impact of warning lights and sirens, as well as the timing and locations of incidents. By identifying theses key contributing factors, the thesis presents policymakers and stakeholders with valuable insights to develop targeted strategies and preventive measures, such as educational programs and awareness campaigns, to promote a greater emphasis on ambulance safety. Ultimately, these advancements will help raise awareness, enhance training programs, foster a culture of safety for ambulance drivers and enhance the well-being of all individuals on the road. The commitment to prioritizing ambulance safety should be reflected in the implementation of preventive measures and the continuous evaluation of their effectiveness. Policymakers play a crucial role in integrating these measures into existing policies and regulations to ensure consistent and widespread adherence. By focusing on ambulance safety, policymakers can significantly reduce the frequency of collisions and mitigate the associated risks, safeguarding the well-being of those involved in emergency response situations.

APPENDIX A
Table A1 FINDINGS FROM INCLUDED STUDIES

Author	Findings
Chiu P.W. et al. 2018	From January 2011 to October 2016, 715 ambulance collisions resulted in 8 deaths and 1844 injuries. On average, one ambulance collision happened for every 8598 ambulance runs. Such collisions were 1.7 times more likely to result in fatality and 1.9 times more likely to involve injuries compared to overall traffic collisions. **Sex:** Fatal collisions: Male = 100%. Non-fatal collisions: Male = 681 (96.2%) and female = 27 (3.8%). **Time of day/Day of the week:** Fatal collisions: 2 (25%) from 4 p.m. to 8 p.m., and 3 (37.5%) from 8 p.m. to 12 a.m. Non-fatal collisions: 199 (28.1%) from 8 a.m. to 12 p.m. and 148 (20.9%) from 12 p.m. to 4 p.m. **Transportation mode:** Fatal collisions: Motorcycles = 8 (88.9%) and vehicles = 1 (11.1%). Non-fatal collisions: motorcycles = 488 (63.3%) and vehicles = 283 (36.7%). There were only 1 ambulance in 13 (1.8%) non-fatal collisions and 2 ambulances in 1 (0.1%) non-fatal collision. **Type of Environment:** Fatal collisions: 8 (100%) happened on urban roads and 5 (62.5%) occurred at 4-point intersections. Non-fatal collisions: 529 (74.8%) happened on urban roads and 463 (65.5%) occurred at 4-point intersections.
Custalow C.B., Gravitz C.S. 2004	From 1989 to 1997, 39 injuries (81 dead or injured) and 167 non-injury-causing collisions resulted from 4.3 collisions and 1.7 injuries or fatalities occurred per 10,000 responses (0.02%). Of these, 192 (93%) were moving collisions and 14 (7%) occurred while the ambulance was parked. **Age:** mean = 32 and standard deviation = 6.6. **Sex:** male = 157 (82%) and female = 35 (18%). **History of collisions:** Emergency drivers had a history of multiple collisions in 71% of cases. **Citation of the civilian driver:** Impaired civilian drivers can increase the odds ratio of injury-causing collisions by 6.1 ($p < 0.05$). **Type of Environment:** 57.9% of fatal collisions happened at intersections. Intersections can increase the odds ratio of injury-causing collisions by 4.3 ($p < 0.05$). Most fatal collisions happened on roads with speed limits of less than 50 mph; 87.2% of fatal crashes occurred on the straight segments of the roadway.

	Weather condition: There is no statistical difference between emergency and non-emergency responses by weather and road surface conditions; 79.8% of fatal crashes happened when the sky was clear (67.9% of fatal collisions occurred on dry roadways) and 5.5% of collisions occurred when there was snow or ice. **Response mode/Lights and sirens:** Warning lights and sirens (WLSs) were involved in 91% of response mode collisions.
Pirrallo R.G., Swor R.A. 1994	There were 109 fatal ambulance collisions (including 126 deaths) during the study period. The trend of fatal collisions when responding to emergency calls decreased while that for non-emergency calls increased. **Traffic citation:** When ambulance drivers are responding to an emergency call, they may commit a traffic violation more than in non-emergency modes (88.2% vs. 11.8%, respectively). **Time of day/Day of the week:** Emergency use (EU): 37.6% of fatal crashes occurred in the afternoon (12:00–18:00) and 15.6% happened at night. Non-emergency use (NEU): Most fatal crashes occurred in poor light conditions. There is no statistical difference between EU and NEU among different days of the week or seasons. Fatal collisions happened more in spring and summer compared to other seasons. The highest number of fatal collisions happened on Saturday (19.3%) and Monday (18.3%) and the lowest happened on Tuesday (9.2%). **Transportation mode:** Vehicles were involved in 92 (84.4%) of fatal collisions and non-motor vehicle users (most commonly pedestrians) were involved in 17 (15.6%) of fatal crashes. **Type of traffic collision:** Angle collisions = 72.8% and striking another vehicle = 74.3%. **Model of car:** There is no statistical difference between EU and NEU among years of manufacture. **Response mode/Lights and sirens**: EU = 75 (69%) and NEU = 34 (31%) fatal crashes.
Bentley M.A., Levine R. 2016	The percentage of "excellent" health in paramedics was 38.5% in 1999 which decreased to 32.2% in 2008. Sleeping problems (20–27%), back problems (20–24%), and hearing problems (7–10%) are among the top health issues. Sleepiness: 8.0% of ambulance drivers faced difficulty in driving for short distances and 17.5% for long distances. **Seat belt:** 75.8% of EMS professionals declared that their organization has a written seat belt policy, and 66.3% confirmed that enforcement of this policy was "very strict" or "somewhat strict." Front seat: 65.1% wear a seat belt, and patient compartment: 3.1% wear a seat belt.

	There was a 15.1% and 10% increase in using a seat belt for the front seat for work-related and non-work-related trips, respectively, from 2002 and 2008.
Ray A.F., Kupas D.F. 2005	Ambulances, with 2038 collisions, are more often involved in injuries (76%) compared to other similar-sized vehicles (61%). **Time of day/Day of the week:** There is a higher number of collisions in the evenings and on weekends compared to other times. **Transportation mode:** Pedestrian involvement is rare (<5%). **Type of traffic collision:** Almost half of the collisions are angle collisions (45%). **Type of environment:** Ambulances are more often involved in collisions at four-way intersections (43% vs. 23%, $p = 0.001$) and at traffic signals (37% vs. 18%, $p = 0.001$) compared to other similar-sized vehicles.
Becker L.R. et al. 2003	An estimated 37,132 ambulance vehicles were involved in 305 fatal and 36,693 non-fatal ambulance crashes between 1988 and 1997. This resulted in 0.24 emergency vehicle occupant (EVO) fatalities per fatal ambulance crash and 0.28 injured EVOs per injury-causing ambulance crash. **Seat belt:** The risk of being killed or injured is 3.77 ($p < 0.009$) and 6.49 ($p < 0.0001$) times lower for restrained ambulance occupants. The probability of being killed versus not injured for rear occupants was 5.32 times higher than for front seat occupants ($p < 0.0001$). **Response mode/Lights and sirens**: The probability of being killed or severely injured for non-emergency trips is significantly higher than for emergency trips.
Clawson J.J. et al. 1997	In 73 surveys, 60 collisions were found with a mean of 0.82 (per polled paramedic); 78% (57) of paramedics reported either being involved in a collision or witnessing at least one wake-effect collision. **Years of experience:** Min = 3, max = 12, and mean = 8.1.
Ray A.M., Kupas D.F. 2007	There were 311 ambulance crashes in rural areas and 1434 in urban areas between January 1997 and December 2001. **Liability of collision:** Urban collisions = 93% and rural collisions = 75%. There is a low percentage (<1%) of using alcohol and/or drugs in both urban and rural areas. **Time of day/Day of the week:** There is no difference between the time and day of rural and urban collisions.

