

Historical Analysis of the Types of Accidents in the North American Region

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Accidents can occur for several reasons in the chemical and petrochemical industries, whether during the transportation of hazardous materials or at industrial facilities. Frequently, the reasons for these accidents are physical effects that can damage the equipment. If equipment is damaged and a fire occurs, it can provoke a domino effect, increasing the severity of the primary event, as mentioned by Mercedes and colleagues (Gómez-Mares et al., 2008), where databases focused on European countries, such as the Major Hazard Incident Data Service (MHIDAS), are used to analyse the types of accidents that occurred due not only to fires, explosions, and gas emissions, but also different equipment malfunctions or the transportation of hazardous materials, with the total number of accidents being recorded. In the present work, an in-depth analysis of the different types of accidents that occurred in the chemical and petrochemical industries between the 90s and recent years in the North American region (i.e., the United States, Mexico, and Canada), has been carried out. The database used for the present research work was the International Disaster Database (EM-DAT Query Tool, 2020). On this platform, different types of accidents, such as those caused naturally, technologically, and by more complex disasters, can be investigated. In the present research article, a total of 340 accidents which occurred over the last 3 decades in the United States, Mexico, and Canada, have been analysed. The total number of accidents per decade for each country was collected and their types, causes, consequences, and number of deaths were analysed. Finally, safety measures have also been suggested through the comparisons obtained for the three countries.

1. Introduction

Frequently, the reasons for industrial accidents are physical effects that can damage the equipment. If the equipment receives damages and a fire occurs, it can create a domino effect, as mentioned by Mercedes Gómez and colleagues (Gómez-Mares et al., 2008), where they use databases focused on European countries, such as the Major Hazard Incident Data Service (MHIDAS) to analyze not only the types of jet fire accidents caused by explosions, emissions, or gases, but also by equipment or on the road, with the total number of accidents recorded. They also used the database known as "*Analyse, Recherche et Information sur les Accidents*" (ARIA), which is a data collector of accidents of all types created by the French Ministry of Environment and the database of the Failure and Accidents Technical Information System (FACTS), which stores the number of accidents that involve hazardous materials. Other types of historical measurements for the analysis were those used by Darbra and colleagues (Darbra et al., 2010), where they indicated that domino effects can occur in different ways. In that study, both the MHIDAS database and Major Accidents Reporting System (MARS), were used to classify the number of accidents for each year in the given report, resulting in an accident frequency table. In the present study, a historical analysis of the types of accidents in the North American region has been developed. An in-depth analysis of the types of technological accidents that occurred in the industry between the 90s and recent

years in the North American region, i.e., the United States, Mexico, and Canada, has been carried out, having in total 340 accidents in the last 3 decades.

In the present article, the total number of accidents per decade for each country, the types of accidents, and the number of deaths registered were analyzed to determine the development of safety measures in the industry in these three countries. According to the data collected in the present study, it was observed that in Mexico, the causes that occurred the least between 1990 and 2023 were gas leaks and fire, so it was deduced that accidents occur mostly due to equipment failure that cause explosions and tanks in transportation that suffer road accidents. The current article mentions that, as time progressed, the chemical industry evolved and grew on a large scale, so both the number of accidents and their type have changed over time. It is also noteworthy that, in the current database used in this article, a total of 340 accidents were analyzed among the North American countries: Mexico, which has 129 accidents, the United States with a total of 183 accidents, and Canada, which has only 28 recorded accidents. This article also includes the equipment that provoked or was the main cause in each incident, as well as the number of injured and dead caused by the accidents.

1.1 Serious Accidents with Fire

In the chemical industry, it is common knowledge that there can be accidents caused by fires, although there may be different reasons why they occur. The most common causes are equipment failures and human error during the operation of the different types of equipment in the chemical industry, such as compressors and heat exchangers, among others. A lot of accidents are usually caused by jet fires, flames derived from gas leaks from a process equipment, caused either by human error or malfunctioning equipment, provoking a chain reaction called a domino effect (Casal, 2017). One example of a technological accident would be what happened in Coatzacoalcos, Veracruz, Mexico, in the Pajaritos complex at the Clorados III plant in 2016, where a gas pipeline exploded due to an electrical failure. This accident left 24 registered deaths and 136 injured people, in addition to a large debt to be covered by the owners of the company MexiChem. This accident was preventable, or at least could have been controlled better, because days earlier, people living nearby noticed strong odors of ethanol and chlorine, among other compounds. Similarly, some employees reported failures and several leaks in the equipment and pipelines, but those responsible ignored these warnings (Petroquimex, 2021), and the employees were forced to work under those conditions. Had these reports been heeded in a timely manner, this accident could have been prevented (Demos and Córdova, 2021).

