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School of Transportation Sciences

Master of Transportation Sciences

Master's thesis

Impact Assessment of Latin NCAP on the safety performance of cars in Latin America

Jhonny Rodrigo Rojas Morales

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences, specialization Traffic Safety

SUPERVISOR :

Prof. dr. ir. Ansar-Ul-Haque YASAR

MENTOR :

De heer Shiraz AHMED

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PREFACE

I decided to conduct this research related to vehicle safety because I strongly believe that this is a topic that needs to be urgently addressed in the region form where I come from, Latin America, and at the same time I'm convinced that the results of the analysis conducted in this thesis, can have a positive impact in the provision of safer vehicles in that region of the world.

As an urban mobility planner with experience in road network regulation and as a current student of Master in Transportation Sciences and Road safety, I came to realize that no matter how safe can be the road infrastructure, human error is intrinsic to our condition and therefore traffic accidents will be there always, however we can address the situation in a manner that crashes do not finish in death or serious injuries, and to achieve this objective it is fundamental to ensure that the vehicles that are circulating in the road network are safe enough to save the lives of their occupants and the other road users.

With the research conducted in this thesis, I pretend to contribute to the academy field, by means of creating scientific academic content in a topic that needs more research, especially focused on developing regions of the world. Simultaneously, there is a practical purpose behind this research, which is to provide governments, local authorities and policy makers in Latin America with scientific evidence that reveals the magnitude of the unsafe vehicle's problem and what aspects need to be addressed with more urgency.

I have to recognize that there is also a personal motivation behind this research. As someone who lost his father in a traffic accident while being a child, I experienced the consequences behind a traffic death and I comprehend all the pain that can be saved from saving just one life. If the results of this research serve as a catalyst for the provision of safer vehicles in any country of Latin America, I will be satisfied with all the effort invested in this thesis, knowing that more lives are being saved.

SUMMARY

This master thesis was structured in a manner that can be clearly distinguished 2 main parts: a more theoretical part (Chapter 1 to 6) and a more practical/analytical part (Chapters 6 to 8).

The more theoretical part of the thesis is composed of the introduction, the literature review and methodology proposed for the data analysis. The introduction contains the general framework of this research like the objectives, research question and assumptions for the analysis, besides the background of the problem.

The literature review covers three relevant sub-topics: the role of safe vehicles to achieve road safety improvement, the situation of Latin America regarding road safety and the problem of unsafe vehicles in this region, and finally the creation of Latin NCAP, the work they have been conducting since 2010 and the estimations of the safety score/ratings. Posterior to this theoretical part of the thesis there is a chapter describing in detail the methodology adopted for the data collection, data processing and the post-processing of the results for their correct interpretation.

The second part of this thesis is focused on the more analytical part of the research based on the data collection, processing, post-processing and analysis of results. Posterior to the data analysis it will take place a discussion about the results of the research and what implications could be extracted from them.

The final part of thesis (chapters 9 and 10) are dedicated to the conclusions of the thesis, that consist of the main findings obtained from the research conducted in the thesis, and the scientific-based recommendations for governments, local authorities and car manufacturers to address the problem of unsafe cars in their countries and Latin America in general.

LIST OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Background

There is no doubt that road safety is a growing concern worldwide, with more and more victims, institutions and organizations around the world raising their voice to point out the seriousness of the problem and asking for urgent action to improve the situation. In 2016, deaths caused by road traffic injuries were the 8th leading cause of death worldwide accounting for 2.5% of the total number of deaths (World Health Organization, 2018). In the list of the 10 leading causes of death, road safety appears as the first non-health related cause of death in the world and it is expected that for 2030, road safety injuries will become the 7th leading cause of death worldwide (Martinez, Sanchez, & Yañez-Pagans, 2018).

Road safety is affected by a wide range of factors and different actors, and it evident that vehicles play a fundamental role in the equation. In recent years, relevant worldwide organizations already pointed out the necessity to improve vehicle safety to reduce negative outcomes of traffic accidents. Among other worldwide relevant organizations, United Nations, considered the provision of safer vehicles as one of the pillars of their "Global Plan for the Decade of Action for Road Safety, 2011-2020" (United Nations, 2011) and the World Health Organization included the vehicle safety standards as a core component in their road safety technical package "SAVE Lives" (World Health Organization, 2017).

1.2 Problem statement

The provision of safer vehicles is especially urgent in developing regions like Latin America, characterized by higher fatality and injury rates than in high-income countries and by accelerated motorization, as a result of economic growth during the last decades. The increase in the number of vehicles in most of the countries in Latin America was not complemented by a proper improvement of vehicle safety standards like occurred in regions like the United States, Europe Union or Japan (Consumers International, 2016). The first results of crash testing conducted in Latin America at the beginning of this decade demonstrated that in terms of road safety, the best-selling models in the region were 20 years behind the vehicles in Europe, the United States (US), Japan and Australia (Furas, 2014).

These developed regions achieved great results in the provision of safer vehicles greatly in part to the work conducted by New Car Assessment Programs (NCAP), which are "highly successful in promoting supply and demand for safer vehicles" (World Health Organization, 2015). Europe is a clear example of how initiatives as NCAP programs have pushed the automotive industry to make their cars much safer (Van Ratingen et al., 2016). At present, there are established 9 NCAP programs around the world working in different countries and regions (FIA Foundation, 2015). NCAP programs were implemented firstly in high-income regions some decades ago, regions like the US or Europe (Van Ratingen, 2016),

while in other developing regions like South Asia or Latin America and the Caribbean, the NCAP programs started operations close to one decade ago. The NCAP program created for the region of Latin America and the Caribbean is Latin NCAP and its main headquarters are located in Montevideo (Uruguay).

Latin NCAP started operations in 2010 and during this decade they already tested more than 120 different cars (Latin NCAP, 2019c) produced for the region, providing the respective safety score and safety rating for each one for the models tested. Nowadays, there is enough data to measure the impact of the Latin NCAP on the safety performance of the vehicles, by means of answering the next question: **Since the creation of the Latin NCAP, are the vehicles produced for Latin America becoming safer?**

1.3 Objectives

This thesis has the scientific or academic purpose of assessing the impact of Latin NCAP safety scores and safety ratings, on the occupant's protection offered by the different models available in the car market of Latin America. This scientific purpose can be understood more precisely after reading the research questions of this study, that are stated in the following section of this chapter.

At the same time, the practical purpose behind this research is to provide national authorities and regional policy makers with facts and guidelines for the provision of safer vehicles in their countries and consequently in the region. Implementation of policies based on scientific findings may lead to effective measures in favor of safer cars.

Behind these purposes, there is also a personal motivation to contribute to society by means of applying the knowledge and research skills acquired at the Master program in Transportation Sciences at Hasselt University. It is expected that the results of the research will represent a personal contribution to the provision of safer vehicles in Latin America and the Caribbean, and consequently to reduce the number of fatalities and injured people caused by traffic accidents in this region.

1.4 Research questions

1.4.1 Main research question

Since the creation of Latin NCAP and the implementation of the safety ratings are the vehicles produced for Latin America becoming safer?

1.4.2 Secondary research questions

The secondary questions that complement the main research question are the next:

- Are the models produced in the very recent years achieving higher safety scores than the first models tested by Latin NCAP?

- Is the impact of Latin NCAP larger in adult protection than in child protection?
- Is the impact of Latin NCAP the same among the different types of urban vehicles or segments?
- Is the impact of Latin NCAP similar among the different brands tested?

1.5 Proposed methodology/research process

The methodology adopted in this research is mainly based in the analysis of the safety scores and safety ratings of the cars tested by Latin NCAP in the period 2010-2019, including also other relevant information like the safety devices installed in the cars, the type/segment of the car and the country/region where the vehicle was produced among other aspects.

However, the sole interpretation of the safety ratings and safety scores along the years, without a comprehension of all the other aspects involved in the issue, can lead to misperceptions and biased conclusions, therefore, a comprehensive literature review was conducted firstly, in order to answer some relevant and complementary interrogatives that provide a proper comprehension of the context surrounding the problematic. The literature review helped to answer questions like: How well or bad is performing the region regarding road safety? How important is the provision of safer vehicles to improve the situation? What brands are present in Latin America and in what countries are they producing cars for the region? What are the New Car Assessment Programs (NCAP's) and how Latin NCAP is working in the region? What tests and protocols are being used by Latin NCAP for the obtention of the safety ratings?

The literature review will be followed by data collection. In the case of this thesis, all the data related to the safety performance of the cars was collected directly from the official website of Latin NCAP, where all the safety ratings and scores are freely available and open to the public in general.

The statistical processing of the safety scores and safety ratings, complemented by a proper literature review of the problematic, was followed by a chapter that comprehend the of visualization of the results obtained. The results will be represented using different types of graphics and comparisons, looking to show in a clear and visual manner the main findings of the research.

The data visualization highlights issues like:

- The evolution of the safety rating and safety scores in the last decade
- Type/segment of cars that show greater positive impact and lower positive impact along the years
- Countries or regions that are producing the safest cars in the Latin American market and the countries or regions that are producing the most unsafe cars

- The brands that shown greater improvement in the safety performance of their cars over the years and the brands that are less concern about improving the safety offered by their vehicles.

Posterior to the analysis of the results, there is a chapter dedicated to the discussion of the results, the current situation of Latin America and the impact of Latin NCAP in the situation so far.

All the findings of the research were translated into concise conclusions and recommendations that are easy to understand by every academic, scientific, transport authority or policy maker concerned about the provision of safer vehicles or interested in acquire scientific-based criteria to promote the provision of safer vehicles. Although the conclusions and recommendations can be more useful for professionals working in the region of Latin America and the Caribbean, they can be also helpful for professionals of other regions of the world, especially in developing regions characterized by unsafe vehicles.

1.6 Data sets required

The data required for the analysis is composed by all the safety scores/ratings published by Latin NCAP since 2010 (year of creation of Latin NCAP) until the end of 2019, in order to use only complete annual data. The sample is composed by all the cars tested by NCAP in this period of time. All the official safety scores are available on the website of Latin NCAP, and there will be extracted from this source the test results of the 134 cars tested by Latin NCAP in the period 2010-2019.

The variables that were extracted from every safety score are the next:

- Brand, year and model of the car
- Safety rating (number of stars) for adult protection and child protection
- Performance (total points achieved) in the different type of tests carried out (frontal impact and side impact when available)
- Type of urban car (supermini, sedan, familiar….) and weight
- Country or region where the car was produced
- Equipment of the car (number of airbags, Seat-belt pretensioner, ESC…)
- Bodyshell integrity
- Other aspects when available

The data collected was in Excel tables and with the help of this software, there were elaborated graphics and illustrations to find patterns and trends useful to answer the research questions, to lead to discussion of the results obtained and that help to make scientific-based recommendations for the improvement of the situation.

1.7 Assumptions

The research was conducted based on the next assumptions:

- In this thesis, the term "Latin America" refers to the region composed by: "the entire continent of South America in addition to Mexico, Central America, and the islands of the Caribbean whose inhabitants speak a Romance language" (Encyclopedia Britannica, 2019). Therefore, while using this term during the study, it is understood that the countries of the Caribbean are also included. This, to avoid any confusion caused that the fact that in some of the information collected, Latin America and the Caribbean are mentioned separately.
- It is expected to find that the vehicles produced for Latin America are not as safe as their equivalent models produced for developed regions like Europe or North America, as it was stated previously, some bestselling models in the region are 20 years behind their equivalent models in developed regions regarding safety performance (Furas 2014) (WHO, 2015). Some other comparison studies and interviews with crash testing experts at the global level have pointed out this issue also.
- NCAP programs with their respective crash protocols and consumer ratings are assumed to be a reliable source of information regarding the safety performance of vehicles, and they are recommended by UN (WHO, 2018) because they have demonstrated to be an effective tool to promote the provision of safer vehicles (WHO, 2015) (van Ratingen, 2016).
- Latin NCAP, is the only organization in Latin America in charge of crash testing and safety rating of vehicles. As this organization/program works independently from the companies in charge of car production, their test results are assumed to be unbiased and independent (Furas, 2012).
- For the data analysis, there were considered only the safety scores and ratings of the first decade of Latin NCAP, comprehended in the period 2010-2019. Taking into account that most of the statistical comparisons will be based on annual periods, and contemplating the fact that this study is intended to be finished in the middle of 2020, therefore the data from this year will not be included in the analysis because will be incomplete and cannot be directly compared with data from previous years on an annual basis.

CHAPTER 2: THE KEY ROLE OF SAFER VEHICLES TO ACHIEVE ROAD SAFETY GOALS

There are different factors that increase or decrease the risk of being involved in an accident and that define the severity of it. Factors related to the human, road, law, enforcement, and vehicles used by the different road users. Because of their size, weight and speed, cars have an even more important effect on crash risk and the magnitude of their negative outcomes.

During last years, the concern for the provision of safer cars and the promotion of vehicle safety standards have gained momentum among national and regional authorities, in developed and developing regions, and international organizations like United Nations (UN) or World Health Organization (WHO). Nowadays, most of the road safety plans/approaches include "vehicle safety" or "safer vehicles" as a main component or pillar to achieve road safety targets.

2.1 Safe vehicles in the safe system approach

The safe system approach is a framework adopted by many developed countries, especially from Asia and North of Europe, to address road safety problems in a sustainable, more human but at the same time more ambitious manner than the traditional perspectives. This approach is based in the "Vision Zero", adopted by Sweden in 1997 (OECD, 2008), and that intended to reduce to number of deaths and serious injuries to zero (World Health Organization, 2017). Another framework that influenced the evolution of the Safe System Approach, was the "Sustainable Safety" approach developed by the Netherlands, that tries to eliminate all the accident that can be prevented and that defines road users as unpredictable and open to commit errors (OECD, 2008).