	Type of traffic collision: Angled collisions with other vehicles are more common in urban compared to rural areas (54% vs. 19%, $p<0.0001$). However, striking a fixed object is more common in rural compared to urban areas (33% vs. 7%, $p < 0.0001$). **Transportation mode:** Collisions involving more than 1 vehicle (88% vs. 56%, $p < 0.0001$) and more than 4 people (35% vs. 23%, $p < 0.0001$) are more in urban compared to rural areas. Pedestrians are involved in less than 5% of collisions in both urban and rural areas. For almost half of the rural crashes, only the ambulance is involved. **Type of environment:** Crashes are more likely to occur at intersections (67% vs. 26%, $p < 0.0001$) or at a stop sign or signal (53% vs. 14%, $p < 0.0001$) in urban than rural areas. There is no difference in injury severity in urban and rural areas. **Weather conditions:** Adverse weather conditions: Crashes on snowy roads (13% vs. 5%, $p<0.0001$) and at night without light (25% vs. 4%, $p<0.0001$) are more common in rural compared to urban areas. Urban crashes happen frequently in rainy weather on wet roads. Non-adverse weather conditions: Collisions mostly happen on dry roads.
Gałązkowski R. et al. 2015	There were 32 ambulance collisions in 2008 and this number reduced to 5 collisions in 2012, resulting in 5 deaths and 120 injured in total. **Age:** Less than 30 years old. **Sex:** Male = 80% and female = 20% The trend of females involved in collisions increased in the last two years (2011–2012). **Time of day/Day of the week:** Working days = 120 injuries and non-working days = 33 injuries. The number of collisions on working days was two times more than on weekends. **Response mode/Lights and sirens**: Trips caring for a patient = 29%.
Sanddal T.L. et al. 2010	There were 79 (17%) fatalities, 279 (60%) injuries, and 108 (23%) non-injury-causing collisions in the studied period. This resulted in 99 deaths for ambulance occupants and 883 deaths for civilian drivers. The probability of being killed by civilian drivers is higher than the probability of being killed by paramedics. **Liability of collision:** Ambulance drivers were responsible in 29 cases (6%) and over the legal limit for alcohol use in 7 cases (2%). **Citations of civilian drivers:** Civilian drivers were cited in 39 (8%) collisions.

	Time of day/Day of the week: The highest percentage of collisions (n = 100 out of 320) happened between 12:00 and 17:59 and, after that, 85 crashes occurred between 06:00 and 11:59. Although there is no statistical difference (p = 0.201) between monthly variations, January (n=60), May (n=51), and December (n=47) had more collisions compared to other months. **Type of traffic collision:** Striking another vehicle or object = 150 (32%) and being struck by another vehicle = 209 (45%). Rollovers happened in 27 (14%) of 196 intersection crashes and 49 non-intersection crashes. **Type of environment:** Urban = 382 (82%) and rural = 84 (18%). Regarding urban collisions, 196 happened at intersections, and in 35% of them, ambulances struck another vehicle. **Weather conditions:** 51 (out of 54, with reported weather) collisions happened in adverse conditions, including 14 rain, 6 fog, 10 slippery, 1 whiteout/blizzard, 6 wet and icy, and 13 ice and snow. **Response mode/Lights and sirens**: Using emergency warning devices = 80% of reported cases (resulting in injuries or fatalities). Responding to an emergency = 68% of reported cases, returning from a call = 12% of reported cases, and routine matters = 21% of reported cases. Caring for no patient = 52% of reported cases and caring for one or more patients = 48% of reported cases.
Biggers W.A., Jr. et al. 1996	There were 86 ambulance collisions that resulted in 3.2 collisions per 100,000 miles driven or 4.8 collisions per 10,000 responses in 1993. These collisions led to 0.64 injuries per 100,000 miles driven or 0.94 injuries per 10,000 responses. There were no fatalities. **History of collisions:** Drivers with a history of ambulance collisions were involved in 33% of collisions. Five drivers, with prior ambulance collisions, were involved in fifteen (88.2%) injuries. **Liability of collision:** Ambulance drivers were not responsible of collisions in 68.7% of all cases, and they were liable of collisions in only 21.2% of cases. There was no difference between the responsibility and irresponsibility of ambulance drivers regarding collision severity. **Citations of civilian drivers:** Civilian drivers received 16 (88.8%) citations. **Time of day/Day of the week:** There was no difference between day and night or weekend and weekday regarding collision severity.

	Twenty-four collisions (33.33%) happened on Friday. **Type of traffic collision (or mechanism of collision):** The most common type involved backing up of the ambulance. **Type of environment:** 8% (n = 6) of collisions happened at controlled intersections and 85.1% of collisions (n = 63) occurred at other places. There was no statistical relation betweenthe collision occurred at an intersection and the severity of collisions. **Response mode/Lights and sirens**: 50% of collisions (n = 37) occurred during WLSs, resulting in 2.06 collisions per 10,000 responses. There was no statistical relation between using WLSs and the severity of collisions.
Fournier M. et al. 2013	**Seat belt:** 77 (72%) of emergency medical service (EMS) personnel used seat belts at departure. Fourteen (14%) EMS personnel wore seat belts and thirty-three (31%) stood up during patient transport. Stretcher belts and vacuum stretchers were used with the patient in 37 (35%) and 49 (46%) cases.
Saunders C.E., Heye C.J. 1994	From June 1989 to August 1991, 135 collisions happened, resulting in 13.3 collisions per 100,000 miles traveled. **Liability of collision:** WLSs: Failure to yield = 58.1% and inattention = 22.6%. No WLSs: Inattention = 41% and failure to yield = 4.7%. Ambulance drivers were liable in 48.9% of collisions with inattention as the primary cause of collisions. In cases of unsafe backing up, ambulance drivers were responsible for 67% of collisions. **Type of traffic collision:** The following movements were happening at the time of collision: Forward = 33.3%, stationary = 20.7%, backing up = 11.1%, turning = 17.7%, “squeezing” an ambulance between two other vehicles = 7.4%, and slowing, passing, and parking = 9.6%. **Speed:** In 89.6% of collisions, the speed was <20 mph, resulting in minor damage. Of collisions, 10.4% happened at moderate speed (21–45 mph), resulting in moderate or major damage in 33.33% of cases; 22.5% of WLS and 5.5% of non-WLS collisions happened at moderate speed. **Type of environment:** Urban street = 78.5%, parking or hospital lot = 20.8%, and freeway = 0.7%.

	Vehicle was en route, either to the scene or to the hospital = 50% and at the scene, at the hospital, or waiting for a call = 50% **Weather condition:** Clear weather and daylight = 68.1%, dark = 28.1%, and rain or light precipitation = 3.7%. **Response mode/Lights and sirens**: WLS calls = 45.9 collisions per 100,000 ambulance runs, resulting in an injury rate of 1.46 per 100,000 runs or 0.05 injuries per WLS collision. All patient-related collisions (10 out of 31 WLS collisions) happened when WLSs were used. There were 68.1 collisions per 100,000 journeys to the hospital with WLSs compared to 42.6 per 100,000 journeys en route to the call with WLSs. Non-WLS calls = 27.0 collisions per 100,000 ambulance runs, resulting in an injury rate of 22.2 per 100,000 runs or 0.48 injuries per WLS collision. All non-WLS collisions (n = 37) resulted in minor damage. There was no significant difference between WLS and non-WLS trips regarding the frequency of collisions.
Kahn C.A. et al. 2001	There were 339 ambulance crashes and 1.78 crashes per 1,000,000 persons over 18 years of age, resulting in 405 deaths and 838 injuries from 1987 to 1997 for the 50 states of the USA and the District of Columbia. **Traffic citations:** Ambulance drivers were cited for lane, signaling, turning, and intersection control violations in 16% of fatal collisions. There is no difference between fatal emergency and non-emergency crashes regarding citations. **History of collisions:** 41% of ambulance drivers had a previous collision, suspension, and/or motor vehicle citation. **Seat belts:** Use of the rear compartment can increase the odds of incapacitating and fatal injuries to 2.7 (95% CI 2.0–3.7) compared to the front seat. Unrestrained occupants have increased odds of incapacitating and fatal injuries of 2.5 (95% CI 1.8–3.6) compared to properly restrained occupants. Unrestrained rear occupants have increased odds of incapacitating and fatal injuries of 2.8 (95% CI 1.8–4.2) compared to unrestrained front occupants. **Time of day/Day of the week:** 39% of collisions happened from 12:00 p.m. to 6:00 p.m. There is no significant variation by year (p = 0.33), season (p = 0.74), or day of the week (p = 0.57). **Transportation mode:** Occupants of other vehicles accounted for 78% of fatalities. Thirty pedestrians and one bicyclist accounted for 9% of all fatalities. **Type of traffic collision:** Striking another vehicle = 80% and angle collisions = 56%.