2. Methodology

2.1 Database used for this investigation

The database used for this article is the International Disaster Database. On this platform, it is possible to investigate the different types of accidents, such as accidents caused naturally, technologically, and by more complex disasters (EM-DAT Query Tool, 2020). It should be noted that EM-DAT does not include all accidents, but focuses on major disasters as a global collection of human and economic losses for disasters with at least one of the following criteria: (i) 10 fatalities, (ii) 100 affected people, (iii) a declaration of state of emergency, (iv) a call for international assistance (EM-DAT Query Tool, 2020). In this article, technological accidents occurred from 1990 to the present have been analyzed. Accidents occurred in all continents can be viewed, and for each continent, each country can be analyzed. In this case, only the accidents in the North American area have been analyzed, consisting of Mexico, the United States, and Canada, with a total of 340 accidents between the three countries from 1990 to the present.

2.2 Countries Analyzed

Using the information given by the International Disaster Database, the number of disasters that occurred in the technological category were analyzed, including what year they occurred in, between the 1990s to the present, in the North American region, which includes Mexico, the United States, and Canada, in order to analyze not only the number of accidents, but also the mortality rate, the type of disaster, and the number of accidents for each decade analyzed in the document. The United States has more than half of the accidents recorded among the three countries, with a total of 183 accidents, Canada has the least with 8% of all the accidents analyzed and only 28 accidents recorded, and Mexico has almost 40% of those recorded in the database, with a total of 129 registered accidents. In Mexico, accidents involving technological disasters have been very common. A well-known case was what happened in Coatzacoalcos, Veracruz, in the Clorados III plant, which is focused on vinyl chloride production, and exploded due to a chain reaction and chemical spills (Demos and Córdova, 2021). This is a great example of the consequences that can be generated, both economically and for the people around, since this accident caused an acid rain and a high number of deaths. Among the countries to be analyzed, the United States has the most recorded technological accidents, with a total of 183. Of the three countries analyzed, Canada is the one with the fewest number of registered accidents, with a total of 28.

3. Results and Discussion

This section analyzes the type of accidents occurred, the years in which they occurred, the total deaths recorded, and the types of disasters.

3.1 Mexico

In Mexico, different types of accidents have been registered, with a total of 129 registered accidents, where most have been due to “transportation accidents”, an example being when the transport tanks of products sent by companies explode for some sellers, being a total of 87. The types of accidents are represented in Figure 1a, showing that in Mexico, transport accidents are the most common, with a tendency of two out of three types of accidents, or 68%. Only 20% occur in the industry, and miscellaneous accidents are the least common in Mexico, with the remaining 12% of recorded accidents. Of the subtypes, the type of accidents most frequently recorded in Mexico are road accidents (44%), followed by explosions (16%), air (11%), rail (10%), and fire (5%). Many of the recorded accidents occur on the road, when the compound causes destruction on the road, and as for explosions, many of the accidents occur due to human error or lack of maintenance. The classification is explained in Figure 1b.