Posteriorly, different cities and jurisdictions of Australia started to adopt these concepts, structuring and organizing them, giving shape to the current Safe System Approach, where "Safe Vehicles" stand out as one of the main components of this framework:

FIGURE 1 Safe System Approach (Department of Transport & Main Roads - Queensland, 2015)

The Safe System Approach started to being developed a couple of decades ago (OECD, 2008) and over the time has being demonstrated to be so effective that many of the principles suggested by this framework were adopted by United Nations and World Health Organization and included in their road safety plans/technical packages, being one of these main components, the provision of "Save Vehicles".

2.2 Global Plan for the Decade of Action for Road Safety 2011-2020

This plan was proclaimed by resolution of the United Nations General Assembly in March of 2010 to stabilize, in first place, and then reduce the estimated number of road traffic fatalities worldwide by means of taking different actions at a global, regional and national level (United Nations, 2011). All the countries that area part of United Nations, are encouraged to take actions based on the next five pillars of road safety and "Safer Vehicles" is one of these pillars, the third pillar to be exact:

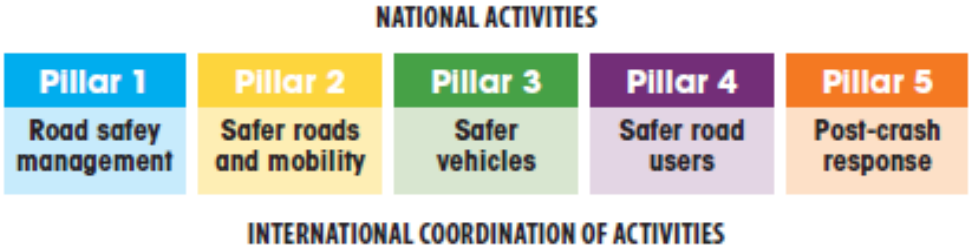


FIGURE 2 The five pillar of road safety (World Health Organization, 2017)

The Pillar 3: Safer Vehicles, promote governments to implement measures like the deployment of vehicle safety technologies, incentives to adopt these technologies and consumer information schemes (United Nations, 2011). Every pillar is composed of a number of specific activities that must be conducted in order to achieve positive results in that pillar. The Activity 2 of the Pillar 3: Safer Vehicles, states the next:

"Encourage implementation of new car assessment programmes in all regions of the world in order to increase the availability of consumer information about the safety performance of motor vehicles" (United Nations, 2011).

The other activities specified in this Pillar are also related to vehicle safety standards and safety devices, however, the already mentioned Activity 2 is specifically related to the implementation of NCAP programs. Latin NCAP was created in 2010, the same year that this global plan was approved by the United Nations.

2.3 Save LIVES: A road safety technical package (2017)

This tool was developed by World Health Organization to provide guidance to governments, local authorities, decision-makers and road safety practitioners to reduce the number of road crash fatalities and injured in their regions and countries. This technical package, published in 2017, include the next main goals (World Health Organization, 2017):

- "A 50% reduction in road traffic deaths and injuries across the world by 2020 and beyond"
- "The provision, by 2030 of access to safe, affordable accessible and sustainable transport systems for all and improvements in safety……."

The Save LIVES approach is divided into 6 main components and follows a similar focus adopted by the "Global Plan for the Decade of Action for Road Safety 2011-2020", with the main difference that in the Save LIVES technical package, "Speed Management" received more attention. In this approach, the relevance given to the provision of safer vehicles is reflected in the fact that "Vehicle Safety Standards" is one of the components and includes interventions to improve safety in cars and motorcycles.

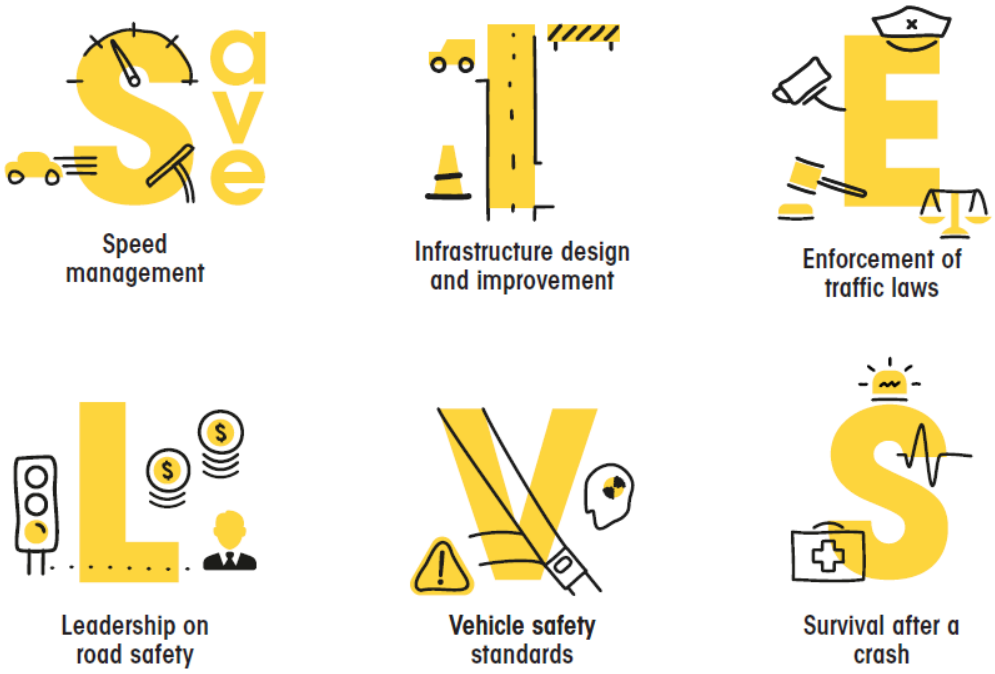


FIGURE 3 The Save LIVES technical package (World Health Organization, 2017)

2.4 Vehicle safety as a worldwide priority

The literature review of this chapter showed that vehicle safety has become a worldwide priority related to road safety, and now it is being promoted at national road safety plans of different developed countries that adopted the safe system approach, it is also present in the technical road safety package (SAVE Lives) developed by WHO and it is strongly recommended by the United Nations in the "Global Plan for the Decade of Action for Road Safety 2011-2020", a resolution signed by most of the countries in the world, including countries from Latin America.

The plan proclaimed by United Nations goes further and specifically encourages countries and regions to implement NCAP's, revealing a worldwide approach where vehicle safety does not only consist in the provision of some basic safety devices, instead the perspective now it is to ensure that every new car in the market is safe enough to protect car occupants (adults and children) during accident in a manner that the risk of death or serious injuries is reduced considerably. This can only be achieved by means of crash testing, conducted with standardized procedures and performed by specialized independent organizations like NCAP's.

CHAPTER 3: THE LATIN AMERICAN CONTEXT AND THE URGENCY FOR SAFER VEHICLES

In the previous chapter, there was demonstrated that at worldwide level the provision of safer vehicles is fundamental to improve road safety and that the approach related vehicle safety is becoming more exigent, going from the requirement of basic safety devices to submitting the cars to crash testing conducted by NCAP's programs.

In this chapter, there will be analyzed the situation of road safety in different income level countries with a special focus on Latin America and in the role that unsafe vehicles are playing in the problems. In order to comprehend the current situation of vehicle safety in the region, there will be also described the Latin American vehicles market and the compliance of the countries in the region to the United Nations vehicle safety standards. The literature review of this chapter will be useful to understand the reasons behind the implementation of Latin NCAP and the importance of the work they are realizing in the region, topics that will be studied in detail in the next chapter.

3.1 Road safety in middle-income and low-income countries

From the approximately 1,25 million of people killed in road crashes around the world every year (Consumers International, 2016), 93% are people from low-income and middle-income countries (World Health Organization, 2018) where the cars sold to the consumers are unsafe compared to the cars sold in regions like US, Australia, Japan and Europe by the same car manufacturers (Consumers International, 2016).

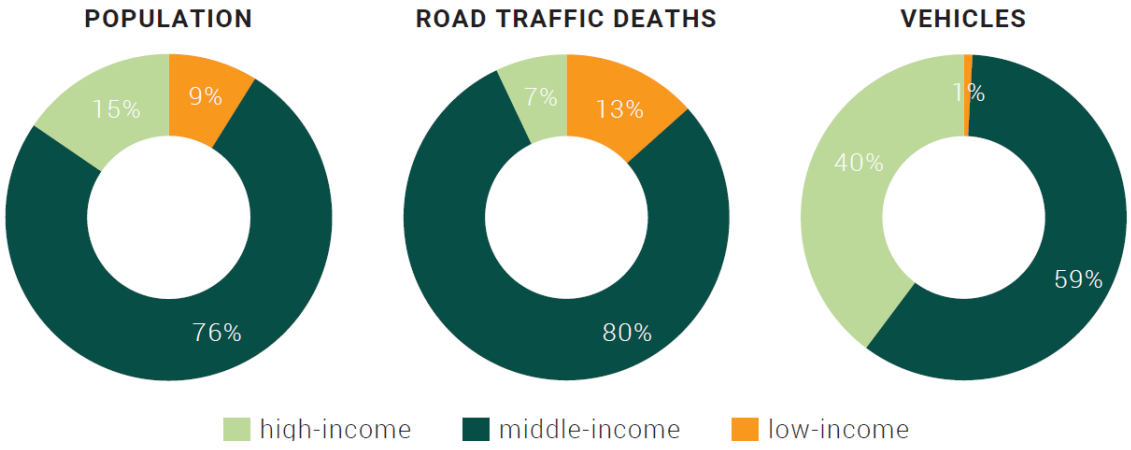


FIGURE 4 Distribution of population, road traffics deaths and registered vehicles by income level (World Health Organization, 2018)

The estimations made by World Health Organization (2018), in their "Global Status Report on Road Safety", reveals the next interesting facts:

- Low-income countries comprehend only 1% of the whole vehicles in the world however they account for 13% of road traffic deaths
- Something similar happens with middle-income countries where 59% of the registered vehicles are related to 80% of the total traffic deaths
- In contrast, high-income countries account just for the 7% of road traffic deaths considering that 40% of the vehicles registered in the world are located in these countries

The previous findings are showing the tendency that the regions with less safe vehicles present the higher proportions of road traffic deaths and this is something that was also remarked by some international organizations in more than one opportunity: "millions of sub-standard cars that would be illegal in high-income countries are being sold in low and middle-income countries" (GLOBAL NCAP, 2015), "This is entirely unacceptable. Manufacturers cannot continue to treat millions of their costumers as second class citizens when it comes to life-saving standards of occupant protection" (FIA Foundation, 2015).

TABLE 1 Top ten causes of death in 2013 (Martinez et al., 2018), based on data from WHO (2015)

	World	High-income countries	Low- and middle-income countries					
			East Asia and Pacific	Europe and Central Asia	Latin America and Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa
Ischemic heart disease	7,593,875	1,292,609	2,023,162	1,455,823	468,580	370,278	1,629,386	354,037
Stroke	6,699,717	764,051	2,911,243	815,131	309,911	239,370	1,142,133	517,879
Lower respiratory infections	3,222,634	379,177	475,855	66,981	206,418	95,812	798,400	1,199,991
Chronic obstructive pulmonary disease	3,216,606	369,748	1,104,306	83,865	133,634	45,641	1,375,033	104,378
Diarrheal diseases	1,807,702	35,190	91,934	11,472	23,266	21,893	881,311	742,637
HIV/AIDS	1,666,646	20,483	158,465	93,978	57,518	21,100	167,512	1,147,589
Trachea, bronchus, lung cancers	1,636,037	583,707	694,081	126,183	76,665	22,520	112,952	19,929
Other circulatory diseases	1,583,574	758,799	348,258	74,157	136,304	65,897	119,299	80,859
Road injury	**1,423,355**	**87,958**	**453,851**	**57,140**	**124,035**	**90,630**	**367,212**	**242,530**
Hypertensive heart disease	1,136,930	222,327	341,390	88,985	122,834	59,513	207,975	93,906
Total of top 10 causes of death	29,987,076	4,514,049	8,602,545	2,873,715	1,659,165	1,032,654	6,801,213	4,503,735

There is a significant contrast in the severity of the road safety problems of high-income countries compared to low- and middle-income countries. While in high-income countries road traffic deaths were the 8th cause of death in 2013, in the other regions composed of low and middle-income countries like Latin America and the Caribbean, Sub-Saharan Africa or South Asia, traffic fatalities occupied the 6th position, and even getting worse in the regions of North Africa and Middle East, where road traffic deaths occupied the 4th place among the top ten causes of death (Martinez et al., 2018).

3.2 The situation of Latin America regarding road safety

There are evident differences in the situation of the road safety of different countries when they are compared based on their income level, nevertheless, in some specific cases, these differences may to become blurry on confusing when the comparison of fatality rates is done at regional or continental. The analysis and comparison of representative road safety numbers at regional level must take into account the fact that every continent can be composed of a mix of low, middle and high-income countries, and the American continent or region of the Americas is a clear example of this diversity.