	Fatal collisions are more common in emergency mode at intersections ($p < 0.001$), at an angle ($p < 0.001$), and with another motor vehicle ($p < 0.001$) compared to non-emergency mode. **Type of environment:** Straight roads = 86% and intersection = 53%. **Weather condition:** Dry roads = 69% and during clear weather = 77%. **Response mode/Lights and sirens**: 60% of collisions (n = 202) and 58% of fatal crashes (n = 233) happened during emergency use.
Weiss S.J. et al. 2001	There were 183 ambulance crashes, 2.6 persons/crash, resulting in 55 injury-causing collisions, 1.4 people/injury-causing crash, over the study period. This resulted in 78 injured people, 46% in rural areas and 54% in urban areas, and no deaths. **Traffic citation:** Ambulance and civilian drivers were cited more in urban areas. **Seat belt:** 80% of occupants (out of 484) were wearing seat belts. Those who did not use seat belts were more often injured in rural areas compared to urban areas. **Time of day/Day of the week:** There is no significant difference between urban and rural areas regarding weekday versus weekend, or day versus night. **Type of traffic collision:** Rural ambulances were significantly more likely to have an impact at the front while urban ambulances were more likely to have back-end collisions. There was an equal chance to be impacted on the side for rural and urban areas. **Type of environment:** Urban areas = 115 (out of 183) collisions or 19 collisions/million persons/year, resulting in 28 injury-causing collisions. In rural areas = 68 (out of 183) collisions or 8 collisions/million persons/year, resulting in 27 injury-causing collisions. The ambulance was more likely to be damaged, disabled, or towed in rural areas.
Schwartz R.J. et al. 1993	During the 6 months of the study period, 4.1% (439 in total) of paramedics were involved in a collision, resulting in 9.9 collisions/100 full-time equivalent (FTE)/year. Six injuries (out of eighteen collisions) occurred in the studied period. **Age:** Mean= 35. **Sex:** Male = 71% and female = 29%. **Seat belt:** Sixty-six percent of the drivers stated they were wearing their seat belts.

	Response mode/Lights and sirens: 10 (55.6%) collisions occurred while traveling to the scene, 4 (22.2%) while transporting the patient, and 4 (22.2%) at other times.
Watanabe B.L. et al. 2019	Response phase: 4.6 collisions per 100,000 trips without WLSs and 5.4 collisions per 100,000 with WLSs. Transport phase: 7 collisions per 100,000 trips without WLSs and 17.1 collisions per 100,000 with WLSs.
Lai Y.L. et al. 2018	Although there were 56 ambulance crashes in Taiwan from 2011 to 2015, the trend of the crashes did not increase while the number of an emergency call increased. **Time of day/Day of the week:** 29% of collisions occurred from 16:00–20:00 and 27% from 08:00–12:00. **Type of environment:** Most collisions happened in urban areas; 48% of collisions with motorists happened at intersections while passing red lights.
Yilmaz A. et al. 2016	Ambulance collisions resulted in 41.3% of work-related injuries (WRIs). In order, traffic collisions (31.9%), needlestick injuries (16.0%), ocular exposure to bodily fluids (15.4%), and sharp injuries (9.8%) are the most common mechanisms of WRI.
Reichard A.A., Jackson L.L. 2010	In 2000 and 2001, 123,900 injuries happened to emergency responders (3% of the total work-related injuries). Emergency medical services (EMSs) were involved in 18% (21,900) of these injuries, resulting in 4.9 injuries per 100 EMS workers; 8% of sprains and strains were caused by vehicle collisions. **Age:** <25 years old = 25% of EMS injuries.
Gülen B. et al. 2016	Of WRIs, 81.4% were due to ambulance collisions that led to the death of 3 paramedics and 7 civilian drivers. **Transportation mode:** In 53.6% of all cases, ambulances struck another vehicle. **Response mode/Lights and sirens**: 733 paramedics (81.4%) were involved in at least 1 collision while on duty.
Studnek J.R., Fernandez A.R. 2008	EMS professionals with sleep problems were more likely to be involved in a crash than those who did not face this problem (14.9% vs. 7.5%, respectively) The risk of collisions for those who had sleep problems within the last 12 months or spent more time in an ambulance was higher than for others.

	Age: Mean = 31.0 ± 8.2 The likelihood of being involved in a collision increased when decreasing the ambulance driver age by five years.
Larmon B. et al. 1993	**Seat belt:** Front seat: Most respondents use safety belts during emergency and non-emergency runs. Rear seat: No significant difference between respondents use of safety belts during emergency and non-emergency runs.
Tennyson J., Maranda L., Darnobid A.. 2015	No clear benefit and increased risk when using WLSs are not related to a reduction of the use of WLSs by the surveyed providers. **Response mode/Lights and sirens**: More than 80% of ambulance trips were made with WLSs in the surveyed group. It was found that paramedics know the risk of WLSs and having a history of collisions did not significantly affect their belief in the risk of using WLSs.
Ersoy G. et al. 2012	From 1996 to 2005, 15 deaths (out of 21 cases) happened on the day of the collision and 6 (40%) deaths caused by ambulance collisions were found among the forensic medical reports. **Age:** Mean = 47. Paramedics were aged 0–92 years. **Type of collision:** Crashes of two vehicles = 12 (57.14%), rollovers = 4 (19.05%), run off road = 1 (4.76%), and unknown = 4 (19.05%). **Type of environment**: Highways out of cities = 14 (66%), roads in cities = 6 (29%), and unknown scene = 1 (5%). **Response mode/Lights and sirens**: Transport from the scene to the health center = 6 patients (29%) and transport from one health center to another one= 15 patients (71%).
Maguire B.J. et al. 2002	According to the Census of Fatal Occupational Injuries (CFOI), 67 (74%) EMS fatalities were caused by traffic collisions and 46 of these paramedics were driving at the time of collision. According to the National Emergency Medical Services Memorial Service (NEMSMS), 52 (74%) EMS fatalities were caused by transportation-related incidents and 33 (47%) of them were associated with ground vehicle crashes or pedestrian fatalities. **Response mode/Lights and sirens**: 6 (out of 33) EMS fatalities identified from NEMSMS were struck by moving vehicles; 5 were caring for patients, and 1 was listed as “other.”

BIBLIOGRAPHIE

Afdhal, A., & Elizar, E. (2015). *Enhanced route guidance and navigation for emergency vehicle using V2I-based cooperative communication.* Paper presented at the 2015 international electronics symposium (ies).

Alrazeeni, D. (2021). Knowledge, attitude, and practice toward COVID-19 among paramedics in Saudi Arabia: Implications for educational program. *Int J Adv Appl Sci, 8*(3), 71-77.

American Medical Association. (1903). *Principles of Medical Ethics of the American Medical Association*. Retrieved from Chicago, IL.

American Medical Association. (2001). *Principles of Medical Ethics of the American Medical Association*. Retrieved from https://code-medical-ethics.ama-assn.org/principles

Apiratwarakul, K., Artpru, R., Ienghong, K., Rattanaseeha, W., Piwhom, T., & Phungoen, P. (2018). The study of driving behavior when encounter the light and siren on ambulance. *Srinagarind Medical Journal-ศรีนครินทร์ เวช สาร, 33*(5), 404-407.

Arnedt, J. T., Wilde, G. J., Munt, P. W., & MacLean, A. W. (2001). How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accident Analysis & Prevention, 33*(3), 337-344.

Asgharizadeh, E., Kadivar, M., Noroozi, M., Mottaghi, V., Mohammadi, H., & Chobar, A. P. (2022). The intelligent traffic management system for emergency medical service station location and allocation of ambulances. *Computational intelligence and neuroscience, 2022*.

Auerbach, P. S., Morris, J. A., Phillips, J. B., Redlinger, S. R., & Vaughn, W. K. (1987). An analysis of ambulance accidents in Tennessee. *JAMA, 258*(11), 1487-1490.

Barishansky, R. M., & O'Connor, K. (2007). Best practices for EMS. Who's found a better way of doing things, and how can you benefit too? *Emergency medical services, 36*(1), 71-74.

Becker, J., & Hugelius, K. (2021). Driving the ambulance: an essential component of emergency medical services: an integrative review. *BMC Emergency Medicine, 21*(1), 1-8.

Becker, L. R., Zaloshnja, E., Levick, N., Li, G., & Miller, T. R. (2003). Relative risk of injury and death in ambulances and other emergency vehicles. *Accident Analysis & Prevention, 35*(6), 941-948.

Bęczkowska, S., Grabarek, I., & Mróz, K. (2020). *Occupational Safety in a Medical Ambulances.* Paper presented at the Research Methods and Solutions to Current Transport Problems: Proceedings of the International Scientific Conference Transport of the 21st Century, 9–12th of June 2019, Ryn, Poland 15.

Bell, J. L., Taylor, M. A., Chen, G.-X., Kirk, R. D., & Leatherman, E. R. (2017). Evaluation of an in-vehicle monitoring system (IVMS) to reduce risky driving behaviors in commercial drivers: Comparison of in-cab warning lights and supervisory coaching with videos of driving behavior. *Journal of safety research, 60*, 125-136.