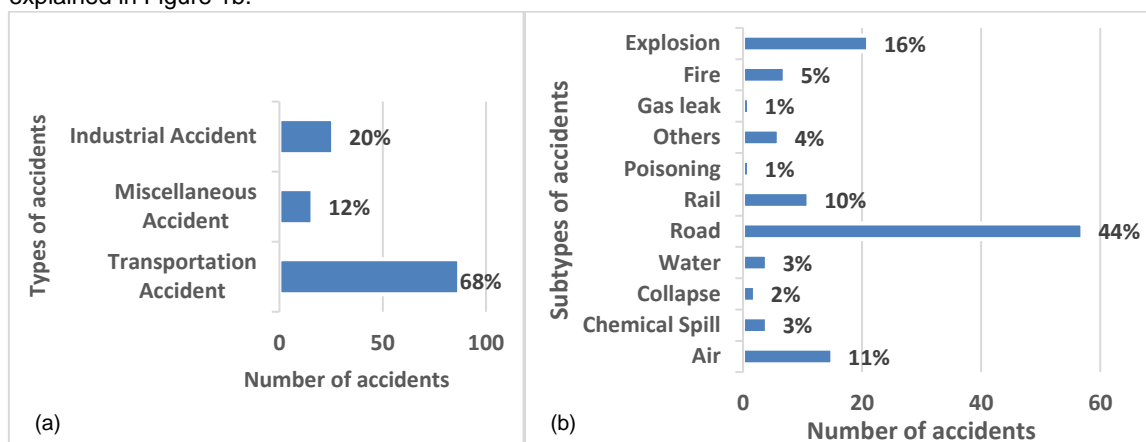


Figure 1: (a) Types of accidents in Mexico; (b) Subtypes of accidents in Mexico (EM-DAT Query Tool, 2020).

In Figure 2a, it can be seen that 38% of the accidents occurred in the 90s, while 33% were in recent years. There have been no visible improvements in accident prevention, with the 2000s being the decade with the fewest accidents, with only 29%, compared to the 33% occurred in the 2010s and the 38% occurred in the 1990s.

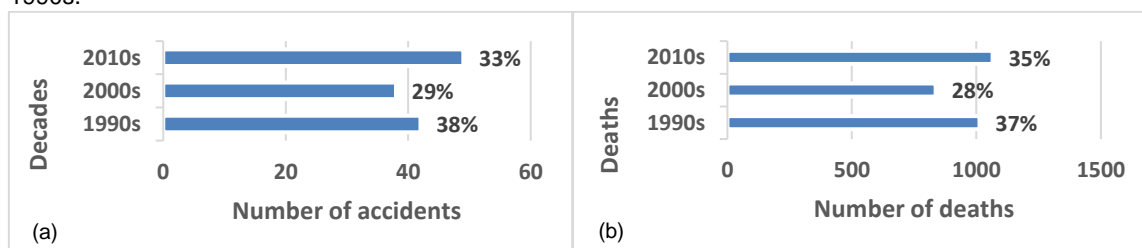


Figure 2: (a) Number of accidents occurred in Mexico per decade; (b) Deaths by industrial accidents recorded in Mexico per decade (EM-DAT Query Tool, 2020).

The number of deaths by industrial accidents registered per decade has also been analyzed. Unfortunately, there was a total of almost 3000 deaths recorded, with the decades of the 1990s and the 2010s having more than 1,000 deaths recorded, as can be seen in the above figure (Figure 2b). In the registry of deaths in Mexico, 37% were recorded in the 1990s, while 35% were recorded in recent years. This tendency correlates to the number of accidents recorded per decade in Figure 2b, where there is no visible improvement in accident prevention, with the 2000s being the decade with the fewest deaths, but not so far behind the other two decades, with 28% recorded. Finally, the possible causes that led to these accidents were analyzed (Figure 3). The following figure shows the causes of the recorded accidents, where in this case, in Mexico the highest number of accidents occur due to transportation accidents and mechanical failures (30%), being followed by accidents occurred by chemicals used in chemical and petrochemical plants (29%), accidents caused due to human error (26%), and unspecified causes (15%).

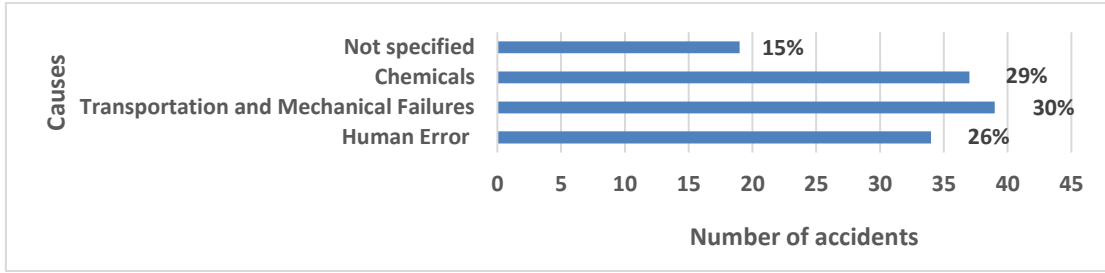


Figure 3: Causes of accidents in Mexico (EM-DAT Query Tool, 2020).