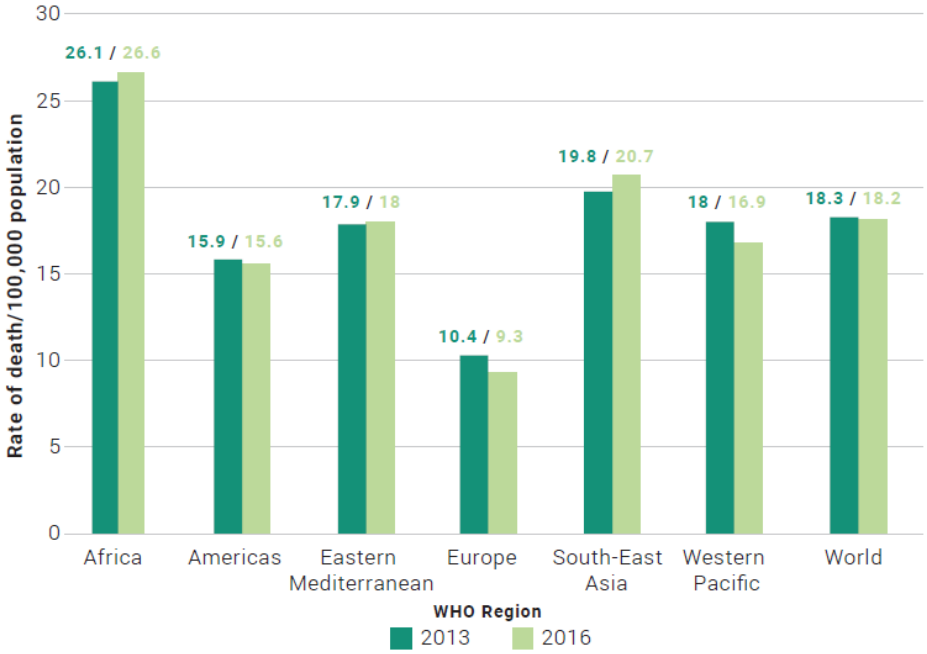


FIGURE 5 Road traffic deaths per 100 000 inhabitants in the different regions of the world (World Health Organization, 2018)

The American continent is composed by two main regions or subdivisions regions:

- Anglo America: Comprehends high-income countries like Canada or the US besides some small size islands that used to be colonies from the European countries.
- Latin America: composed of "the entire continent of South America in addition to Mexico, Central America, and the islands of the Caribbean whose inhabitants speak a Romance language" (Encyclopedia Britannica, 2019). In this region, the big majority of the countries belongs to the middle-income level, with some countries still in the low-income level.

At first look to the road safety indicators of the year 2016, developed by the World Health Organization (2018), at regional or continental level, shows that that the region of the Americas (with 15.6 deaths/100 000 inhabitants) is the second region with the lowest fatality rates after Europe (with 9.3 deaths/100 000 inhabitants) and that is not performing so bad compared Africa (with 26.8 deaths/100 000

inhabitants). However, in the case of the American continent, the indicators are located in a middle point of two contrasting regional realities inside the continent, the alarming number showed by the Latin American countries and the very low mortality rates of developed countries like Canada and US, that belong to Anglo America.

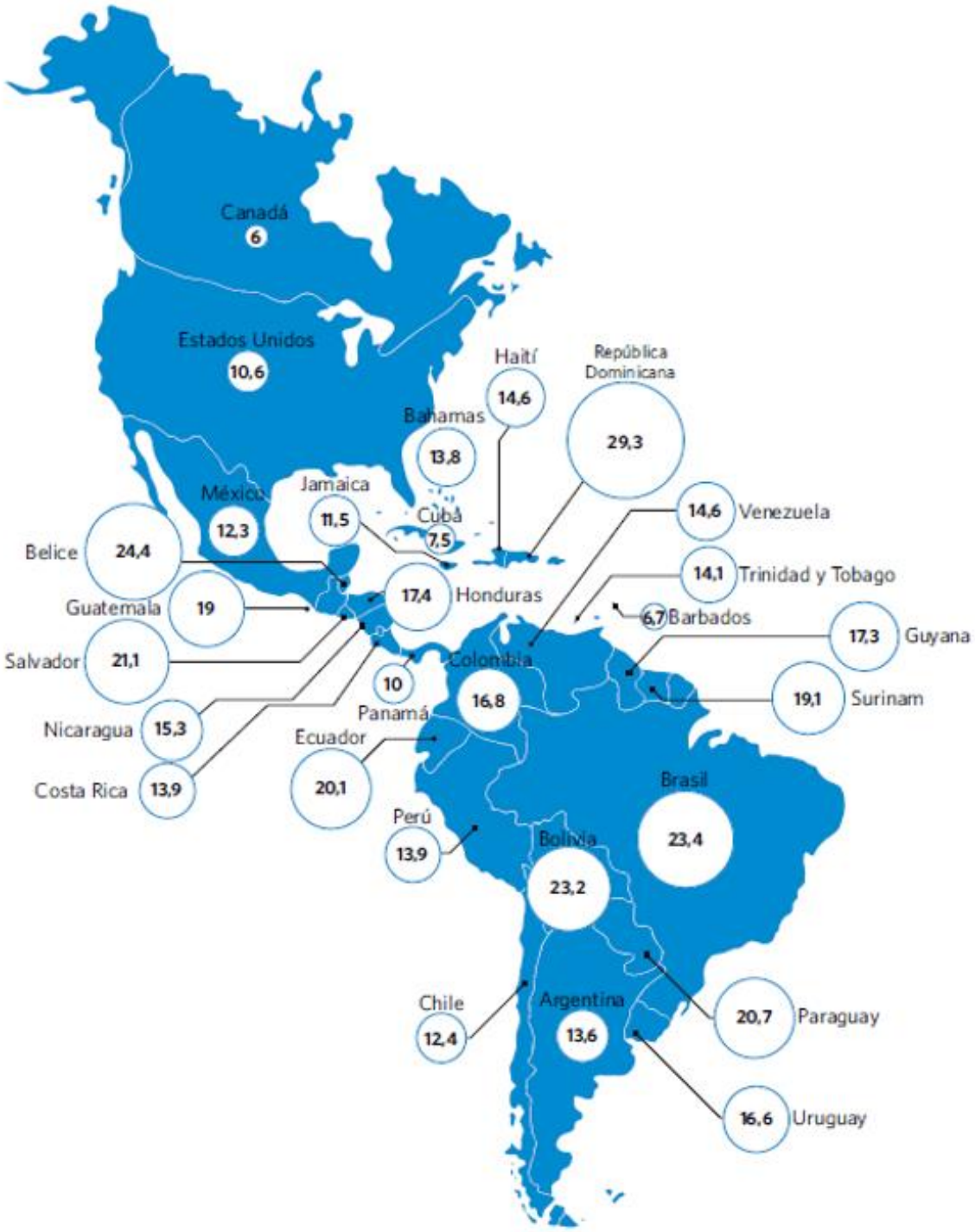


FIGURE 6 Road traffic deaths per every 100 000 inhabitants in the different countries of the American Continent (Alves, Pinto, Ponce de León, & Café, 2017) based on data from (World Health Organization, 2015)

In the previous image, it can be easily appreciated that the difference in the mortality rate of countries like Canada (6 deaths/100 000 inhabitants) is duplicated and triplicated by most of the countries of Latin America and even quadruplicated by some specific cases like Bolivia, Brazil, Belize and Dominican Republic (Alves et al., 2017).

In fact, the numbers are revealing that Latin America suffers serious road safety problems, with fatality rates that almost duplicate the fatality rates of high-income countries (Van Ratingen, 2016). The current fatality rate of Latin America is expected to increase from 17 deaths per 100 000 inhabitants to 24 deaths per 100 000 inhabitants if urgent actions do not take place (Consumers International, 2016). In Latin America, road crashes are the main cause of death among children from 5 to 14 years old, and the second main cause of death for the age group of 15 to 29 years old (Gallego Galenao et al., 2015).

As some authors stated: "Road accidents cause more deaths than homicides in Latin America, nevertheless it is no highlighted as a major concern by media and society" (Bezerra, Kaiser, & Battistelle, 2015). And this should be a serious concern considering that traffic accidents have an economic impact in the order of 1% to 5% of the GDP of the countries in the region (Alves et al., 2017), besides the pain and difficulties they cause to the victims and their relatives, aspects that cannot be monetized or represented in economic terms.

3.3 The vehicle factor

Regarding the distribution of traffic deaths in the American continent, are the drivers and passenger of 4 wheeled vehicles (car occupants), the group that present the largest proportion of deaths with 34% of the total, followed by the users of motorized 2-3 wheelers with 23% and the pedestrian in third place with 22% (World Health Organization, 2018). Also, in Europe the car drivers and passengers occupy the first position in the distribution of traffic deaths, nevertheless the fatality rates in this region are considerably lower than in the American Continent.

The distribution in Latin America also follows the same tendency that the American continent, with car occupants (drivers and passengers) sharing the largest proportion of the total number of road traffic deaths with 34,18% (World Health Organization, 2015).

TABLE 2 Distribution of traffic deaths by type of road user (Martinez et al., 2018), based on (World Health Organization, 2015)

Country	Drivers/passengers in four-wheel vehicles	Drivers/passengers in motorized two- or three-wheel vehicles	Cyclists	Pedestrians	Other/unspecified road users
Argentina	88.00	-	2.00	10.10	-
Bahamas	57.70	17.30	3.80	21.20	-
Barbados	33.30	16.70	11.10	38.90	-
Belize	46.60	21.90	17.80	9.60	4.10
Bolivia	56.10	9.90	0.90	32.50	0.60
Brazil	23.50	28.00	3.30	19.70	25.50
Chile	36.10	7.00	7.60	38.90	10.40
Colombia	7.60	44.30	5.00	29.30	13.80
Costa Rica	27.80	28.30	9.30	32.10	2.50
Cuba	21.20	12.40	12.70	38.60	15.00
Dominica	63.60	-	18.20	18.20	-
Dominican Republic	12.90	63.20	0.50	19.70	3.60
Ecuador	2.20	6.90	0.50	30.00	60.30
El Salvador	11.60	11.00	4.60	58.90	13.90
Guatemala	-	25.10	-	50.90	24.00
Guyana	25.00	18.80	11.60	34.80	9.80
Honduras	30.80	8.10	4.90	46.70	10.30
Jamaica	31.90	20.80	8.50	29.00	9.80
Mexico	18.30	6.00	1.50	30.30	44.00
Nicaragua	23.20	26.00	5.50	32.80	12.50
Panama	58.30	-	-	40.90	0.80
Paraguay	23.40	54.10	0.70	20.70	1.10
Peru	6.90	1.00	0.30	23.30	68.40
St. Lucia	57.10	-	-	42.90	-
Suriname	35.50	42.10	3.90	18.40	-
Trinidad and Tobago	64.20	2.60	2.00	31.10	-
Uruguay	25.90	52.90	2.80	15.70	2.60
Region average	34.18	22.80	5.79	30.19	17.39

Source: Prepared by the authors based on data from WHO (2015).

At country level, the proportions of car occupants (drivers and passengers) death in road crashes, vary from one to country to another, however in most of cases they represent the largest proportion. There are some alarming specific cases like Argentina, Bahamas, Bolivia, Brazil, Dominica, Panama, St. Lucia and Trinidad and Tobago, where the proportion of car drivers and passengers killed in traffic accidents is above 50% (Martinez et al., 2018).

In some specific cases like Ecuador and Peru, where the proportions car occupants death is below 10%, there is also a large proportion (above 60%) of road user deaths identified as "other/not specified" (Martinez et al., 2018).

Argentina and Brazil are some of the few car producers in the region, and it calls attention than in these countries' car occupants represent by far, the largest proportion of road traffic deaths. This may suggest that cars produced in the country are not safe enough to protect the life of any person, including the own inhabitants of the country.

The indicators are making evident a common tendency that is repeating at continental, regional and national level (in most of the cases), the fact that the most common victims of traffic accidents are the car occupants (drivers and passengers), and the same tendency give insights about effect that unsafe vehicles are producing in the region. Some studies already pointed out that regarding vehicle safety, the best-selling car models in Latin America are 20 years behind

the models sold in high-income regions like US, Australia, Japan and Europe (Furas, 2014) (GLOBAL NCAP, 2015)

3.4 Motorization and vehicle age in Latin America

The most of the countries in Latin America are from the middle-income level, and in these countries, buying a vehicle (even a second-hand car) can represent a considerable investment for the owner, nevertheless, the economic growth in some of these countries in the last years was enough to produce an increase in the number of vehicles the region. According to Consumers International (2016), the share of Latin America in the total number of registered cars at global level, has increased by 165% during the period 2005-2016. Every year there is a growth of close to 15% in the number of new vehicle sales in Latin America (Bezerra et al., 2015). This explosive increase is directly affecting the motorization rates (cars/inhabitant) in Latin America.

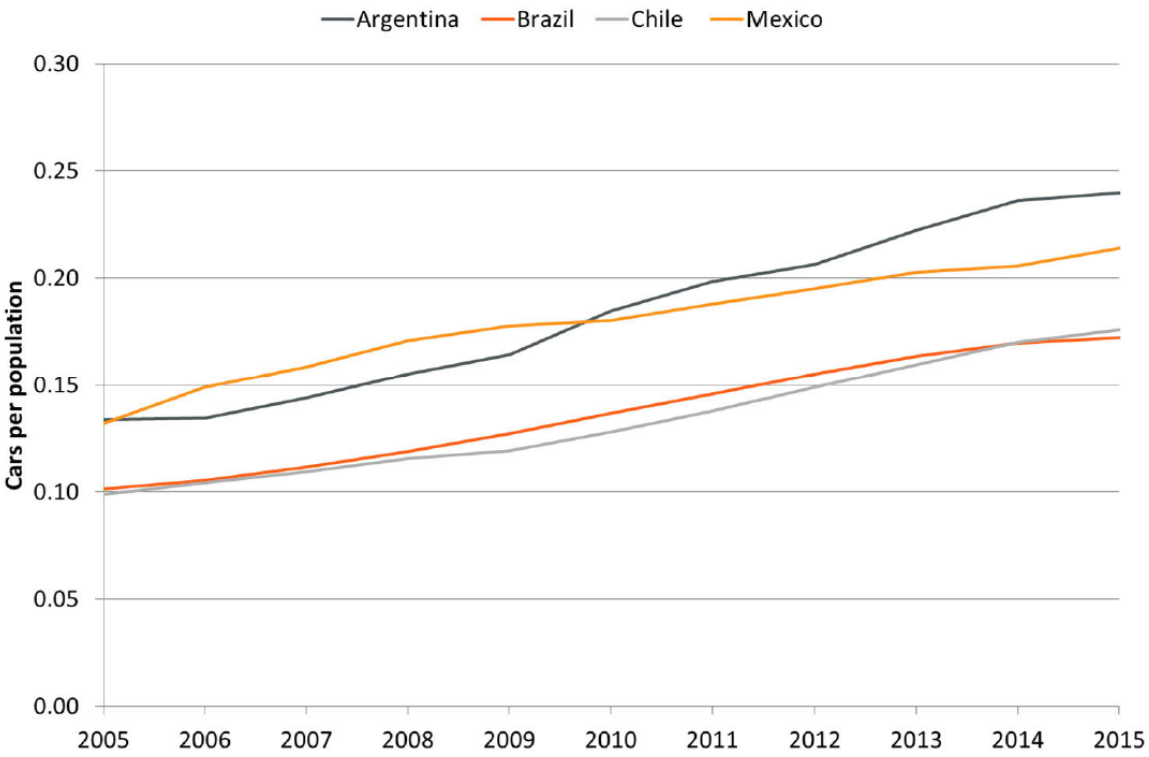


FIGURE 7 Motorization rates in Argentina, Brazil, Chile and Mexico in the period 2005-2015 (Caroline Wallbank, Kent, Ellis, Seidl, & Carroll, 2019)

Although the motorization rates in the countries from Latin America are still below the values of North America or Europe (Bezerra et al., 2015), the motorization growth in most of the countries in the region (especially the countries with higher GDP with a strong automobile production industry) is being more accelerated compared to developed markets were the motorization rates are already stable.