Bellavance, F., Duguay, P, pignatelli, S. (2016). *Road Accidents at Work - an overview*. Retrieved from Quebec: www.irsst.qc.ca

Bentley, M. A., & Levine, R. (2016). A national assessment of the health and safety of emergency medical services professionals. *Prehospital and disaster medicine, 31*(S1), S96-S104. doi:10.1017/S1049023X16001102

Biggers, W. A., Zachariah, B. S., & Pepe, P. E. (1996). Emergency medical vehicle collisions in an urban system. *Prehospital and Disaster Medicine, 11*(3), 195-201.

Bonneson, J. B. (2014). *Highway Safety Manual (HSM)*. Washington, D.C.: American Association of State Highway and Transportation Officials.

Borowsky, A., Oron-Gilad, T., Meir, A., & Parmet, Y. (2012). Drivers' perception of vulnerable road users: A hazard perception approach. *Accident Analysis & Prevention, 44*(1), 160-166.

Boston University of Public Health. (2016). SAS - The One Sample t-Test. Retrieved from https://sphweb.bumc.bu.edu/otlt/mph-modules/bs/sas/sas4-onesamplettest/SAS4-OneSampleTtest7.html

Botzoris, G., Profillidis, V., Galanis, A., Lemonakis, P., & Argyropoulos, G. (2022). *An Investigation of Distraction Factors on Road Safety.* Paper presented at the Conference on Sustainable Urban Mobility.

Boufous, S., & Williamson, A. (2006). Work-related traffic crashes: A record linkage study. *Accident Analysis & Prevention, 38*(1), 14-21. doi:10.1016/j.aap.2005.06.014

Broughton, J., Baughan, C., Pearce, L., Smith, L., & Buckle, G. (2003). Work-related road accidents. In: Citeseer,.

Bui, D., Hu, C., Jung, A., Pollack Porter, K., Griffin, S., French, D., . . . Burgess, J. (2018). Driving behaviors associated with emergency service vehicle crashes in the US fire service. *Traffic injury prevention, 19*(8), 849-855.

Bui, D. P., Balland, S., Giblin, C., Jung, A. M., Kramer, S., Peng, A., . . . Porter, K. P. (2018). Interventions and controls to prevent emergency service vehicle incidents: A mixed methods review. *Accident Analysis & Prevention, 115*, 189-201.

Canada, T. (2023). Canadian Motor Vehicle Traffic Collision Statistics: 2021. Retrieved from https://tc.canada.ca/en/road-transportation/statistics-data/canadian-motor-vehicle-traffic-collision-statistics-2021

Canadian institute for health Information. (2022). COVID-19 Intervention Timeline in Canada. Retrieved from https://www.cihi.ca/en/covid-19-intervention-timeline-in-canada#:~:text=The%20first%20COVID%2D19%20case,reflect%20the%20actual%20infection%20rate.

Centers for Disease Control and Prevention (CDC). (2020a). *CDC health information for international travel* (Vol. Chapter 8).

Centers for Disease Control and Prevention (CDC). (2020b). National Center for Injury Prevention and Control (NCIPC). Web-based Injury Statistics Query and Reporting System (WISQARS). Retrieved from https://www.cdc.gov/injury/wisqars

Centers for Disease Control Prevention. (2005). NCIPC: Web-based Injury Statistics Query and Reporting System (WISQARS). In.

Centers for Disease Control Prevention. (2020). *Health Information for International Travel*.

Chapman, P. R., & Underwood, G. (1998). Visual search of driving situations: Danger and experience. *Perception, 27*(8), 951-964.

Chen, C., Zhang, G., Tarefder, R., Ma, J., Wei, H., & Guan, H. (2015). A multinomial logit model-Bayesian network hybrid approach for driver injury severity analyses in rear-end crashes. *Accident Analysis & Prevention, 80*, 76-88.

Chen, X., Guyette, F. X., Peitzman, A. B., Billiar, T. R., Sperry, J. L., & Brown, J. B. (2019). Identifying patients with time-sensitive injuries: association of mortality with increasing prehospital time. *Journal of Trauma and Acute Care Surgery, 86*(6), 1015-1022.

Chiou, Y.-C., & Fu, C. (2015). Modeling crash frequency and severity with spatiotemporal dependence. *Analytic Methods in Accident Research, 5*, 43-58.

Chiu, P.-W., Lin, C.-H., Wu, C.-L., Fang, P.-H., Lu, C.-H., Hsu, H.-C., & Chi, C.-H. (2018). Ambulance traffic accidents in Taiwan. *Journal of the formosan medical association, 117*(4), 283-291.

Choi, E.-H. (2010). *Crash factors in intersection-related crashes: An on-scene perspective*.

Claret, P. L., del Castillo, J. d. D. L., Moleón, J. J. J., Cavanillas, A. B., Martín, M. G. a., & Vargas, R. G. (2003). Age and sex differences in the risk of causing vehicle collisions in Spain, 1990 to 1999. *Accident Analysis & Prevention, 35*(2), 261-272. doi:10.1016/S0001-4575(02)00004-0

Clarke, C., Zak, M.J. (1999). Fatalities to law enforcement officers and firefighters, 1992-97. *Environments, 15*(2), 3-8.

Clarke, D. D., Ward, P., Bartle, C., & Truman, W. (2009). Work-related road traffic collisions in the UK. *Accident Analysis & Prevention, 41*(2), 345-351.

Clarkson, L. E. (1986). Ambulance safety stabilizer harness for para-medics. In: Google Patents.

Clawson, J. J., Martin, R. L., Cady, G. A., & Maio, R. F. (1997). The wake-effect—emergency vehicle-related collisions. *Prehospital and disaster medicine, 12*(4), 41-44.

Coleman, J. A. (1996). *Summary Report of the FHWA Study Tour for Speed Management and Enforcement Technology*: The Administration.

Committee for Guidance on Setting and Enforcing Speed Limits. (1998). *Managing speed: Review of Current Practice for Setting and Enforcing Speed Limits*.

Corman, M. K. (2018). Driving to work: The front seat work of paramedics to and from the scene. *Symbolic interaction, 41*(3), 291-310.

Cortés, C. E., & Stefoni, B. (2023). Trajectory Simulation of Emergency Vehicles and Interactions with Surrounding Traffic. *Journal of Advanced Transportation, 2023*.

Cowan Jr, J. A., Jones, B., & Ho, H. (2006). Safety belt use by law enforcement officers on reality television: A missed opportunity for injury prevention? *Journal of Trauma and Acute Care Surgery, 61*(4), 1001-1004.

Custalow, C. B., & Gravitz, C. S. (2004). Emergency medical vehicle collisions and potential for preventive intervention. *Prehospital Emergency Care, 8*(2), 175-184.

Dawson, D., & Reid, K. (1997). Fatigue, alcohol and performance impairment. *Nature, 388*(6639), 235-235.

Delavary, M., de Montigny, L., Castellucci, H. I., Tremblay, M., & Lavallière, M. . (2021). *Characteristics of Paramedics’ Collisions in a Metropolitan Area of Quebec: a Bayesian Network Analysis*. Paper presented at the Communication présentée au 30e Conférence de l’ACPSER et 14e Congrès mondial de la PRI : L’équité : La sécurité routière pour tous grâce à la Vision zéro et à la sécurité routière durable, Canada.

Delavary, M., Ghayeninezhad, Z., & Lavallière, M. (2023). Prevalence and characteristics of ambulance collisions, a systematic literature review. *Safety, 9*(2), 24.

Delavary, M., Tremblay, M., & Lavallière, M. (2024). Navigating Paramedics' Safety: Unraveling Factors in Emergency Service Vehicle Incidents. *International Journal of Paramedicine*(5), 82-102.

Dong, B., Ma, X., Chen, F., & Chen, S. (2018). Investigating the differences of single-vehicle and multivehicle accident probability using mixed logit model. *Journal of Advanced Transportation, 2018*.

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., . . . Leitao, P. J. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography, 36*(1), 27-46.

Drucker, C. J. (2013). *An epidemiological approach to emergency vehicle advanced warning system development: a two-phase study.* University of Minnesota.

Durak, D., Fedakar, R., Türkmen, N., Akgöz, S., & Baduroğlu, E. (2008). Road traffic collisions in Bursa, Turkey, during 2003, 2004 and 2005. *Injury, 39*(5), 547-553. doi:10.1016/j.injury.2007.07.013

Elvik, M. R., Ortenwall, M. P., Mackay, M. M., Pelckmans, M. J., Monclus, M. J., Tecl, M. J., . . . Wodzin, M. E. (2007). Social and economic consequences of road traffic injury in Europe. *Brussels, Belgium*.