3.2 Canada

In Canada, 28 accidents were recorded, where most accidents have occurred in industry, representing 64%, having a total of 18 accidents, while both miscellaneous and those taking place during transport have a percentage of 18%, with only 5 accidents registered in each category, as can be seen in Figure 4a. Figure 4b shows the accident subtypes most frequently recorded in Canada. In Figure 4b, there is a triple tie, with water, air, and road being most common subtypes of accidents, with 18% each. They are followed by rail, fire, and others, with 11% each. The last subtypes are explosions and chemicals spills, with 7% each.

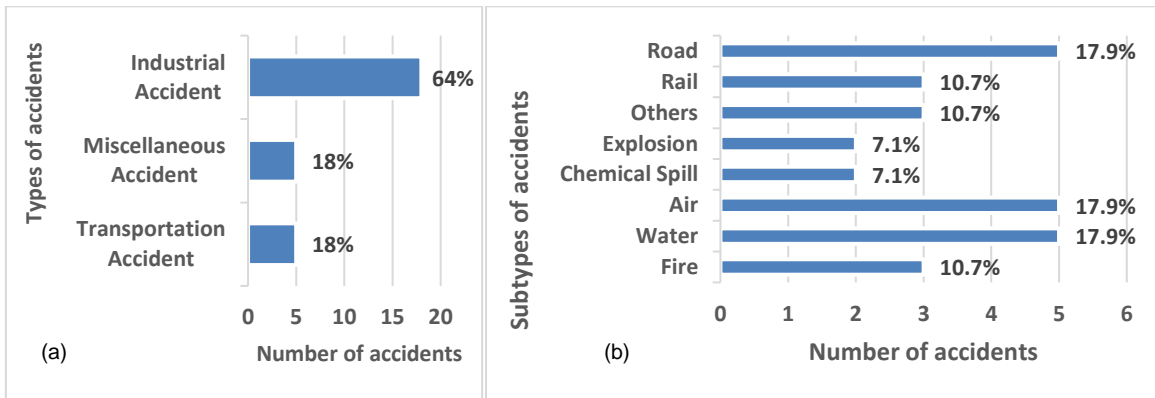


Figure 4: (a) Types of accidents in Canada; (b) Subtypes of accidents in Canada (EM-DAT Query Tool, 2020).

Of the number of accidents per decade in Canada, it can be observed that a total of 14 accidents were recorded in the 90s, while the 2000s and 2010s significantly have fewer accidents, with 7 each (Figure 5a). In Canada, having few accidents, there are consequently fewer deaths recorded, with a total of 620, where more than 447 occurred in the 1990s, while the decade with the fewest deaths is the 2000s with only 34 deaths, according to the following graph (Figure 5b).

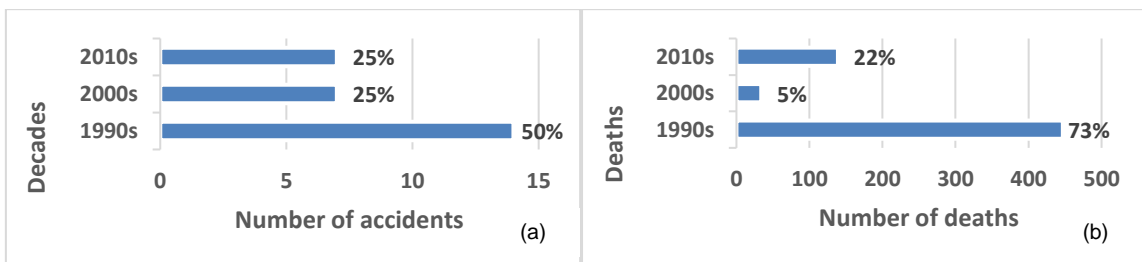


Figure 5: (a) Accidents recorded in Canada by decade; (b) Deaths recorded by decade (EM-DAT Query Tool, 2020).

Finally, the causes of accidents in Canada were analyzed, as shown in the following figure (Figure 6). In this case, there are only four recorded categories of the causes of accidents in Canada, with transportation accidents and mechanical failures causing the most accidents with 36%, while chemicals and human error in residential areas cause 29% of accidents each. The fewest number of accidents were provoked by unspecified causes, with 6%.