In just 10 years (from 2005 to 2015), the motorization rate in Brazil, Chile and Mexico increased around 70% while in cases like Argentina the situation was even

more drastic, almost reaching an increase of 85% (Caroline Wallbank et al., 2019). In 2015 Mexico and Argentina already had more than 20 million of cars in circulation, while in the case of Brazil this number is 4 times higher, already reaching more than 80 million cars in circulation (Consumers International, 2016).

Regarding the age of the vehicles, in Latin America the average age is 14 years, this is significantly higher compared to some developed regions like Spain and the US where the average is close to 10 years (Bezerra et al., 2015). According to other sources, the average age of the cars in every country of the country can vary, however, the average is in general at least 10 years (Caroline Wallbank et al., 2019).

In some particular cases, the average age is alarmingly higher, for instance Argentina (19,5 years) and Bolivia (23 years) (Hidalgo, 2011). The proportion of vehicles in the region with more than 20 years is in the range of 5% to 20% (BBVA, 2010) while in regions like the United Kingdom this proportion is only 1% (Caroline Wallbank et al., 2019).

3.5 Vehicle market

In Latin America there are three main cars producers and they are Argentina Brazil and Mexico. Some of the most relevant brands of passenger cars in the world are installed in these countries and from there they are producing cars to be sold in the region.

TABLE 3 Relevant brands that are producing passenger cars in the region, based on information from (Consumers International, 2016) and (Latin NCAP, 2019c)

Country	Argentina	Brazil	Mexico
Relevant brands producing passenger cars in the country	• Fiat • GM/Chevrolet • Nissan • Peugeot • Renault	• Citroen • Fiat • Ford • GM/Chevrolet • Honda • Hyundai • Jeep • Peugeot • Toyota • Volkswagen	• GM/Chevrolet • Honda • Kia • Mazda • Nissan • Volkswagen

Among these countries, Brazil and Mexico excel also at worldwide level positioning in the top ten of car producers. For both countries, the automobile industry is very important for their economy, in the case of Brazil, represents also the 5% of the entire national GDP and 23% of industry-related GDP (Telles Pascoal, Lopes Nogueira da Silva, & Silva Ferreira Filho, 2015). Brazil and Mexico, besides to be the main car producers, they are also the biggest vehicle markets in the region,

therefore the models that are the most popular in these countries, will be also the best sellers in Latin America (Consumers International, 2016).

TABLE 4 Top ten car producer countries at a global level in 2018 (International Organization of Motor Vehicle Manufacturers, 2019)

Position	Country	Passenger cars produced
1st	China	23.529.423
2nd	Japan	8.358.220
3rd	Germany	5.120.409
4th	India	4.064.774
5th	South Korea	3.661.730
6th	USA	2.795.971
7th	**Brazil**	**2.386.758**
8th	Spain	2.267.396
9th	France	1.763.000
10th	**Mexico**	**1.575.808**

There is a worldwide tendency driven by car manufacturers that consist in relocate most of the car production to middle-income countries. In 2007, 30% of the global automobile industry profits came from middle-income countries, and this number increased to 60% in 2012 and it expected that in 2020 will increase even more until reaching the value of 75% (GLOBAL NCAP, 2015). This projection is indicating that more and more cars will be produced in middle-income countries like Argentina, Brazil and Mexico, and therefore more and more cars produced in these countries will be sold in the region, therefore it this primordial to analyze also the situation of Latin America related to regulation of car production and the UN vehicles safety standards.

3.6 Compliance of the UN vehicle safety standards in Latin America

The provision of safer vehicles became a major challenge in developing regions characterized by accelerated growth in the number of vehicles (Van Ratingen, 2016) and Latin America is a clear example of a growing vehicle market that is poorly regulated (Consumers International, 2016). The most of countries in the region have legislation related to technical inspection of the vehicles, however, these inspections are oriented to the environmental performance of the car (Emissions) rather than to the safety of the vehicle (Bezerra et al., 2015).

There is no clear vehicle safety regulation at national levels neither a common framework at the regional level, however that doesn't exempt the countries in Latin America to stick to the international normative existing with the purpose to ensure the production of cars that are safe for the users, in this case, the UN vehicle safety standards.

The United Nations adopted the vehicle regulations, developed by the World Forum for the Harmonization of Vehicle Regulations, and among those regulations there

are 8 minimum regulations related to vehicle safety, that are recommended by WHO (2018) and that must be implemented in every country in order to provide safer vehicles.

TABLE 5 The UN vehicle safety standards, suggested for implementation by WHO (World Health Organization, 2018)

Safety standard	Number of regulation	Description
Frontal impact protection	Regulation 94	Cars must be safe enough to resist frontal and side when tested at a certain speed
Side impact protection	Regulation 95	
Electronic Stability Control (ESC)	Regulation 140	Prevent the loss of control of the car while oversteering and understeering
Pedestrian front protection	Regulation 127	The cars must avoid excessively rigid structures and provide softer bumpers to reduce impact severity over pedestrians
Seat-belt	Regulation 14	Ensure that seat-belts are installed in the car from the fabric and that the anchor points can resist the impact during an accident
Seat-belt anchorages	Regulation 16	
Child restraints	Regulation 129	To provide ISOFIX child anchorage points to secure the child seat
Motorcycle anti-lock braking system	Regulation 78	Help the driver to control the motorcycle during emergency braking

Except by the regulation 78, the other 7 vehicle safety standards are directly related to car safety, and regarding to the implementation of these regulations, Latin America is performing very bad, in fact, none of the countries in the region accomplishes the 7 or 8 of the UN vehicle safety standards, and therefore, "because of the lack of legislation in Latin America, cars that would not be permitted in other markets are allowed on the roads" (Bezerra et al., 2015).

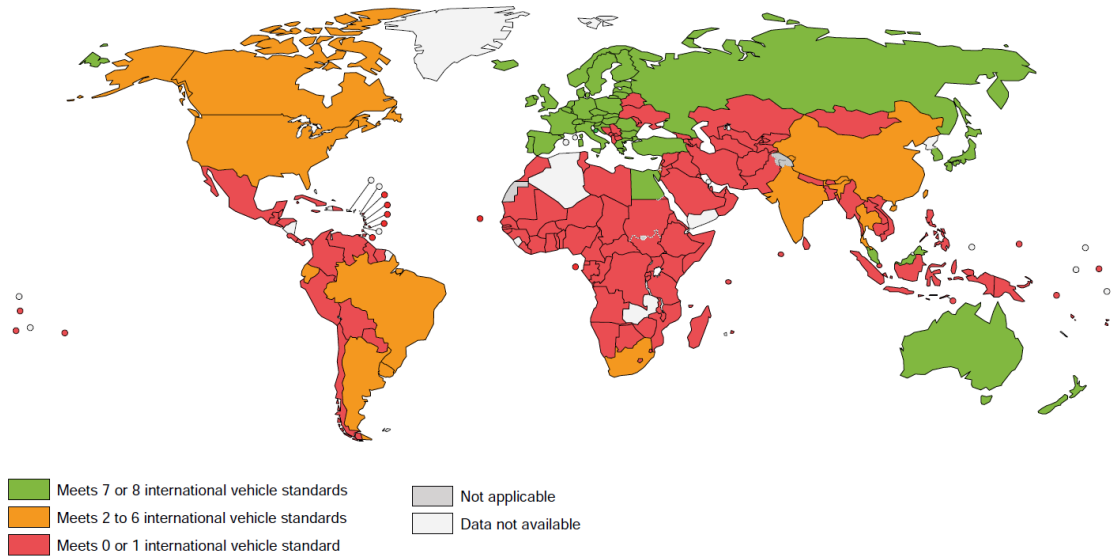


FIGURE 8 Implementation of Un vehicle safety standards at country level (World Health Organization, 2018)

At a more specific level, it is evident that the three main car producer countries in the region are not accomplishing even half of the UN vehicle safety standards. The situation of Brazil is concerning because they are accomplishing only the very basic safety standards (seat-belt, seat belt anchorages related and front airbag), however, the Situation of Mexico is even more alarming, accomplishing only one of the UN vehicle safety standards, the mandatory provision of Seat-belts. This is a clear red flag for the car production in Brazil and Mexico, especially considering that these countries are among the top ten passenger car producers in the world (International Organization of Motor Vehicle Manufacturers, 2019).

TABLE 6 Application of the UN vehicle safety standards in the three main car producer countries in Latin America, based on data from WHO (World Health Organization, 2018)

	UN vehicle safety standards						
Regulation	**14**	**16**	**94**	**95**	**140**	**127**	**129**
Safety standard	**Seat-belt**	**Seat-belt anchorages**	**Frontal impact**	**Side impact**	**Electronic Stability Control**	**Pedestrian protection**	**Child seats**
Argentina	Yes	Yes	Yes	Yes	No	No	No
Brazil	Yes	Yes	Yes	No	No	No	No
Mexico	Yes	No	No	No	No	No	No

Relevant studies demonstrated that the application of the UN vehicle safety standards in Argentina, Brazil and Mexico (the three main car producers in Latin America) plus Chile (one of the main consumers of cars in Latin America), would

have a great impact on the region. If the UN vehicle safety standards would be applied in these four countries in the period 2016-2030, up to 40000 deaths and 400000 serious injuries could be prevented in Latin America by 2030 (C. Wallbank, McRae-McKee, Durrell, & Hynd, 2017). This is a not minor fact considering that this reduction in the traffic fatalities represents economic savings close to US$ 143 billion over the same period (World Health Organization, 2017).

A more recent study states that "In total, if Argentina, Brazil, Chile, and Mexico adopted the full set of priority vehicle safety standards from 2020, more than 25000 lives could be saved and over 170000 serious injuries prevented, by 2030" (Caroline Wallbank et al., 2019). In that study, the authors refer the "full set of vehicle safety standards" to 6 of the UN vehicle safety standards (regulations 14, 16, 94, 95, 127 and 140) plus the implementation of Autonomous Emergency Braking (AEB).

The situation in Latin America regarding vehicle safety is alarming and there is too much work to do and too much space to improve, as noticed by the last studies mentioned. There is an urgent need to provide safer vehicles for people in Latin America, by means of pushing car manufacturers to produce safer cars through stricter law and normative, and by means of supporting NCAPs to increase the consumer information regarding the safety of vehicles available in the market.

Is for that reason that Latin NCAP has become fundamental to improve vehicle safety in Latin America, because "In the absence of national regulatory frameworks that fully comply with minimum UN Vehicle Safety Standards, consumers in these countries must rely on independent information to navigate the market and assess the relative safety offered by different products. At this point, the only truly independent source for unbiased and accurate information is Latin NCAP" (Consumers International, 2016).

CHAPTER 4: LATIN NCAP, THE SAFETY SCORES AND THE SAFETY RATINGS

This chapter constitutes the last chapter of the literature review and will consist mostly in the description of Latin NCAP, the work they have been realizing since 2010, the safety scores/ratings and the procedures they use in their crash tests. The description must start with an explanation of the emergence of NCAP programs in developed countries and how they have been implemented in developing regions (like Latin America) in the relatively recent past.

4.1 The emergence of New Car Assessment Programmes (NCAPs)

Basically, an NCAP is an organization or a "consumer information program" in charge to conduct crash tests to new cars to measure the impact on dummies in order to rate the safety performance of the vehicle.

NCAPs have been implemented firstly in developed regions and the results obtained in these first projects demonstrated that NCAPs are effective in "promoting the supply and demand for safer vehicles" (World Health Organization, 2015) and successful in raising the "levels of vehicle safety significantly above minimum regulatory requirements (World Health Organization, 2018). For that reason, the UN encourages the "implementation of NCAP's in all regions of the world" (United Nations, 2011).

Although Euro NCAP is considered one of the best-established NCAPs and a reference for the other NCAP's (Van Ratingen, 2016), the origin of these programmes is not related to Europe. The first NCAP in the world was launched in the US in 1978, implemented by the National Highway Traffic Safety Administration (NHTSA) to provide information to the consumers about the level of safety offered by the cars existing in the North American market (Domingues & de Lucinda, 2018).

Encouraged by the initial results obtained with this first pilot project, other high-income countries and regions decided to also launch their own NCAPs. After 15 years, Australia became the second country to launch its own program (Australian NCAP) in 1993, followed by Japan NCAP a couple of years later (1995) and by European NCAP in 1997 (GLOBAL NCAP, 2015). Posteriorly Korea also created its own NCAP in 1999 (GLOBAL NCAP, 2017).

It was only in the first decade of this century that NCAPs were launched in low and middle-income countries, in regions like China in 2006, Latin America in 2010 and South-East Asia in 2012 (GLOBAL NCAP, 2017). In 2011 was created GLOBAL NCAP, a common platform among all NCAP's for cooperation purposes (GLOBAL NCAP, 2015).