Erich, J. (2007). Rules of the road. The must-haves of an effective vehicle-safety program. *EMS magazine, 36*(6), 69-73, 75.

Ersoy, G., Ersoy, O., Yuksekbas, O., Kurnaz, G., Akyildiz, E. U., & Ekemen, S. (2012). Why did the patient die? The relationship between ambulance accidents and death of patients: Forensic medical issues. *Journal of forensic and legal medicine, 19*(8), 474-479.

European Agency for Safety and Health at Work (EU-OSHA). (2019). *Commuting accidents*. Retrieved from Luxembourg: Oshwiki.org

European Agency for Safety and Health at Work(EU-OSHA). (2019). Commuting accidents. Retrieved from https://oshwiki.osha.europa.eu/en

Ferron, R., Agarwal, G., Cooper, R., & Munkley, D. (2021). The effect of COVID-19 on emergency medical service call volumes and patient acuity: a cross-sectional study in Niagara, Ontario. *BMC Emergency Medicine, 21*(1), 1-8.

Fetto Law Group. (2018). Statistics on Emergency Vehicle Accidents in the United States. Retrieved from https://www.fettolawgroup.com/personal-injury-blog/2018/march/statistics-on-emergency-vehicle-accidents-in-the/

Finucane, M. J. (2010). Vehicle detection. New technology aims to inform the public about emergency vehicles. *EMS magazine, 39*(3).

Fournier, M., Chenaitia, H., Masson, C., Michelet, P., Behr, M., & Auffray, J.-P. (2013). Crew and patient safety in ambulances: results of a personnel survey and experimental side impact crash test. *Prehospital and disaster medicine, 28*(4), 370-375.

Galazkowski, R., Binkowska, A., & Samolinski, K. (2015). Occupational injury rates in personnel of emergency medical services. *Annals of agricultural and environmental medicine, 22*(4). doi:10.5604/12321966.1185775

Garber, N. J., & Ehrhart, A. A. (2000). Effect of speed, flow, and geometric characteristics on crash frequency for two-lane highways. *Transportation Research Record, 1717*(1), 76-83.

George, A. (2017). Making an Inherently Dangerous Profession Safer: New Ambulance Designs.

Gilad, I., & Byran, E. (2007). Ergonomic evaluation of the ambulance interior to reduce paramedic discomfort and posture stress. *Human factors, 49*(6), 1019-1032.

Gotbaum, R. (2005). Safety of medical residents' long hours questioned. *National Public Radio, 28*.

Gouvernement du Québec. (2021). How to Obey the Move-Over Law. Retrieved from https://www.quebec.ca/en/transports/traffic-road-safety/traffic-rules-tips-for-all-vehicles/rules-safety-tips-driving-traffic-lanes/move-over-law

Gouvernement du Québec. (2023a). *CODE DE LA SÉCURITÉ ROUTIÈRE*. Retrieved from https://www.legisquebec.gouv.qc.ca/fr/pdf/lc/C-24.2.pdf

Gouvernement du Québec. (2023b). Traffic Rules for Emergency Vehicles. Retrieved from https://www.quebec.ca/en/transports/traffic-road-safety/traffic-rules-tips-various-transportation-modes/traffic-rules-for-emergency-vehicles

Grande, Z., Castillo, E., Mora, E., & Lo, H. K. (2017). Highway and road probabilistic safety assessment based on Bayesian network models. *Computer-Aided Civil and Infrastructure Engineering, 32*(5), 379-396.

Grayson, G. (1999). *Company cars and road safety.* Paper presented at the Behavioural Research in Road Safety IX. PA3524/99.

Grundgeiger, T., Scharf, M., Grundgeiger, J., & Scheuchenpflug, R. (2014). *Manual Distractions of Ambulance Drivers: Light-and-siren vs. Non-light-and-siren Travel.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

Gülen, B., Serinken, M., Hatipoğlu, C., Özaşır, D., Sönmez, E., Kaya, G., & Akpınar, G. (2016). Work-related injuries sustained by emergency medical technicians and paramedics in Turkey. doi: 10.5505/tjtes.2015.94224.

Gustafson, B. G. (2015). Then & now: trends in fatal law enforcement traffic collisions. *Policing: An International Journal of Police Strategies & Management*.

Haddon Jr, W. (1972). A logical framework for categorizing highway safety phenomena and activity. *Journal of Trauma and Acute Care Surgery, 12*(3), 193-207.

Hatamabadi, H., Vafaee, R., Haddadi, M., Abdalvand, A., Esnaashari, H., & Soori, H. (2012). Epidemiologic study of road traffic injuries by road user type characteristics and road environment in Iran: a community-based approach. *Traffic injury prevention, 13*(1), 61-64.

Heightman, A. (2006). Crew & patient safety receive high priority. *JEMS: a journal of emergency medical services, 31*(2), 114.

Heightman, A. (2009). Protect your rear. Putting your best lights forward. *JEMS: a journal of emergency medical services, 34*(10), 12-12.

Hockey, G. R. J. (2003). Operator Functional State GRJ Hockey et al.(Eds.) IOS Press, 2003. *Operator Functional State: The Assessment and Prediction of Human Performance Degradation in Complex Tasks, 355*, 8.

Hollnagel, E. (2002). *Understanding accidents-from root causes to performance variability.* Paper presented at the IEEE 7th Human Factors Meeting, Scottsdale AZ.

Hollnagel, E. (2004). *Barriers and accident prevention*. Burlington VT: Ashgate.

Holmberg, M., Nørgaard, J., Eriksson, M., & Svensson, A. (2020). Dyadic teams and nursing care: A critical incident study of nurses in the emergency medical service. *Journal of clinical nursing, 29*(19-20), 3743-3753.

Hsiao, H., Chang, J., & Simeonov, P. (2018). Preventing emergency vehicle crashes: status and challenges of human factors issues. *Human factors, 60*(7), 1048-1072.

Huang, H., Chin, H. C., & Haque, M. M. (2008). Severity of driver injury and vehicle damage in traffic crashes at intersections: a Bayesian hierarchical analysis. *Accident Analysis & Prevention, 40*(1), 45-54.

Isenberg, D., Cone, D. C., & Stiell, I. G. (2012). A simple three-step dispatch rule may reduce lights and sirens responses to motor vehicle crashes. *Emergency medicine journal, 29*(7), 592-595.

Jackman, S., Tahk, A., Zeileis, A., Maimone, Ch., Fearon, J., and Meers, Z., . (2020). *Political Science Computational Laboratory*. Retrieved from https://github.com/atahk/pscl

James, S. M., & Vila, B. (2015). Police drowsy driving: Predicting fatigue-related performance decay. *Policing: An International Journal of Police Strategies & Management*.

Johnston, K., & Scialfa, C. (2016). Hazard perception in emergency medical service responders. *Accident Analysis & Prevention, 95*, 91-96.

Kahn, C. A., Pirrallo, R. G., & Kuhn, E. M. (2001). Characteristics of fatal ambulance crahses in the United States: An 11-year retrospective analysis Prehospital Emergency Care, 5(3), 261-269.

Keebler, J. R., Lazzara, E. H., & Misasi, P. (2017). *Human factors and ergonomics of prehospital emergency care*: CRC Press.

Kim, H., Jang, J., & Choi, Y. (2022). Spatial analysis of collision risk of child pedestrians–A case of urban elementary school districts in Busan, Korea. *Travel behaviour and society, 29*, 165-175.

Kmet, L. M., Cook, L. S., & Lee, R. C. (2004). Standard quality assessment criteria for evaluating primary research papers from a variety of fields.

Koski, A., & Sumanen, H. (2019). The risk factors Finnish paramedics recognize when performing emergency response driving. *Accident Analysis and Prevention, 125*, 40-48.

Król, A. (2014a). Application of the Bayesian network to identify the correlations in the circumstances of the road accidents for selected streets in Katowice. *Logistyka*(4), 2947-2957.

Król, A. (2014b). Application of the Bayesian network to identify the correlations in the circumstances of the road accidents for selected streets in Katowice. *Logistyka*(4), 2947--2957.

Kun, A. L., Wachtel, J., Miller, W. T., Son, P., & Lavallière, M. (2015). *User interfaces for first responder vehicles: views from practitioners, industry, and academia.* Paper presented at the Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.

Lai, Y.-L., Chou, Y.-H., & Chang, L.-C. (2018). An intelligent IoT emergency vehicle warning system using RFID and Wi-Fi technologies for emergency medical services. *Technology and health care, 26*(1), 43-55.