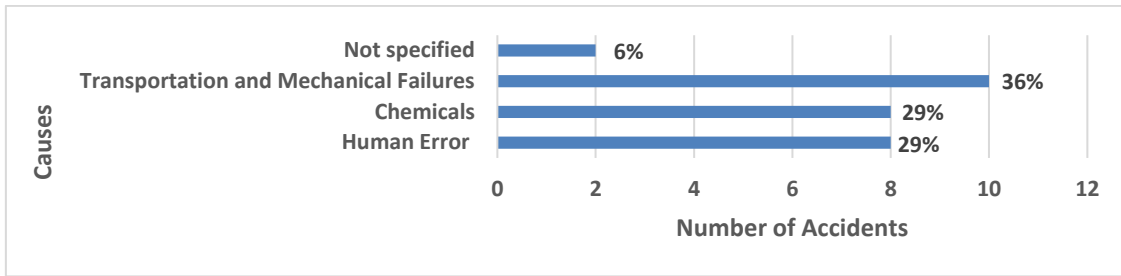


Figure 6: Causes of accidents recorded in Canada (EM-DAT Query Tool, 2020).

3.3 United States

In the United States, there are a total of 183 recorded accidents, with transportation accidents being the most common, with 107 (59%), while industrial accidents only have a total of 39 (21%), as can be seen in the graph below (Figure 7).

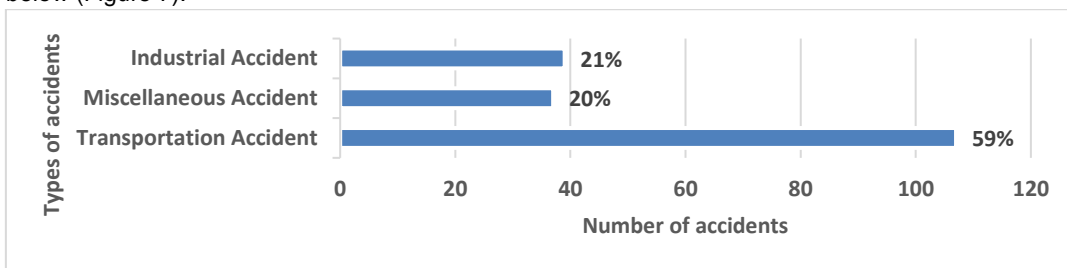


Figure 7: Types of accidents in the United States (EM-DAT Query Tool, 2020).

As seen in Figure 8a, air is the subtype that causes the most accidents in the U.S. with 28%, then there is a tie between two types, these being explosions and fires, with 13% each, and then comes the rail subtype, with 12%. There also are chemical spills, oil spills, gas spills, rail and road accidents, as shown in the figure below. The possible causes were reviewed according to the database (Figure 8b), and it can be observed that in the U.S., many of the technological accidents were caused by transportation accidents and mechanical failures (66 accidents), while the least common cause were chemicals (45 accidents) and not specified (16 accidents). Following an analysis of the causes registered in the database, 35% of accidents are caused by transportation accidents and mechanical failures, followed by human error with 31%. As in the other countries, most of the accidents are caused by transportation accidents and mechanical failures or human error.