FIGURE 9 NCAPs launched around the world (Anwar, Kassim, Hashim, & Ilyas, 2017)

4.2 The implementation of Latin NCAP and their purpose

In 2010 was launched the NCAP for Latin America (composed by Mexico, the Caribbean, Central, and South America) and received the name of Latin NCAP. This program is one of the newest NCAP's and is just reaching one decade of life in the current year 2019.

Latin NCAP is an independent program, directed to the consumers and that follows the same framework and strategies adopted by other previous and effective NCAP programs implemented in developed regions like Euro NCAP (De La Peña, Millares, Díaz, Taddia, & Bustamante, 2016), therefore their tests are based in recognized international methodologies (GLOBAL NCAP, 2019), used to award the vehicle "with a safety rating between 0 and 5 stars, indicating the protection the cars offer to adult and child occupants" (Latin NCAP, 2019a). In their tests there are used dummies to measure the impact that car occupants would suffer in a real crash.

FIGURE 10 Example of a crash test conducted by Latin NCAP (GLOBAL NCAP, 2019)

The work of Latin NCAP can be conducted independently from governments and car manufacturers mainly because this program is economically supported by relevant international organizations like the FIA Foundation, Global NCAP, Gonzalo Rodríguez Foundation, the Inter-American Development Bank (IADB) and the International Consumer Research & Testing (ICRT) among the major sponsors (De La Peña et al., 2016).

Latin NCAP has the next objectives (Telles Pascoal et al., 2015) (GLOBAL NCAP, 2019):

- "To provide consumers in the region with independent and impartial safety assessment of new cars"
- "To encourage manufacturers to improve the safety performance of the vehicles they offer for sale" in Latin America
- To push "governments across the region to apply UN vehicle crash test regulations to passenger cars"

Latin NCAP started operations in a scenario even more complicated compared to Euro NCAP in 1997, because in that time, there were already applied many car safety regulations in Europe (Abu Kassim, Furas, & Mustaffa, 2017), therefore the car manufacturers were already accomplishing minimum levels of safety and, as it was noticed in the previous chapter, this is not the case of Latin America (Furas, 2013).

4.3 Test and protocols used by NCAP

4.3.1 Steps of the whole process

Latin NCAP follows a series of steps for the testing of a specific model, that goes from the selection of the model to be tested until the final publication of the results to the consumers. The process followed by Latin NCAP was elaborated trying to ensure independency from the car manufacturers, and, in order to show transparency to the consumers, Latin NCAP always tests the most basic version of the models selected (Furas, 2013), using only the safety devices that come fitted in the car as standard. The crash tests are conducted in the laboratories of ADAC (Allgemeiner Deutscher Automobil-Club) in Germany. In all these tests that are initiative of Latin NCAP, all the costs are covered by this organization.

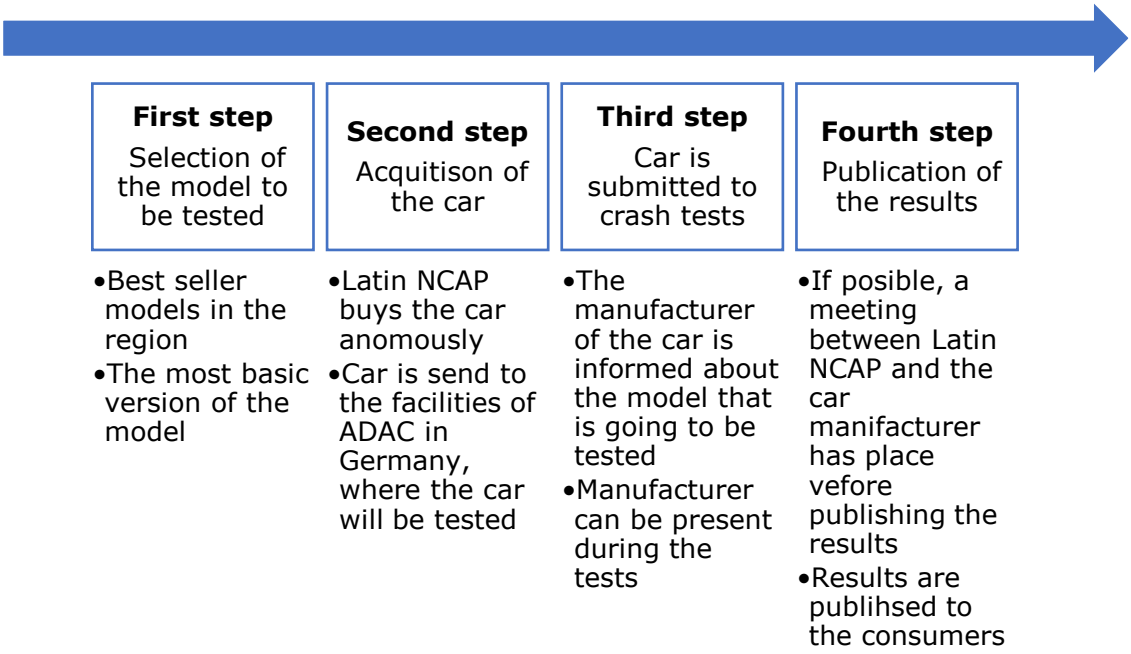


FIGURE 11 Process followed by Latin NCAP for the selection, acquisition, test of the car and the publication of the results (Domingues, 2016)

There is also the possibility to test cars that were not selected by Latin NCAP but that were sponsored by the car manufacturers. In the case of sponsored tests, the car manufacturer is in charge of covering the costs related to the test (Domingues, 2016). In general, car manufacturers sponsor tests for the models they believe are going to perform well during the crash tests and consequently to receive a high score and good rating of the car (Domingues & de Lucinda, 2018). In both cases, Latin NCAP publishes the results to the consumers.

4.3.2 The tests

All the tests are based on the same tests performed by Euro NCAP, actually, the protocols used in both cases are similar. Although the manner the test are performed did not change during the last decade, the requirements of these tests (optional or mandatory) and the manner their results account for the rating of the car, have changed since 2016, year in which a new protocol for the ratings was implemented, making the evaluation stricter than in past, in order to push car manufacturers to make their cars safer. A similar strategy was successfully implemented in older NCAP programs like Euro NCAP, considered "one of the better-stablished programs" (Van Ratingen, 2016).

4.3.2.1 Frontal impact test

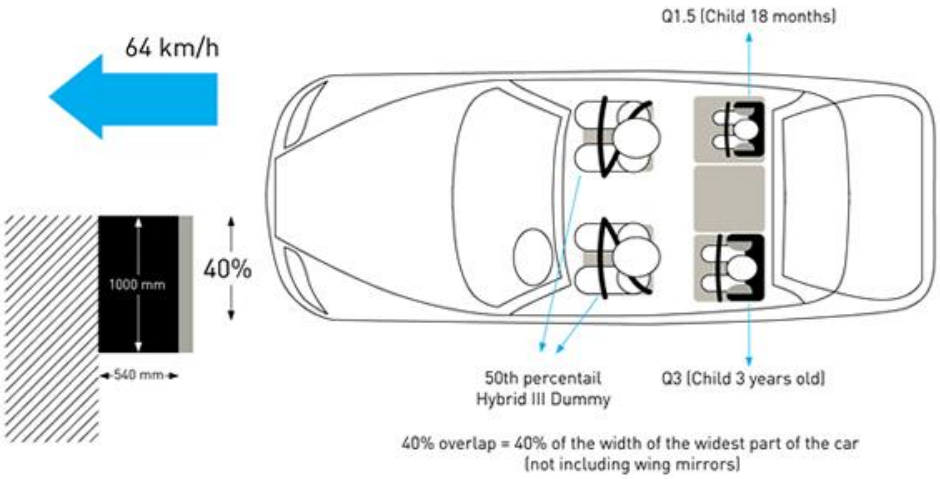


FIGURE 12 Frontal impact test (Latin NCAP, 2019b)

In this test, the car is accelerated until reaching a speed of 64 km/h and then is impacted against a deformable and fixed barrier at a 40% offset of the front of the car. This test is mandatory for all cars tested since 2010. This test tries to replicate a frontal collision with a car of similar mass 55 km/h and a 50% offset of their width (Latin NCAP, 2019b). In this test 4 dummies are used: two adult dummies in the front (driver and front passenger) and two child dummies in the rear seats, representing children of 18 months and 3 years old. The dummies assess the impact that car occupants would suffer in real crash conditions.

4.3.2.2 Side impact test

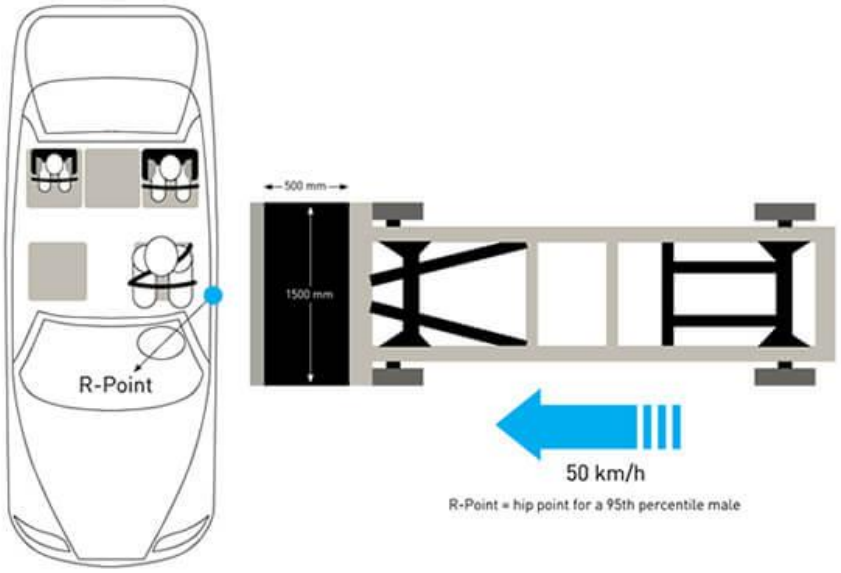


FIGURE 13 Side impact test (Latin NCAP, 2019b)

There are used the same dummies than in the previous one, except the dummy of the front passenger seat. In this case, the car remains static, and a deformable barrier strikes the cars at 50 km/h at the driver seat location at an approximated height of the hip of the driver (Latin NCAP, 2019b). This test was optional before 2016, and it was a special requirement to the car manufacturers in a manner that if they wanted their car to achieve 5 stars, the car should pass this test, however, since 2016 this test is mandatory for all the cars models tested by Latin NCAP (Latin NCAP, 2016).

4.3.2.3 Side pole impact test

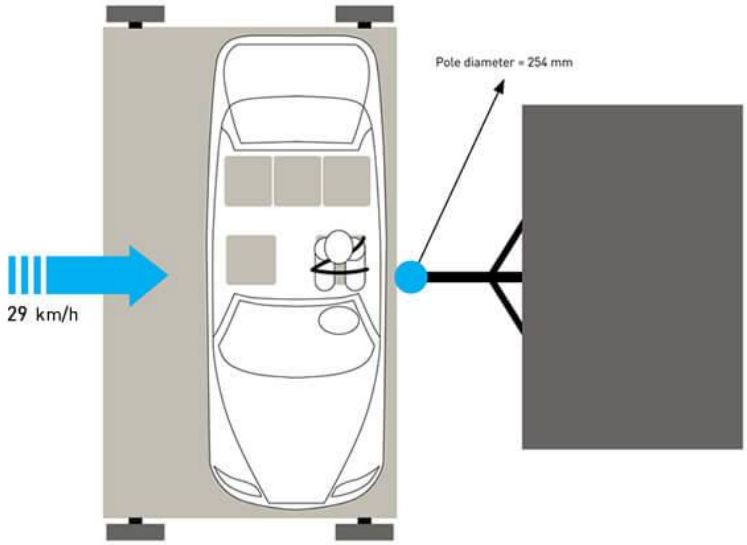


FIGURE 14 Side pole impact test (Latin NCAP, 2019b)

This test was not available before 2016, however since that year, it is an optional requirement for all the cars to obtain the highest safety rating (Latin NCAP, 2016). If car manufacturers want some specific model to obtain 5 stars, their car must pass this test. This test uses only the dummy in the driver position. In this optional test, the car is installed above a moving platform, that strikes the vehicle against a rigid pole at 29 km/h (Latin NCAP, 2019b).

4.3.2.4 Car inspection before and after the crash tests

For the assessment of the adult occupant protection, a post-crash inspection takes place to analyze the structural performance of the car, considering the displacement of the wheel, the pedal, the compartment for the feet and the pillars (Latin NCAP, 2013).

In the case of the assessment of child occupant protection, it takes place a vehicle inspection before and after the test. Before the test the vehicle is studied to measure the compatibility of the car with Child Restraint Systems (CRS). After the crash tests, the vehicle is inspected again to assess aspects like airbag disabling,

labeling, ISOFIX usability, the displacement of the CRS and others (Euro NCAP & Latin NCAP, 2014).

4.4 The safety scores and safety ratings

Latin NCAP estimates a safety score for adult occupant protection and child occupant protection, based on the results of the tests and the vehicle inspections explained in the previous point of this chapter. In both cases the scores are converted to safety ratings that go from 0 to 5 stars, therefore every car tested by Latin NCAP will have two different safety ratings, one for adult occupant protection and one for child occupant protection.

4.4.1 Adult occupant protection

The estimation of the safety score is done based mainly in the response of the dummies to the impacts during the tests. It is measured the impact in four regions of the body of the dummies that represent the driver and the front passenger occupant (only in frontal impact test) and according to a scale, each part of the region can receive an individual score from 0 to 4 points (Latin NCAP, 2013). The four body regions assessed in the dummy are:

- Head and neck
- Chest
- Femur, Pelvis, and Knee
- Leg and Foot

The maximum score that can be obtained from this assessment is 16 points in the frontal impact test and another 16 points in the side impact test (that was optional until 2015).