Langham, M., Hole, G., Edwards, J., & O'Neil, C. (2002). An analysis of'looked but failed to see'accidents involving parked police vehicles. *Ergonomics, 45*(3), 167-185.

Larmon, B., LeGassick, T. L., & Schriger, D. L. (1993). Differential front and back seat safety belt use by prehospital care providers. *The American journal of emergency medicine, 11*(6), 595-599.

Lavallière, M., & Bellavance, F. (2020). Perceptions et attitudes face à la conduite automobile dans un contexte de travail chez les policiers et fonction et les aspirants policiers. *IRSST. https://www. irsst. qc. ca/publications-et-outils/publication/i/101070/n/perceptions-etattitudes-face-a-la-conduite-automobile-dans-un-contexte-de-travail-chez-les-policiers-en-fonction-et-les-aspirants-policiers*.

Lavallière, M., Delavary, M., de Montigny, L., Tremblay, M., & Ignacio Castellucci, H. (2021). *Characteristics of Paramedics' Collisions in a Metropolitan Area of Quebec: a Bayesian Network Analysis*. Paper presented at the Canadian Association of Road Safety Professionals.

Lavallière, M., Duguay, P., & Bellavance, F. . (2015). *Characterization of work-related collisions in a sample of emergency drivers: a Quebec's province study*. Paper presented at the Transportation Research Board 94th Annual Meeting, Washington D.C.

Le, J. (2018). Logistic Regression in R Tutorial. Retrieved from https://www.datacamp.com/community/tutorials/logistic-regression-R

Lebeau, M., Duguay, P. (2021). *Le coût des accidents routiers au travail survenus au Québec de 2001 à 2015*.

Lee, P.-H., & Huang, T.-C. (2014). *A geocasting application for ambulance service.* Paper presented at the 2014 International Conference on Computing, Networking and Communications (ICNC).

Lenné, M. G., Triggs, T. J., Mulvihill, C. M., Regan, M. A., & Corben, B. F. (2008). Detection of emergency vehicles: Driver responses to advance warning in a driving simulator. *Human Factors, 50*(1), 135-144.

Levick, N. R., & Swanson, J. (2005). *An optimal solution for enhancing ambulance safety: implementing a driver performance feedback and monitoring device in ground emergency medical service vehicles.* Paper presented at the Annual Proceedings/Association for the Advancement of Automotive Medicine.

Lilitsis, E., Xenaki, S., Athanasakis, E., Papadakis, E., Syrogianni, P., Chalkiadakis, G., & Chrysos, E. (2018). Guiding management in severe trauma: reviewing factors predicting outcome in vastly injured patients. *Journal of Emergencies, Trauma, and Shock, 11*(2), 80.

Lin, P.-W., Kang, K.-P., & Chang, G.-L. (2004). *Exploring the effectiveness of variable speed limit controls on highway work-zone operations.* Paper presented at the Intelligent transportation systems.

Lindridge, J., Blackwood, L., & Edwards, T. (2022). 238 A qualitative exploration of restraint decisions made by paramedics and advanced paramedics in the context of acute behavioural disturbance (ABD) in the pre-hospital setting. In: British Medical Journal Publishing Group.

Lindsey, J. T., & Barron, A. E. (2008). Effects of simulation on emergency vehicle drivers' competency in training. *Prehospital and disaster medicine, 23*(4), 361-368.

Lizarazo, C., & Valencia, V. (2018). Macroscopic spatial analysis of pedestrian crashes in Medellin, Colombia. *Transportation research record, 2672*(31), 54-62.

Lloyd, D., Wilson, D., Mais, D., Deda, W., & Bhagat, A. (2015). Reported Road Casualties Great Britain: 2014 Annual Report. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/467465/rrcgb-2014.pdf

Luo, S., Yi, X., Shao, Y., & Xu, J. (2022). Effects of distracting behaviors on driving workload and driving performance in a city scenario. *International journal of environmental research and public health, 19*(22), 15191.

Lutman, D., Montgomery, M., Ramnarayan, P., & Petros, A. (2008a). Ambulance and aeromedical accident rates during emergency retrieval in Great Britain. *Emergency medicine journal: EMJ, 25*(5), 301.

Lutman, D., Montgomery, M., Ramnarayan, P., & Petros, A. (2008b). Ambulance and aeromedical accident rates during emergency retrieval in Great Britain. *Emergency Medicine Journal, 25*(5), 301-302.

Lynn, P., & Lockwood, C. R. (1999). The accident liability of company car drivers. *TRL Report, 317*. Retrieved from https://trid.trb.org/view/499630

Lyu, N., Cao, Y., Wu, C., Xu, J., & Xie, L. (2018). The effect of gender, occupation and experience on behavior while driving on a freeway deceleration lane based on field operational test data. *Accident Analysis & Prevention, 121*, 82-93. doi:10.1016/j.aap.2018.07.034

Lyu, P., Lin, Y., Wang, L., & Yang, X. (2017). Variable speed limit control for delay and crash reductions at freeway work zone area. *Journal of Transportation Engineering, Part A: Systems, 143*(12), 04017062.

Ma, Z., Shao, C., Yue, H., & Ma, S. (2009). *Analysis of the logistic model for accident severity on urban road environment.* Paper presented at the 2009 IEEE Intelligent Vehicles Symposium.

Maguire, B., & Porco, F. (1997). EMS and vehicle safety. *Emergency Medical Services, 26*(11), 39-40, 42.

Maguire, B. J. (2011). Transportation-related injuries and fatalities among Emergency Medical Technicans and Paramedics. *Prehospital and disaster medicine, 26*(5), 346. doi:10.1017/S1049023X11006601

Maguire, B. J., Hunting, K. L., Guidotti, T. L., & Smith, G. S. (2005). Occupational injuries among emergency medical services personnel. *Prehospital Emergency Care, 9*(4), 405-411. doi:10.1080/10903120500255065

Maguire, B. J., Hunting, K. L., Smith, G. S., & Levick, N. R. (2002). Occupational fatalities in emergency medical services: a hidden crisis. *Annals of emergency medicine, 40*(6), 625-632.

Marasini, G., Caleffi, F., Machado, L. M., & Pereira, B. M. (2022). Psychological consequences of motor vehicle accidents: a systematic review. *Transportation research part F: traffic psychology and behaviour, 89*, 249-264.

Markham, K. (2014). Simple guide to confusion matrix terminology. *data school, 25*.

Mascarenhas, M. D. M., Souto, R. M. C. V., Malta, D. C., Silva, M. M. A. d., Lima, C. M. d., & Montenegro, M. d. M. S. (2016). Characteristics of motorcyclists involved in road traffic accidents attended at public urgent and emergency services. *Ciencia & saude coletiva, 21*, 3661-3671. doi:10.1590/1413-812320152112.24332016.

Mayou, R., Bryant, B., & Duthie, R. (1993). Psychiatric consequences of road traffic accidents. *British Medical Journal, 307*(6905), 647-651.

McCann, L. (2022). *The paramedic at work: a sociology of A new profession*: Oxford University Press.

McGowan, D. R. (2014). Safety on the streets. *Journal of Emergency Medical Services*, 10-12.

McLeod, A. I. (2005). Kendall rank correlation and Mann-Kendall trend test. *R Package Kendall*.

Miller, W. T., & Kun, A. L. (2013). *Using speech, GUIs and buttons in police vehicles: field data on user preferences for the Project54 system.* Paper presented at the Proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.

Ministère de l'Emploi et de la Solidarité social. (2023). Act respecting pre-hospital emergency services. Retrieved from https://www.legisquebec.gouv.qc.ca/en/document/cs/S-6.2?langCont=en#ga:l_i-gb:l_iii-h1

Mirbaha, B., Safaarzadeh, M., & Noruzoliaee, M. H. (2012). A model for predicting schoolchildren accidents in the vicinity of rural roads based on geometric design and traffic conditions.

Missikpode, C., Peek-Asa, C., Young, T., & Hamann, C. (2018). Does crash risk increase when emergency vehicles are driving with lights and sirens? *Accident Analysis & Prevention, 113*, 257-262.

Mujalli, R. O., López, G., & Garach, L. (2016). Bayes classifiers for imbalanced traffic accidents datasets. *Accident Analysis & Prevention, 88*, 37-51.

Mund, E. (2010). Developing a safety culture. Rockland Paramedic Services is serious about safety. *EMS world, 39*(10), S6-S7.

Myers, L. A., Russi, C. S., Will, M. D., & Hankins, D. G. (2012). Effect of an onboard event recorder and a formal review process on ambulance driving behaviour. *Emergency medicine journal, 29*(2), 133-135.