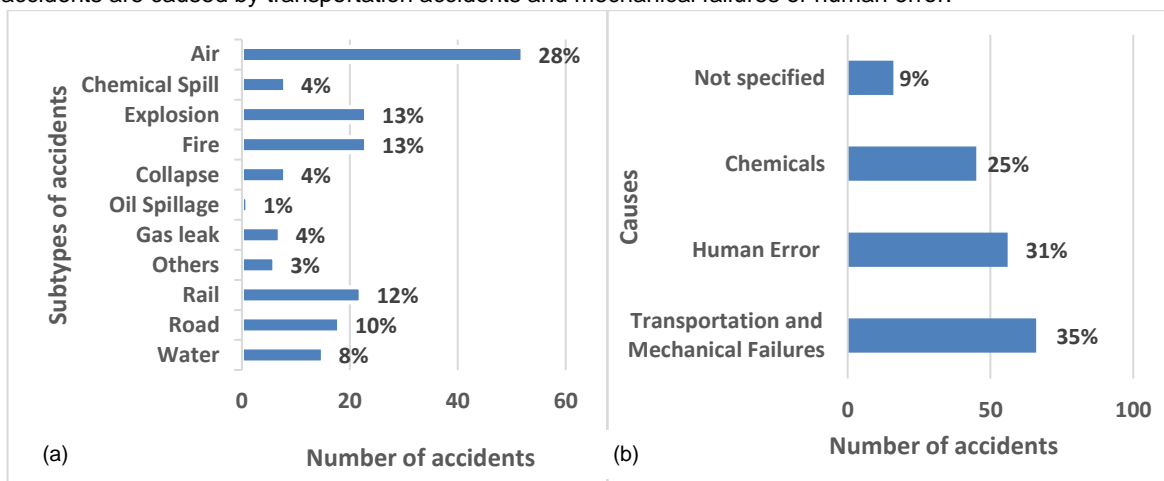


Figure 8: (a) Subtypes of accidents in the United States; (b) Number of causes of accidents in the United States (EM-DAT Query Tool, 2020).

Finally, it has been found that the U.S. has recorded fewer accidents as the years go by, with the 2010s having the fewest recorded number of accidents, with 38 in total. It can also be seen that they have made a lot of progress in accident control by improving their safety measures, as can be seen in Figure 9a. In the U.S., the

2010s have the lowest recorded number of deaths, with a total of 653 (18%), so it is evident that the number of major accidents and deaths have been reduced. This can be seen in Figure 9b.

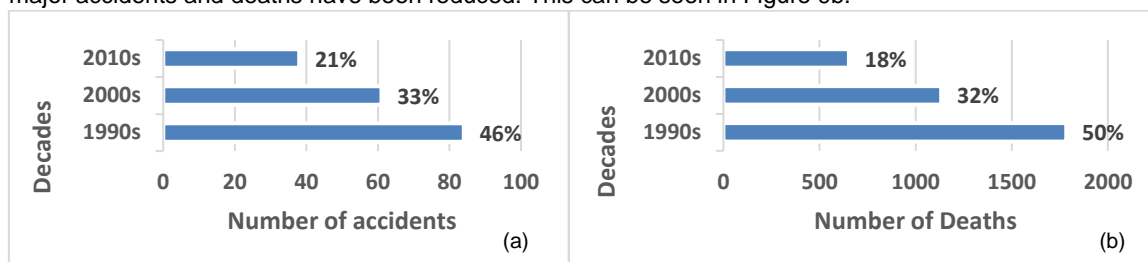


Figure 9: (a) Number of accidents by decade in the U.S.; (b) Number of deaths in the United States (EM-DAT Query Tool, 2020).

4. Conclusions

In the present study, a comparison of technological accidents was carried out between the countries in the North American region, which are Mexico, Canada, and the United States, where a total of 340 accidents were analyzed. As part of the result of this analysis, it could be observed how, in the first instance, it is Canada that registered the least accidents in the last decades, with only 28 accidents registered, a very small number in comparison with Mexico and the United States, where 129 and 183 accidents were registered, respectively. In Canada, apart from being the country with the least accidents, the number of accidents has fallen in the last two decades compared to the 90s, as well as the number of deaths. Although there were more deaths in the last decade than in the 2000s, they do not exceed the more than 450 deaths in the 90s. It was also observed that the most frequent types of accidents are road, air, and water. The United States is the country with the most accidents recorded in the area, but when looking at the figure of accidents per decade (Figure 9a), an improvement in safety measures can be observed, since in the last decade there were no more than 40 accidents, while in the 1990s there were more than 80 accidents, so there has been a great improvement per decade in the safety methods in the plants as time goes on. Many of the technological accidents have been found to be caused by transportation accidents and mechanical failures (35%), while the least common cause were chemicals (25%) and unspecified causes (9%). Mexico, compared to the other two countries, is the one that has had the least development with respect to accident prevention. On the contrary, it has registered the most accidents in the last decade, with almost fifty accidents and over 1,000 deaths, worse than its record in the 1990s. In the United States, although it has more accidents than Mexico, it can be shown that they have improved plant safety, while Mexico remains the same as it was two decades ago. The type of accidents that occur with the highest frequency in Mexico are road accidents (44%), including the transportation of hazardous substances. Overall, the country with the greatest safety over technological accidents has been Canada, with far fewer accidents than the other two countries mentioned, and they still maintain that margin of causing fewer accidents with less deaths. However, the United States cannot be left behind, since, unlike in the 90s, they have greatly improved their safety, and they register fewer deaths and accidents for each passing decade.

Acknowledgments

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