For the period 2010-2015

In this period the only mandatory test was the frontal impact test, making the maximum score to be obtained 16 points. However, another extra point could be obtained if the car had installed Seat Belt Reminder (SBR) in the front seats (driver and passenger). The scores were translated into a star rating using the next scale and requirements:

TABLE 7 Safety scores and safety rating scale for adult occupant protection in the period 2010-2015 (Latin NCAP, 2013)

Minimum Score (out of 16)	Additional requirements	Star Rating
14.00	1 point SBR + ABS + Side Impact test	5 stars
11.00	-	4 stars
8.00	-	3 stars
5.00	-	2 stars
2.00	-	1 star
0.00	-	0 stars

To obtain a safety rating of 5 stars, the car tested had to accomplish additional special requirements besides to obtain a minimum of 14 points of safety score. The requirements were to offer SRB in front seats, Automatic Braking System (ABS) and also the car should pass an optional side impact test, that had to be sponsored by the car manufacturer (Latin NCAP, 2013).

For the period 2016-2019

Since 2016 there was applied a new protocol that is more exigent than the previous one. In this case, the side test impact became mandatory therefore all the cars are submitted to both tests (frontal and side impact). Each test have a maximum score of 16 points, following the same methodology than before, based on the same scores and the same body regions (maximum 4 points for each body region) and making a total of 32 points to be achieved in the both tests, plus 2 extra points that could be achieved if SBR is present in front and rear seats (Latin NCAP, 2015). The scores are converted to ratings according to the next ranges:

TABLE 8 Safety scores and safety rating scale for adult occupant protection in the period 2016-2019

Minimum Score (out of 34)	Minimum SBR Score	ESC	Pole impact test	Star Rating
27.00	1 point	Fitted in the car	Pass	5 stars
22.00	1 point	-	-	4 stars
16.00	0.5 point	-	-	3 stars
10.00	-	-	-	2 stars
4.00	-	-	-	1 star
0.00	-	-	-	0 stars

In order to receive a safety rating of 5 stars the car tested must achieve a minimum of 37 points in the frontal and side-impact tests, at least offer SBR in front seats (driver and passenger), count with Electronic Stability Control (ESC) and pass an

optional pole side impact test (Latin NCAP, 2016). If the car has installed SBR only in the driver seat, it will receive only 0.5 points in this category.

4.4.2 Child occupant protection

The score for child occupant protection is estimated based on assessment related to the next aspects:

- Dynamic performance: based on the impact of the crash on the dummies, during the frontal impact test and side impact test (when performed)
- Installation of child restraints: the car is studied to see if can accommodate different CRS available in the market
- Vehicle based assessments: related to airbag disabling, labeling, ISOFIX suitability and more.

The new protocol implemented since 2016 made some changes in the maximum score that the car can obtain in each one of these aspects, however, the maximum score for the whole child occupant protection still being 49 points. The new protocol gives more relevance to the dynamic performance rather than the vehicle-based assessments.

TABLE 9 Estimation of the child occupant protection score in the period 2010 – 2015 (Euro NCAP & Latin NCAP, 2014) and the period 2016 -2019 (Euro NCAP & Latin NCAP, 2015)

	Period 2010 - 2015	Period 2016 - 2019
	Maximum points	Maximum points
Dynamic performance	16.00	24.00
Installation of child restraints	12.00	12.00
Vehicle based assessments	21.00	13.00

The safety rating for child occupant protection goes from 0 to 5 stars, and is awarded according to the next scales:

TABLE 10 Safety scores and safety rating scale for child occupant protection in the period 2010 – 2015 (Euro NCAP & Latin NCAP, 2014) and the period 2016 - 2019 (Euro NCAP & Latin NCAP, 2015)

Period 2010 - 2015	Period 2016 - 2019	
Minimum Score (out of 49)	**Minimum Score (out of 49)**	**Star Rating**
43.00	41.00	5 stars
36.00	35.00	4 stars
25.00	27.00	3 stars
14.00	18.00	2 stars
8.00	9.00	1 star
0.00	0.00	0 stars

In contrast to the safety rating for adult occupant protection, there are no extra requirements to achieve 5 stars in the child occupant protection because the rating is based totally on the score obtained by the cars in the different assessments related to child occupant protection.

CHAPTER 5: METHODOLOGY OF THE RESEARCH

The literature review conducted in the previous chapters was helpful to understand the context surrounding the research conducted in this thesis, describing aspects like the road safety problems in Latin America, the urgency for safer vehicles in this region of the world, the creation of Latin NCAP, the work they have been performing since 2010 and the manner the safety scores and safety ratings are estimated.

In this chapter, there will be described the methodology used for the analysis of the data starting from the source of the data, the collection, and treatment of the data, the data processing and the post-processing representation of the results of the analysis.

5.1 Source of the data and data collection

The results of the test conducted by Latin NCAP are open to the consumers and public in general and published on their official website www.latinncap.com, therefore all the safety scores and safety ratings for adult occupant protection and child occupant protection were collected from the official website of Latin NCAP.

There were downloaded in PDF format, the results of all the cars tested by Latin NCAP since 2010 (year of creation of Latin NCAP) until the end of 2019 (in order to have complete annual data for the comparisons). The data comprehend a total of 134 different cars tested by Latin NCAP in the period 2010-2019.

TABLE 11 Number of cars tested by Latin NCAP from 2010 to 2019 (Latin NCAP, 2019c)

Year	Cars tested by Latin NCAP
2010	9
2011	9
2012	8
2013	13
2014	10
2015	22
2016	8
2017	15
2018	13
2019	27
Total	***134***

The variables and descriptive data that was extracted from the safety scores and safety ratings of every car tested by Latin NCAP are the next:

- Brand, year and model of the car

- Safety rating (number of stars) for adult occupant protection and child occupant protection
- Safety score (points) for adult occupant protection and child occupant protection
- Performance (points) in the different adult occupant tests carried out (frontal impact and side impact when available)
- Number of airbags
- Type of urban car (supermini, sedan, familiar….) and weight of the car
- Country or region where the car was produced
- The month when the tests were conducted
- Other relevant information when available

The most relevant data was available for all cars tested since 2010 (brand, year, model, type of car, safety scores and safety ratings), however, there is some extra information that is available only since some specific year, for instance, the side impact test score is mandatory only since 2016, and before that year this test was optional to get a 5 star rating and the most of the cars tested before 2016 were not submitted to this optional test. Nevertheless, when available, there was extracted all the additional data that was helpful to enrich the research.

5.2 Data digitalization and data processing

The data for every year is basically the same with some small differences since the year 2016. For instance, in 2016 Latin NCAP applied a new protocol that included the side impact test as mandatory and only since that year they published the score for this test. Before 2016 the side impact test was optional and the results of the test consisted only in "pass or fail", without receiving any numerical score for this test. Also, since 2016 the adult occupant score can reach a maximum of 34 points while in the period 2010-2015 the maximum score that could be obtained was only 17 points, as explained in the previous chapter.

The information was digitalized in the next tables, from where it was easier to treat and manipulate the data during the analysis:

TABLE 12 Data digitalization from cars tested in the period 2010-2015

Nr.	Brand	Model	Month	Year	Made in	Type of car	kg	Spon-sored?	Number of airbags	Front Seat belt preten-sioners?	SBR Installed?
1	Chevrolet	Meriva Gl Plus	August	2010		5 door monovolume	1477	Yes	2	Yes	Yes
2	Fiat	Palio ELX 1.4	August	2010		5 door hatchback	1231	No	0	No	No
3	Fiat	Palio ELX 1.4	August	2010		5 door hatchback	1276	Yes	2	Yes	Yes
4	Geely	CK 1 1.3	August	2010		4 door Sedan	1263	No	0	No	No
5	Peugeot	207 Compact 5P 1.4	August	2010		5 door hatchback	1243	No	0	No	No
6	Peugeot	207 Compact 5P 1.4	August	2010		5 door hatchback	1261	Yes	2	Yes	Yes
7	Toyota	Corolla XEI	August	2010		4 door Sedan	1456	No	2	Yes	Yes
8	Volkswagen	Gol Trend 1.6	August	2010		5 door hatchback	1216	No	0	No	No
9	Volkswagen	Gol Trend 1.6	August	2010		5 door hatchback	1448	Yes	2	Yes	Yes
10	Chevrolet	Celta	August	2011	Brazil	2 door hatchback	1119	No	0	No	No
11	Chevrolet	Corsa Classic	August	2011	Argentina	4 door Sedan	1151	No	0	No	No
12	Chevrolet	Cruze LT	August	2011	Corea	4 door Sedan	1627	Yes	2	Yes	Yes
13	Fiat	Novo Uno Evo	July	2011	Brazil	4 door hatchback	1195	No	0	No	No
14	Ford	Focus Hatchback	September	2011	Argentina	4 door hatchback	1517	Yes	2	Yes	Yes
15	Ford	Ka Fly Viral	July	2011	Brazil	2 door hatchback	1116	No	0	No	No
16	Nissan	March	November	2011	México	4 door hatchback	1175	No	2	Yes	Yes
17	Nissan	Tiida	May	2011	México	4 door hatchback	1411	No	1	Yes	No
18	Nissan	Tiida	November	2011	México	4 door hatchback	1448	Yes	2	Yes	Yes
19	Ford	Fiesta	June	2012		4 door hatchback	1399	Yes	2	Yes	Yes
20	Honda	City	June	2012		4 door Sedan	1380	Yes	2	Yes	Yes
21	Jac	J3	May	2012		4 door hatchback	1321	No	2	Yes	No
22	Renault	Fluence	September	2012		4 door Sedan	1512	Yes	2	No	Yes
23	Renault	Sandero	April	2012		4 door Sedan	1512	No	0	No	No
24	Toyota	Etios	October	2012		4 door hatchback	1162	Yes	2	Yes	Yes

25	Volkswagen	Polo	August	2012		4 door hatchback	1342	Yes	2	Yes	Yes
26	Volkswagen	Bora	August	2012		4 door Sedan	1449	No	2	Yes	Yes
27	Chevrolet	Agile	July	2013		4 door hatchback	1267	No	0	No	No
28	Chevrolet	Malibu	November	2013		4 door Sedan	1800	Yes	10	Yes	No
29	Ford	EcoSport	March	2013		5 door SUV	1462	No	2	Yes	Yes
30	Ford	EcoSport	November	2013		4 door SUV	1462	Yes	2	Yes	Yes
31	Ford	Focus III	November	2013		4 door hatchback	1517	Yes	2	Yes	Yes
32	Hyundai	HB20	March	2013		5 door hatchback	1301	No	2	Yes	Yes
33	Hyundai	HB20	November	2013		4 door Sedan	1313	Yes	2	Yes	Yes
34	Nissan	Tsuru / Sentra B13	July	2013		4 door Sedan	1124	No	0	No	No
35	Renault	Clio Mio	July	2013		4 door hatchback	1122	No	0	No	No
36	Seat	Leon	July	2013		4 door hatchback	1460	Yes	6	Yes	Yes
37	Suzuki	Alto	July	2013		4 door hatchback	1021	No	0	No	No
38	Suzuki	Celerio	July	2013		4 door hatchback	1108	Yes	2	Yes	No
39	Volkswagen	Jetta / Vento	November	2013		4 door Sedan	1526	Yes	2	Yes	Yes
40	Chevrolet	Onix	December	2014	Brazil	4 door hatchback	1286	No	2	Yes	Yes
41	Chevrolet	Spark	August	2014	South Corea	4 door compact	1034	No	0	No	No
42	Fiat	New Palio	August	2014	Argentina	4 door hatchback	1265	No	0	No	No
43	Fiat	New Palio	August	2014	Argentina	4 door hatchback	1280	No	2	Yes	No
44	Lifan	320	December	2014	China	4 door hatchback	1148	No	0	No	No
45	Peugeot	208	August	2014	Brazil	4 door hatchback	1303	No	2	No	Only driver
46	Suzuki	Swift	November	2014	India	4 door hatchback	1194	No	2	Yes	No
47	Toyota	Corolla	October	2014	Brazil and US	4 door Sedan	1532	Yes	3	Yes	Yes
48	Volkswagen	Golf	October	2014	Mexico	4 door hatchback	1556	Yes	7	Yes	Yes
49	Volkswagen	Up!	January	2014		4 door hatchback	1189	Yes	2	Yes	Yes
50	Chery	iQ	July	2015	China	5 door hatchback	1156	No	0	No	Only driver
51	Chevrolet	Aveo	November	2015	Mexico	4 door Sedan	1326	No	0	No	No
52	Citroen	C3	April	2015	Brazil	4 door hatchback	1358	No	2	No	Only driver
53	Fiat	New Palio	July	2015	Argentina and Brazil	4 door hatchback	1280	Yes	2	Yes	Only driver

54	Ford	Ka	November	2015	Brazil	4 door Sedan	1279	Yes	2	Yes	Only driver
55	Honda	City	November	2015	Brazil	4 door Sedan	1346	Yes	2	Yes	Yes
56	Honda	Fit	November	2015	Brazil and Mexico	4 door hatchback	1345	Yes	2	Yes	Yes
57	Honda	HR-V	November	2015	Brazil and Argentina	4 door SUV	1499	Yes	2	Yes	Yes
58	Hyundai	Grand i10	September	2015	India	5 door hatchback	1160	No	0	No	No
59	Hyundai	Creta	December	2015	India	4 door SUV	1496	Yes	2	Yes	Only driver
60	Jeep	Renegade	July	2015	Brazil	4 door SUV	1661	Yes	2	Yes	Yes
61	Mitsubishi	Montero Sport	December	2015	Thailand	4 door SUV	2248	Yes	3	Yes	Yes
62	Nissan	Tiida Sedan	April	2015	Mexico	4 door Sedan	1336	No	0	No	No
63	Nissan	Tiida Sedan	September	2015	Mexico	4 door Sedan	1387	Yes	2	Yes	No
64	Nissan	March	December	2015	Brazil and Mexico	4 door hatchback	1174	Yes	2	Yes	No
65	Nissan	Versa	December	2015	Brazil and Mexico	4 door Sedan	1289	Yes	2	Yes	No
66	Renault	Duster	September	2015	Colombia	4 door SUV	1467	No	1	No	No
67	Seat	Leon ST	April	2015	Spain	4 door hatchback	1551	Yes	6	Yes	Yes
68	Toyota	Hilux / SW4	December	2015	Thailand and Argentina	4 door Pick up	2309	Yes	3	Yes	Yes
69	Toyota	RAV4	December	2015	Japan	4 door SUV	1823	Yes	3	Yes	Yes
70	Volkswagen	Vento	November	2015	India	4 door Sedan	1387	Yes	2	Yes	Yes
71	Volkswagen	Fox	December	2015	Brazil	4 door hatchback	1288	Yes	2	Yes	Only driver