Nabatilan, L. B. (2007). *Factors that influence visual attention and their effects on safety in driving: an eye movement tracking approach*: Louisiana State University and Agricultural & Mechanical College.

National Highway Traffic Safety Administration (NHTSA). *Estimate of crashes involving emergency vehicles by year, emergency vehicle and emergency use, 2001–2010*.

National Law Enforcement Officers Memorial Fund. (Preliminary 2016). *Law Enforcement Officer Fatalities Report*. Retrieved from http://www.nleomf.org/assets/pdfs/reports/Preliminary-2016-EOY-Officer-Fatalities-Report.pdf

Noh, E. Y. (2011). *Characteristics of law enforcement officers' fatalities in motor vehicle crashes*. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811411

Noonan, D., Ryan, M., Whelan, D., & O'Neill, D. (2023). Medical fitness to drive, emergency service vehicles and crash risk. *Irish Journal of Medical Science (1971-), 192*(5), 2487-2493.

Nordberg, M. (2006a). Driving online. Internet-based program for emergency vehicle safe operations now available. *Emergency Medical Services, 35*(1), 40.

Nordberg, M. (2006b). In Winter Park, employee safety comes first. *Emergency Medical Services, 35*(6), 79-79.

Norii, T., Nakao, S., Miyoshi, T., Hatanaka, T., Miyake, T., Okunaga, A., . . . Yang, M. (2024). Ambulance traffic crashes in Japan: characteristics of casualties, and efforts to improve ambulance safety. *Prehospital Emergency Care*(just-accepted), 1-16.

Pino, O., Baldari, F., Pelosi, A., & Giucastro, G. (2014). Risk factors of road crash: An empirical analysis among an Italian drivers sample. *International Journal of Innovation and Applied Studies, 5*(4), 301.

Pirrallo, R. G., & Swor, R. A. (1994). Characteristics of fatal ambulance crashes during emergency and non-emergency operation. *Prehospital and Disaster Medicine, 9*(2), 125-132.

Pollatsek, A., Narayanaan, V., Pradhan, A., & Fisher, D. L. (2006). Using eye movements to evaluate a PC-based risk awareness and perception training program on a driving simulator. *Human Factors, 48*(3), 447-464.

Prairie, J. (2017). *Contexte de travail de l'intervention préhospitalière et analyses biomécanique et ergonomique de l'activité d'embarquement de la civière chez les techniciens ambulanciers paramédicaux.* Université Laval.

Prohn, M. J., Herbig, B. (2022). Traffic safety knowledge gain of ambulance drivers after simulator-based training. *BMC Medicine Education, 22*(216). doi:https://doi.org/10.1186/s12909-022-03279-w

Proudfoot, S. L. (2005.). Ambulance crashes: fatality factors for EMS workers. *Emergency Medical Service, 34* (6), 71–73.

Proulx, M. H., Vacon, C., Couturier, J., & Lavallière, M. (2016). *La Conduite d'un Véhicule Ambulancier; Analyse des caractéristiques des collisions d'ambulance et des facteurs de risque associés.*

Provost, F., & Domingos, P. (2000). Well-trained PETs: Improving probability estimation trees. *Raport instytutowy IS-00-04, Stern School of Business, New York University*.

Ray, A. F., & Kupas, D. F. (2005). Comparison of crashes involving ambulances with those of similar-sized vehicles. *Prehospital Emergency Care, 9*(4), 412-415.

Ray, A. M., & Kupas, D. F. (2007). Comparison of Rural and Urban Ambulance Crashes in Pennsylvania. *Prehospital emergency care, 11*(4), 416-420.

Reichard, A. A., & Jackson, L. L. (2010). Occupational injuries among emergency responders. *American journal of industrial medicine, 53*(1), 1-11.

Reichard, A. A., Marsh, S. M., & Moore, P. H. (2011). Fatal and nonfatal injuries among emergency medical technicians and paramedics. *Prehospital emergency care, 15*(4), 511-517. doi:10.3109/10903127.2011.598610

Reichard, A. A., Marsh, S. M., Tonozzi, T. R., Konda, S., & Gormley, M. A. (2017). Occupational injuries and exposures among emergency medical services workers. *Prehospital emergency care, 21*(4), 420-431.

Rezapour, M., Moomen, M., & Ksaibati, K. (2019). Ordered logistic models of influencing factors on crash injury severity of single and multiple-vehicle downgrade crashes: A case study in Wyoming. *Journal of safety research, 68*, 107-118.

Sagarra, S. E. (2015). New ambulance design aims to improve safety. *EMS world, 44*(5), 42-44.

San Francisco Trial Lawyer Association (SFTLA). (2019). Statistics on Emergency Vehicle Accidents in the United States. Retrieved from https://www.fettolawgroup.com/Personal-Injury-Blog/.

Sanddal, N. D., Albert, S., Hansen, J. D., & Kupas, D. F. (2008). Contributing Factors andIssues Associated with Rural Ambulance Crashes: Literature Review andAnnotated Bibliography. *Prehospital Emergency Care, 12*(2), 257-267.

Sanddal, T. L., Sanddal, N. D., Ward, N., & Stanley, L. (2010). Ambulance crash characteristics in the US defined by the popular press: a retrospective analysis. *Emergency medicine international*.

Saunders, C. E., & Heye, C. J. (1994). Ambulance collisions in an urban environment. *Prehospital and Disaster Medicine, 9*(2), 118-124.

Saunders, G., & Gough, A. (2003). Emergency ambulances on the public highway linked with inconvenience and potential danger to road users. *Emergency medicine journal, 20*(3), 277-280.

Savolainen, P. T., Dey, K. C., Ghosh, I., Karra, T. L., & Lamb, A. (2009). *Investigation of emergency vehicle crashes in the state of Michigan*.

Schwartz, R. J., Benson, L., & Jacobs, L. M. (1993). The prevalence of occupational injuries in EMTs in New England. *Prehospital and disaster medicine, 8*(1), 45-50.

Sedlár, M. (2022). Work-related factors, cognitive skills, unsafe behavior and safety incident involvement among emergency medical services crew members: relationships and indirect effects. *International journal of occupational safety and ergonomics, 28*(2), 1281-1290.

Segui-Gomez, M. (2000). Evaluating worksite-based interventions that promote safety belt use. *American Journal of Preventive Medicine, 18*(4), 11-22.

Sergio A. Useche, B. C., Francisco Alonso & Luis Montoro (2020). Multidimensional prediction of work traffic crashes among Spanish professional drivers in cargo and passenger transportation. *International Journal of Occupational Safety and Ergonomics*.

Soares, S., Campos, C., Leitão, J. M., Lobo, A., Couto, A., & Ferreira, S. (2021). Distractive Tasks and the Influence of Driver Attributes. *Sustainability, 13*(9), 5094.

Société de l'assurance automobile du Québec (2020). ROAD SAFETY RECORD. Retrieved from https://saaq.gouv.qc.ca/en/saaq/documents/road-safety-record/

Société de l'assurance automobile du Québec. (2020b). *The SAAQ road safety report*. Retrieved from Quebec, Canada: https://saaq.gouv.qc.ca/en/saaq/documents/road-safety-record/

Société de l'assurance automobile du Québec. (2022). *OBTAINING A DRIVER'S LICENCE*. Retrieved from https://saaq.gouv.qc.ca/en/drivers-licences/obtaining-licence/emergency-vehicle-class-4a

Société de l'assurance automobile du Québec. (2023). ROAD SAFETY RECORD. Retrieved from https://saaq.gouv.qc.ca/en/saaq/documents/road-safety-record

Société de l'assurance automobile du Québec. (July 21, 2021). In an Emergency Vehicle. Retrieved from https://saaq.gouv.qc.ca/en/road-safety/modes-transportation/emergency-vehicle

Sterud, T., Ekeberg, Ø., & Hem, E. (2006). Health status in the ambulance services: a systematic review. *BMC health services research, 6*, 1-10.

Studnek, J. R., & Crawford, J. M. (2007). Factors associated with back problems among emergency medical technicians. *American journal of industrial medicine, 50*(6), 464-469.

Studnek, J. R., Crawford, J. M., Wilkins III, J., & Pennell, M. L. (2010). Back problems among emergency medical services professionals: The LEADS health and wellness follow-up study. *American journal of industrial medicine, 53*(1), 12-22.

Studnek, J. R., & Fernandez, A. R. (2008). Characteristics of emergency medical technicians involved in ambulance crashes. *Prehospital and disaster medicine, 23*(5), 432-437.

Symmons, M. A., Haworth, N. L., & Mulvihill, C. M. (2005). *Characteristics of police and other emergency vehicle crashes in New South Wales*. Paper presented at the Road Safety Research, Policing and Education Conference, IRB, Wellington.

Tavakoli Kashani, A., Rakhshani Moghadam, M., Taheri, A., Müller, G., & Dissanayake, D. A. (2023). How does the safety performance of different vehicle types and weights affect the severity of a driver's injury? *International journal of crashworthiness*, 1-12.

Taylor, Y. L. H. (2020). *Shift workers, fatigued driving and the impact on road safety-An investigation involving police service employees.* University of Leeds.

Tennyson, J., Maranda, L., & Darnobid, A. (2015). Knowledge and beliefs of EMS providers toward lights and siren transportation. *Western journal of emergency medicine, 16*(3), 465.

Thomas, B. J., O'Meara, P., Edvardsson, K., & Spelten, E. (2020). Barriers and opportunities for workplace violence interventions in Australian paramedicine: a qualitative study. *Australasian Journal of Paramedicine, 17*, 1-9.

Thorvaldsen, N. Ø., Bergem, A. K., Holst, Ø., & Häikiö, K. (2022). Coercion in the ambulance setting. *Tidsskrift for Den norske legeforening*.

Tiesman, H. M., Gwilliam, M., Rojek, J., Hendricks, S., Montgomery, B., & Alpert, G. (2019). The impact of a crash prevention program in a large law enforcement agency. *American journal of industrial medicine, 62*(10), 847-858.

Tiesman, H. M., Heick, R. J., Konda, S., & Hendricks, S. (2015). Law enforcement officers' risk perceptions toward on-duty motor-vehicle events. *Policing: An International Journal of Police Strategies & Management, 38*(3), 563-577.

Toroyan, T., & Peden, M. (2007). Youth and road safety. *Geneva: World Health Organization*, 5-13.

Transport Canada. (2017). Canadian Motor Vehicle Traffic Collision Statistics. Retrieved from https://tc.canada.ca/en/road-transportation/motor-vehicle-safety/canadian-motor-vehicle-traffic-collision-statistics-2017

Transport Canada. (2018). Canadian Motor Vehicle Traffic Collision Statistics. Retrieved from https://tc.canada.ca/en/road-transportation/motor-vehicle-safety/canadian-motor-vehicle-traffic-collision-statistics-2018

U.S. Fire Administration. (2014). *Firefighter fatalities in the United States in 2013*. Retrieved from https://www.usfa.fema.gov/downloads/pdf/publications/firefighter-fatalities-2013.pdf

United Nations. (2015). General Assembly Resolution 70/1, Transforming Our World: the 2030 Agenda for Sustainable Development. A/70/L.1. Retrieved from http:// undocs.org/A/RES/70/1

Urgences-Sante. (2020). In. Quebec, Canada.

US National Highway Traffic Safety Administration. (2014). Commercial drivers license. Retrieved from http://www.nhtsa.gov/people/injury/enforce/cvm/cmv_license.html

Useche, S. A., Alonso, F., Cendales, B., & Llamazares, J. (2021). More than just "stressful"? Testing the mediating role of fatigue on the relationship between job stress and occupational crashes of long-haul truck drivers. *Psychology research and behavior management*, 1211-1221.

Useche, S. A., Cendales, B., Montoro, L., & Esteban, C. (2018). Work stress and health problems of professional drivers: a hazardous formula for their safety outcomes. *PeerJ, 6*, e6249.

Useche, S. A., Ortiz, V. G., & Cendales, B. E. (2017). Stress-related psychosocial factors at work, fatigue, and risky driving behavior in bus rapid transport (BRT) drivers. *Accident Analysis & Prevention, 104*, 106-114.

Vanlaar, G. M. W., Lyon, C., Simmons, S., & Robertson, R. (2022). *Road Safety Monitor 2022: Drinking and Driving in Canada*. Retrieved from Canada: https://tirf.ca/projects/road-safety-monitor-drinking-driving/

Vila, B. (2006). Impact of long work hours on police officers and the communities they serve. *American journal of industrial medicine, 49*(11), 972-980.

Virginia Transportation Research Council. (2008). *Variance in Speed, Not the Speed Limit, Poses Greatest Risk on Interstate Roads*. Retrieved from https://www.virginiadot.org/projects/resources/newsl-i81-winter00%20.pdf

Vorko-Jović, A., Kern, J., & Biloglav, Z. (2006). Risk factors in urban road traffic accidents. *Journal of safety research, 37*(1), 93-98.

Wang, Y., Wu, Z., Yang, X., & Huang, L. (2013). Design and implementation of an emergency vehicle signal preemption system based on cooperative vehicle-infrastructure technology. *Advances in Mechanical Engineering, 5*, 834976.

Watanabe, B. L., Patterson, G. S., Kempema, J. M., Magallanes, O., & Brown, L. H. (2019). Is use of warning lights and sirens associated with increased risk of ambulance crashes? A contemporary analysis using National EMS Information System (NEMSIS) data. *Annals of emergency medicine, 74*(1), 101-109. doi:10.1016/j.annemergmed.2018.09.032

Weiss, S. J., Ellis, R., Ernst, A. A., Land, R. F., & Garza, A. (2001). A comparison of rural and urban ambulance crashes. *The American journal of emergency medicine, 19*(1), 52-56.

White, J. (2020). PubMed 2.0. *Medical Reference Services Quarterly, 39*(4), 382-387.

Wilbur, M. (2011). Good news: line-of-duty deaths down in 2010. *Firehouse, 36*(3), 114-116.

Wilde, G. J. (1989). Accident countermeasures and behavioural compensation: The position of risk homeostasis theory. *Journal of Occupational Accidents, 10*(4), 267-292. doi:10.1016/0376-6349(89)90021-7

Wiwekananda, K. S. S., Hamukti, R. P., Yogananda, K. S. S., Calisto, K. E., & Utomo, P. S. (2020). Understanding factors of ambulance delay and crash to enhance ambulance efficiency: an integrative literature review. *Journal of Community Empowerment for Health, 3*, 213.

Wolfe, S. E., Rojek, J., Alpert, G., Tiesman, H. M., & James, S. M. (2015). Characteristics of officer-involved vehicle collisions in California. *Policing: An International Journal of Police Strategies & Management*.

World Health Organization. (2008). *Emergency medical services systems in EU: Report of an assessment project coordinated by the WHO.* . Retrieved from Geneva, Switzerland.

World Health Organization (WHO). (2018). Fact Sheet about road injuries. Retrieved from http://www.who.int/mediacentre/factsheets/fs358/en/

World Health Organization (WHO). (2019). *Global Status Report on Road Safety 2018*. Retrieved from Geneva: https://www.who.int/publications/i/item/9789241565684

World Health Organization (WHO). (2020). *Road traffic injuries*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

Yannis, G., Antoniou, C., Papadimitriou, E., & Katsochis, D. (2011). When may road fatalities start to decrease? *Journal of safety research, 42*(1), 17-25.

Yasmin, S., Anowar, S., & Tay, R. (2012). Effects of drivers' actions on severity of emergency vehicle collisions. *Transportation Research Record, 2318*(1), 90-97.

Yasmin, S., Anowar, S., & Tay, R. (2021). Emergency vehicles and traffic safety. *Encyclopedia of Transportation*.

Yilmaz, A., Serinken, M., Dal, O., Yaylacı, S., & Karcioglu, O. (2016). Work-related injuries among emergency medical technicians in western Turkey. *Prehospital and disaster medicine, 31*(5), 505-508.

Yoo, J. B., Kim, J., & Park, C. Y. (2010). *Road reservation for fast and safe emergency vehicle response using ubiquitous sensor network.* Paper presented at the 2010 ieee international conference on sensor networks, ubiquitous, and trustworthy computing.

Yung, M., Du, B., Gruber, J., & Yazdani, A. (2021). Developing a Canadian fatigue risk management standard for first responders: defining the scope. *Safety science, 134*, 105044.

Zahabi, M., & Kaber, D. (2018a). Effect of police mobile computer terminal interface design on officer driving distraction. *Applied ergonomics, 67*, 26-38.

Zahabi, M., & Kaber, D. (2018b). Identification of task demands and usability issues in police use of mobile computing terminals. *Applied ergonomics, 66*, 161-171.

Zeng, Q., Wen, H., Huang, H., & Abdel-Aty, M. (2017). A Bayesian spatial random parameters Tobit model for analyzing crash rates on roadway segments. *Accident Analysis & Prevention, 100*, 37-43.