Nr.	Adult star rating	Adult score	Adult score max	Adult score (%)	Child star rating	Child score	Child score max	Child score (%)	Frontal impact test score	Frontal test max score	Side test performed?	Side test pass?	Bodyshell integrity
1	3	8,64	17	50,82%	1	9,04	49	18,45%	7,64	16	No		
2	1	6,32	17	37,18%	2	16,25	49	33,16%	6,32	16	No		
3	3	10,65	17	62,65%	2	21,27	49	43,41%	9,65	16	No		
4	0	1,06	17	6,24%	2	20,37	49	41,57%	1,06	16	No		
5	1	6,32	17	37,18%	2	16,25	49	33,16%	6,32	16	No		
6	2	7,13	17	41,94%	2	16,26	49	33,18%	6,13	16	No		
7	4	13,6	17	80,00%	1	12,68	49	25,88%	12,6	16	No		
8	1	5,75	17	33,82%	2	18,86	49	38,49%	5,75	16	No		
9	3	10,01	17	58,88%	2	21,16	49	43,18%	9,01	16	No		
10	1	3,82	17	22,47%	2	22,68	49	46,29%	3,82	16	No		
11	1	2,28	17	13,41%	1	9,16	49	18,69%	2,28	16	No		
12	4	13,18	17	77,53%	3	32,56	49	66,45%	12,18	16	No		
13	1	2	17	11,76%	2	20,73	49	42,31%	2	16	No		
14	4	13,56	17	79,76%	3	33,68	49	68,73%	12,56	16	No		
15	1	2,37	17	13,94%	3	30,52	49	62,29%	2,37	16	No		
16	2	7,62	17	44,82%	1	9,68	49	19,76%	6,62	16	No		
17	3	9,54	17	56,12%	1	8	49	16,33%	9,54	16	No		
18	4	13,12	17	77,18%	1	9,29	49	18,96%	12,12	16	No		
19	4	12,86	17	75,65%	4	37,8	49	77,14%	11,86	16	No		
20	4	12,03	17	70,76%	4	37,99	49	77,53%	11,03	16	No		
21	1	3,5	17	20,59%	2	13,03	49	26,59%	3,5	16	No		
22	4	11,97	17	70,41%	2	20,92	49	42,69%	11,97	16	No		
23	1	4,61	17	27,12%	2	18,78	49	38,33%	4,61	16	No		
24	4	12,86	17	75,65%	2	17,38	49	35,47%	11,86	16	No		
25	4	11,34	17	66,71%	3	36,95	49	75,41%	11,34	16	No		
26	3	10,27	17	60,41%	3	35,82	49	73,10%	9,27	16	No		

27	0	0	17	0,00%	2	16,35	49	33,37%	0	16	No		Unstable
28	4	14,56	17	85,65%	1	8,57	49	17,49%	14,56	16	No		Stable
29	4	13,64	17	80,24%	3	31	49	63,27%	12,64	16	No		
30	5	14,64	17	86,12%	3	31	49	63,27%	13,64	16	Yes	Yes	Stable
31	5	16,52	17	97,18%	4	38,06	49	77,67%	15,52	16	Yes	Yes	Stable
32	3	10,23	17	60,18%	1	4,77	49	9,73%	9,23	16	No		
33	4	13,8	17	81,18%	3	34,52	49	70,45%	12,8	16	No		Stable
34	0	1	17	5,88%	0	0	49	0,00%	0	16	No		Unstable
35	0	0	17	0,00%	1	9	49	18,37%	0	16	No		Unstable
36	5	14,52	17	85,41%	4	38,55	49	78,67%	13,52	16	Yes	Yes	Stable
37	0	0	17	0,00%	3	25	49	51,02%	0	16	No		Unstable
38	4	12,99	17	76,41%	2	17,92	49	36,57%	12,99	16	No		Stable
39	5	15,34	17	90,24%	4	39,2	49	80,00%	14,34	16	Yes	Yes	Stable
40	3	10,67	17	62,76%	2	20,14	49	41,10%	9,67	16	No		Stable
41	0	0	17	0,00%	2	16,59	49	33,86%	0	16	No		Unstable
42	0	0	17	0,00%	2	18,01	49	36,76%	0	16	No		Stable
43	3	10,84	17	63,76%	2	20,37	49	41,57%	10,84	16	No		Stable
44	0	0	17	0,00%	0	4,72	49	9,63%	0	16	No		Unstable
45	4	12,64	17	74,35%	3	28,13	49	57,41%	12,14	16	No		Stable
46	3	10,12	17	59,53%	1	3,41	49	6,96%	10,12	16	No		Unstable
47	5	15,83	17	93,12%	4	41,25	49	84,18%	14,83	16	Yes	Yes	Stable
48	5	16,56	17	97,41%	5	44,3	49	90,41%	15,56	16	Yes	Yes	Stable
49	5	15,86	17	93,29%	4	39,54	49	80,69%	14,86	16	Yes	Yes	Stable
50	0	0	17	0,00%	0	3	49	6,12%	0	16	No		Unstable
51	0	0	17	0,00%	2	17,93	49	36,59%	0	16	No		Unstable
52	4	11,19	17	65,82%	2	22,67	49	46,27%	10,69	16	No		Unstable
53	4	11,34	17	66,71%	3	25,28	49	51,59%	10,84	16	No		Stable
54	4	12,17	17	71,59%	3	30,58	49	62,41%	11,67	16	No		Stable
55	5	16,07	17	94,53%	4	41,81	49	85,33%	15,07	16	Yes	Yes	Stable
56	5	16,26	17	95,65%	4	39,48	49	80,57%	15,26	16	Yes	Yes	Stable

57	5	16,7	17	98,24%	5	43,3	49	88,37%	15,7	16	Yes	Yes	Stable
58	0	0	17	0,00%	2	20,81	49	42,47%	0	16	No		Unstable
59	4	15,57	17	91,59%	3	29,87	49	60,96%	15,07	16	No		Stable
60	5	16,12	17	94,82%	5	43,54	49	88,86%	15,12	16	Yes	Yes	Stable
61	5	16,7	17	98,24%	3	31,04	49	63,35%	15,7	16	Yes	Yes	Stable
62	0	0	17	0,00%	2	16,41	49	33,49%	0	16	No		Unstable
63	4	13,08	17	76,94%	2	18,67	49	38,10%	13,08	16	No		Stable
64	3	8	17	47,06%	1	10,71	49	21,86%	8	16	No		Unstable
65	3	8,64	17	50,82%	2	18,22	49	37,18%	8,64	16	No		Unstable
66	4	11	17	64,71%	2	21,37	49	43,61%	11	16	No		Unstable
67	5	14,71	17	86,53%	5	43,39	49	88,55%	13,71	16	Yes	Yes	Stable
68	5	15,71	17	92,41%	5	44,25	49	90,31%	14,71	16	Yes	Yes	Stable
69	5	16,41	17	96,53%	4	36,57	49	74,63%	15,41	16	Yes	Yes	Stable
70	5	14,73	17	86,65%	3	34,16	49	69,71%	13,73	16	Yes	Yes	Stable
71	4	11,34	17	66,71%	2	21,23	49	43,33%	10,84	16	No		Stable

TABLE 13 Data digitalization from cars tested in the period 2016-2019

Nr.	Brand	Model	Month	Year	Made in	Type of car	kg	Spon-sored?	Number of airbags	Front Seat belt preten-sioners ?	SBR Installed?
72	BYD	F0	August	2016	China	5 door hatchback	1083	No	0	No	No
73	Chevrolet	Sail	April	2016	China and Colombia	4 door Sedan	1303	No	0	No	No
74	Chevrolet	Spark GT	September	2016	India	5 door hatchback	1187	No	0	No	No
75	Fiat	New Palio	August	2016	Argentina and Brazil	5 door hatchback	1280	No	2	Yes	Only driver
76	Ford	Ranger	April	2016	Argentina	4 door Pick up	2295	Yes	3	Yes	Yes
77	Kia	Picanto	June	2016	South Korea	4 door hatchback	1120	No	0	No	No
78	Nissan	Murano	December	2016	US	5 door SUV	2074	No	7	Yes	Yes
79	Peugeot	208	June	2016	Brazil	4 door hatchback	1303	No	2	No	Only driver
80	Chevrolet	Aveo	December	2017	Mexico	4 door Sedan	1353	No	2	No	Only driver
81	Chevrolet	N300	August	2017	China	5 door MPV	1370	No	0	No	No
82	Chevrolet	Onix	May	2017	Brazil	5 door hatchback	1286	No	2	Yes	Only driver
83	Fiat	Mobi	August	2017	Brazil	5 door hatchback	1170	No	2	Yes	No
84	Ford	Ka / Figo	October	2017	Brazil	4 door Sedan	1279	No	2	Yes	Only driver
85	Kia	Rio Sedan	May	2017	Korea	5 door Sedan	1261	No	0	No	Only driver
86	Kia	New Rio Sedan	August	2017	Mexico	4 door Sedan	1318	Yes	1	Yes	Only driver
87	Nissan	Kicks	December	2017	Brazil	5 door SUV	1361	Yes	2	Yes	No
88	Nissan	Murano	December	2017	US	5 door SUV	2074	Yes	7	Yes	Yes
89	Renault	Kwid	November	2017	Brazil	5 door hatchback	992	Yes	4	Yes	Yes
90	Renault	Captur	June	2017	Brazil	5 door SUV	1557	Yes	4	Yes	Yes
91	Seat	Ateca	March	2017	Czech Republic	5 door SUV	1539	Yes	7	Yes	Yes
92	Toyota	Corolla	September	2017	Brazil and US	4 door Sedan	1564	Yes	7	Yes	Yes
93	Volkswagen	Polo	September	2017	Brazil	5 door hatchback	1305	Yes	4	Yes	Yes

94	Volkswagen	Golf VII	March	2017	Brazil, Mexico and Germany	5 door hatchback	1511	Yes	7	Yes	Yes
95	Chevrolet	Cruze	November	2018	Argentina	4 door Sedan	1522	Yes	4	Yes	Yes
96	Chevrolet	New Aveo	December	2018	China	4 door Sedan	1323	No	2	Yes	No
97	Chevrolet	Onix / Prisma	January	2018	Brazil	4 door hatchback	1271	Yes	2	Yes	Only driver
98	Fiat	500X	November	2018	Italy	5 door SUV	1572	Yes	6	Yes	Yes
99	Fiat	Toro	March	2018	Brazil	4 door Pick up	1904	Yes	2	Yes	Yes
100	Ford	Ka	September	2018	Brazil	5 door hatchback	1279	Yes	2	Yes	Only driver
101	Hyundai	Accent	September	2018	South Korea	4 door Sedan	1271	No	0	No	Only driver
102	Mazda	2	July	2018	Mexico	5 door hatchback	1269	No	2	Yes	No
103	Nissan	March	July	2018	Brazil and Mexico	5 door hatchback	1161	No	2	Yes	No
104	Renault	Sandero / Logan	June	2018	Brazil, Argentina and Colombia	4 door hatchback	1320	No	2	No	No
105	Seat	Arona	December	2018	Spain	5 door hatchback	1428	Yes	6	Yes	Yes
106	Seat	Ibiza	December	2018	Spain	5 door hatchback	1371	Yes	6	Yes	Yes
107	Volkswagen	Virtus	January	2018	Brazil	4 door Sedan	1431	Yes	4	Yes	Yes
108	Chery	Tiggo 3	September	2019	China	5 door SUV	1593	No	2	No	Only driver
109	Chevrolet	Cruze	August	2019	Argentina	4 door Sedan	1522	Yes	6	Yes	Yes
110	Chevrolet	New Onix Hatchback	November	2019	Brazil	5 door hatchback	1350	Yes	6	Yes	Yes
111	Chevrolet	New Aveo	December	2019	China	4 door Sedan	1323	No	2	Yes	Only driver
112	Chevrolet	New Onix Plus	September	2019	Brazil	4 door Sedan	1350	Yes	6	Yes	Yes
113	Fiat	Argo	July	2019	Brazil and Argentina	4 door Sedan	1392	Yes	2	Yes	Only driver
114	Ford	Figo	September	2019	India	4 door Sedan	1349	Yes	4	Yes	Yes
115	Ford	Ranger	December	2019	Argentina	4 door Pick up	2295	Yes	3	Yes	Yes
116	Hyundai	HB20 Hatchback	December	2019	Brazil	5 door hatchback	1291	Yes	2	Yes	No
117	Mitsubishi	Eclipse Cross	December	2019	Japan	5 door SUV	1689	Yes	3	Yes	Yes
118	Mitsubishi	L200	November	2019	Thailand and Brazil	4 door Pick up	2033	Yes	0	No	No

119	Nissan	Frontier / NP300 Navara	August	2019	Mexico and Argentina	4 door Pick up	2090	Yes	2	Yes	Yes
120	Peugeot	301	December	2019	Spain	4 door Sedan	1373	Yes	4	Yes	Only driver
121	Renault	Kangoo	May	2019	Argentina	5 door MPV	1490	No	2	No	Only driver
122	Renault	New Duster	October	2019	Romania, Brazil and Colombia	4 door SUV	1484	Yes	2	Yes	Yes
123	Renault	New Sandero / Logan	December	2019	Brazil, Argentina and Colombia	4 door hatchback	1259	Yes	4	Yes	Only driver
124	Renault	New Sandero / Logan	December	2019	Brazil, Argentina and Colombia	4 door hatchback	1259	Yes	4	Yes	Only driver
125	Seat	Tarraco	October	2019	Germany	5 door SUV	1836	Yes	7	Yes	Yes
126	Toyota	Etios	July	2019	Brazil	5 door hatchback	1243	Yes	2	Yes	Yes
127	Toyota	Hilux Double Cab	August	2019	Argentina and Thailand	4 door Pick up	2323	Yes	7	Yes	Yes
128	Toyota	New Corolla	December	2019	Brazil	4 door Sedan	1681	Yes	7	Yes	Yes
129	Toyota	RAV4	May	2019	Japan	5 door SUV	1923	Yes	7	Yes	Yes
130	Toyota	Yaris	March	2019	Brazil	4 door Sedan	1375	Yes	2	Yes	Yes
131	Volkswagen	Jetta / Vento	September	2019	Mexico	4 door Sedan	1616	Yes	6	Yes	Yes
132	Volkswagen	Tiguan	September	2019	Mexico	5 door SUV	1808	Yes	6	Yes	Yes
133	Volkswagen	Suran / Fox	March	2019	Brazil and Argentina	4 door MPV	1356	No	2	Yes	Only driver
134	Volkswagen	T-cross	March	2019	Brazil	5 door SUV	1518	Yes	6	Yes	Yes

Nr.	Adult star rating	Adult score	Adult score max	Adult score (%)	Child star rating	Child score	Child score max	Child score (%)	Frontal test score	Front. test max score	Side test perfor-med?	Side test score	Side test max	Bodyshell integrity	Side impact protec-tion?	ESC	Pole side test perfor-med?	Pole side test pass?
72	0	0	34	0,00%	1	12,65	49	25,82%	0	16	No			Stable	Yes	No	No	
73	0	0	34	0,00%	2	23,21	49	47,37%	0	16	No			Unstable		No	No	
74	0	0	34	0,00%	0	8,78	49	17,92%	0	16	No			Stable	Yes	No	No	
75	1	18,09	34	53,21%	3	31,57	49	64,43%			Yes			Stable	Yes	No	No	
76	3	30,62	34	90,06%	4	40,17	49	81,98%			Yes			Stable		No	No	
77	0	0	34	0,00%	1	13,3	49	27,14%	0	16	No			Stable	Yes	No	No	
78	2	22,81	34	67,09%	4	35,22	49	71,88%			Yes			Unstable	Yes	Yes	Yes	
79	2	18,27	34	53,74%	3	30,65	49	62,55%			Yes			Stable	No	No	No	
80	0	17,49	34	51,44%	3	30,11	49	61,45%			Yes			Stable	Yes	No	No	
81	0	11,92	34	35,06%	1	13,28	49	27,10%			Yes			Unstable	No	No	No	
82	0	0	34	0,00%	3	27,38	49	55,88%			Yes			Stable	Yes	No	No	
83	1	19,2	34	56,47%	2	26,98	49	55,06%			Yes			Stable	Yes	No	No	
84	0	0	34	0,00%	3	33,51	49	68,39%			Yes			Stable	Yes	No	No	
85	0	0	34	0,00%	1	16,15	49	32,96%			No			Stable	Yes	No	No	
86	2	23,55	34	69,26%	2	18,27	49	37,29%			Yes			Stable	Yes	No	No	
87	4	25,39	34	74,68%	4	37,41	49	76,35%			Yes			Unstable	Yes	Yes	No	
88	5	28,72	34	84,47%	3	34,66	49	70,73%			Yes			Stable	Yes	Yes	Yes	Yes
89	3	22,85	34	67,21%	3	33,87	49	69,12%			Yes			Stable	Yes	No	No	
90	4	30,27	34	89,03%	3	33,68	49	68,73%			Yes			Stable	Yes	Yes	No	
91	5	32,65	34	96,03%	5	42,48	49	86,69%			Yes			Stable	Yes	Yes	Yes	Yes
92	5	29,6	34	87,06%	5	44,88	49	91,59%			Yes			Stable	Yes	Yes	Yes	Yes
93	5	32,13	34	94,50%	5	43	49	87,76%			Yes			Stable	Yes	Yes	Yes	Yes
94	5	33,3	34	97,94%	5	43,52	49	88,82%			Yes			Stable	Yes	Yes	Yes	Yes
95	4	30,23	34	88,91%	4	38,75	49	79,08%	13,23	16	Yes	16	16	Stable	Yes	Yes	No	
96	2	23,76	34	69,88%	4	37,02	49	75,55%	10,79	16	Yes	12,98	16	Stable	Yes	No	No	
97	3	20,24	34	59,53%	3	32,59	49	66,51%	9,59	16	Yes	10,65	16	Stable	Yes	No	No	

98	5	32,55	34	95,74%	5	43,13	49	88,02%	14,55	16	Yes	16	16	Stable	Yes	Yes	Yes	Yes
99	4	29,4	34	86,47%	4	36,9	49	75,31%	14,4	16	Yes	14	16	Stable	Yes	Yes	No	
100	3	22,83	34	67,15%	4	35,41	49	72,27%	11,54	16	Yes	10,8	16	Stable	Yes	No	No	
101	0	0	34	0,00%	1	16,04	49	32,73%	0	16	Yes	12,95	16	Unstable	Yes	No	No	
102	2	28,66	34	84,29%	3	33,81	49	69,00%	14,35	16	Yes	14,31	16	Stable	Yes	No	No	
103	1	20,11	34	59,15%	2	21,42	49	43,71%	7,16	16	Yes	12,95	16	Unstable	Yes	No	No	
104	1	18,01	34	52,97%	3	28,97	49	59,12%	8,27	16	Yes	9,75	16	Unstable	Yes	No	No	
105	5	29,95	34	88,09%	5	42,54	49	86,82%	13,71	16	Yes	15,24	16	Stable	Yes	Yes	Yes	Yes
106	5	30,44	34	89,53%	5	41,64	49	84,98%	14,2	16	Yes	15,24	16	Stable	Yes	Yes	Yes	Yes
107	5	32,56	34	95,76%	5	43	49	87,76%	15,68	16	Yes	15,88	16	Stable	Yes	Yes	Yes	Yes
108	0	0	34	0,00%	1	10,21	49	20,84%	0	16	No			Unstable	No	No	No	
109	5	30,23	34	88,91%	4	39,83	49	81,29%	13,23	16	Yes	16	16	Stable	Yes	Yes	Yes	Yes
110	5	28,9	34	85,00%	5	44,33	49	90,47%	11,65	16	Yes	15,25	16	Stable	Yes	Yes	Yes	Yes
111	3	23,76	34	69,88%	4	37,02	49	75,55%	10,79	16	Yes	12,98	16	Stable	Yes	No	No	
112	5	28,34	34	83,35%	5	42,33	49	86,39%	11,65	16	Yes	14,69	16	Stable	Yes	Yes	Yes	Yes
113	3	24,41	34	71,79%	4	37,47	49	76,47%	10,97	16	Yes	12,94	16	Unstable	Yes	No	No	
114	4	24,76	34	72,82%	4	35,35	49	72,14%	10,16	16	Yes	13,6	16	Unstable	Yes	Yes	No	
115	4	30,62	34	90,06%	4	39,67	49	80,96%	13,62	16	Yes	16	16	Stable	Yes	Yes	No	
116	4	23,53	34	69,21%	3	29,64	49	60,49%	10,49	16	Yes	12,03	16	Stable	Yes	Yes	No	
117	4	30,94	34	91,00%	3	30	49	61,22%	14,96	16	Yes	14,98	16	Stable	Yes	Yes	No	
118	0	0	16	0,00%	2	20,49	49	41,82%	0	16	No			Unstable	Yes	No	No	
119	4	28,47	34	83,74%	4	36,42	49	74,33%	11,47	16	Yes	16	16	Unstable	Yes	Yes	No	
120	3	23,26	34	68,41%	3	34,1	49	69,59%	9,5	16	Yes	13,25	16	Unstable	Yes	Yes	Yes	Yes
121	3	21,56	34	63,41%	4	38,02	49	77,59%	10,79	16	Yes	10,27	16	Unstable	Yes	Yes	No	
122	4	26,01	34	76,50%	3	14,33	16	89,56%	10,68	16	Yes	14,33	16	Unstable	Yes	Yes	No	
123	1	23,28	34	68,47%	4	38,52	49	78,61%	11,8	16	Yes	10,99	16	Unstable	Yes	No	Yes	No
124	3	23,4	34	68,82%	4	38,52	49	78,61%	11,8	16	Yes	11,1	16	Unstable	Yes	No	Yes	No
125	5	32,35	34	95,15%	5	42,73	49	87,20%	15,35	16	Yes	15	16	Stable	Yes	Yes	Yes	Yes
126	4	25,42	34	74,76%	4	40	49	81,63%	10,61	16	Yes	13,81	16	Unstable	Yes	Yes	No	
127	5	31,63	34	93,03%	5	44,25	49	90,31%	14,63	16	Yes	16	16	Stable	Yes	Yes	Yes	Yes

128	5	29,41	34	86,50%	5	45	49	91,84%	11,41	16	Yes	16	16	Stable	Yes	Yes	Yes	Yes
129	5	29,42	34	86,53%	5	43	49	87,76%	14,42	16	Yes	14	16	Stable	Yes	Yes	Yes	Yes
130	4	26,99	34	79,38%	4	38,05	49	77,65%	11,23	16	Yes	14,76	16	Unstable	Yes	Yes	No	
131	5	30,16	34	88,71%	5	44,98	49	91,80%	14,16	16	Yes	15	16	Stable	Yes	Yes	Yes	Yes
132	5	31,94	34	93,94%	5	44	49	89,80%	14,94	16	Yes	16	16	Stable	Yes	Yes	Yes	Yes
133	3	20,98	34	61,71%	3	27,13	49	55,37%	10,09	16	Yes	10,38	16	Unstable	Yes	No	No	
134	5	31,62	34	93,00%	5	42,77	49	87,29%	14,62	16	Yes	16	16	Stable	Yes	Yes	Yes	Yes

The data of the tables was processed using the software "Excel", and most of the comparisons were done on an annual basis in order to assess the evolution of the safety offered by the cars along the time.

5.3 Effectiveness analysis: Wilcoxon Signed Rank Test

For the analysis of the effectiveness, there was used the "Wilcoxon signed rank test" because with this test it is possible to compare the performance of the cars (safety rating) in different years in order to find if there is a significant increase or decrease of the average rating of the cars tested.

Justification for the selected test

The Wilcoxon sign rank test is a non-parametric test used "to compare the locations of two populations, to determine if one population is shifted with respect to another" (Liu, 2018). The test is ideal for cases where the dependent variable (in this case the safety rating) is not normally distributed.

The test has been used more in health-related research and biostatistics, however, it can be fitted to the data, especially taking into account the ranked data based on the number of starts, because this test is preferred in situations where the data is composed by defined scores (Scheff, 2016)

Data and different scenarios for the Wilcoxon Signed Rank Test

With the Wilcoxon sign rank test, there was compared the safety ratings (number of starts) of the adult occupant and child occupant protection of the cars tested in 2015 and 2019, because a new protocol was implemented in 2016, and a new one is being implemented in the current year 2020. Therefore, will be compared the years before a new protocol was implemented.

There were tested 22 models in 2015 and 27 models in 2019, and like the test is performed between the same number of samples, therefore there excluded 5 models from the sample of 2019, creating in that manner three different analysis for the Wilcoxon sign rank test:

- First scenario: comparing the 22 models from 2015 with the first 22 models tested in 2019, based on the month/date that they have been tested
- Second scenario: comparing the 22 models from 2015 with the 22 models tested in 2019 that obtained the highest ratings
- Third scenario: comparing the 22 models from 2015 with the 22 models that obtained the lowest ratings

The comparison is going to give some light about the effectiveness of the last protocol implemented to push for the continuous improvement of the cars. This comparison will also help us to identify if there is a significant improvement or

decline in the safety performance of the cars tested regarding adult occupant and child occupant protection.

5.4 Post-processing representation

The results of the different analyses are represented in the next chapter using different graphics and illustrative comparisons, looking to show in a clear and visual manner the main findings of the research. There were also used a similar type of graphics than the ones used in the research conducted by Van Ratingen (2016) and Van Ratingen et al. (2016) among others, studies that also analyzed the impact of other NCAP's on the safety performance of the cars in regions like Europe. There were used different type of graphs to represent the results, and the post-processing of the data includes:

- Pie charts
- Histograms
- Bar graphs and grouped bar graphs
- Line graphs
- Dot plots/scatter diagrams
- Other relevant type of graphs

As explained in the introduction chapter, the academic purpose of this research is to assess the impact Latin NCAP and the safety ratings on the safety performance of the vehicles in Latin America, and the practical purpose behind this research is to provide national authorities and regional policy makers with scientific facts that allow them to apply policies that promote the provision of safer vehicles in the region, therefore the representation of the results was done as clear and easy to understand as possible, in a manner that even people without scientific background but that are in charge of vehicle regulation, can easily read this research and find out where to start a change in favor of safer vehicles.

CHAPTER 6: DATA PROCESSING AND VISUALIZATION OF THE RESULTS

The data was digitalized into tables as stated previously and using the different functions of Excel, the data was processed giving as a result the following graphs and illustrations that help to answer the research questions of this thesis.

6.1 Cars tested by year, by type and sponsorship

Up to the present data, Latin NCAP had implemented new protocols only in 2 occasions, in the years 2016 and 2020. When the number of cars tested are compared in an annual base, is interesting to notice that the number of cars tested is considerable higher in 2015 and 2019 the years previous to the implementation of new protocols. Every new protocol implemented is more exigent than its predecessor, and the companies may be aware of this, therefore is logic to expect that car manufacturers prefer to test their cars before the new protocol is implemented so that their cars can achieve higher ratings.

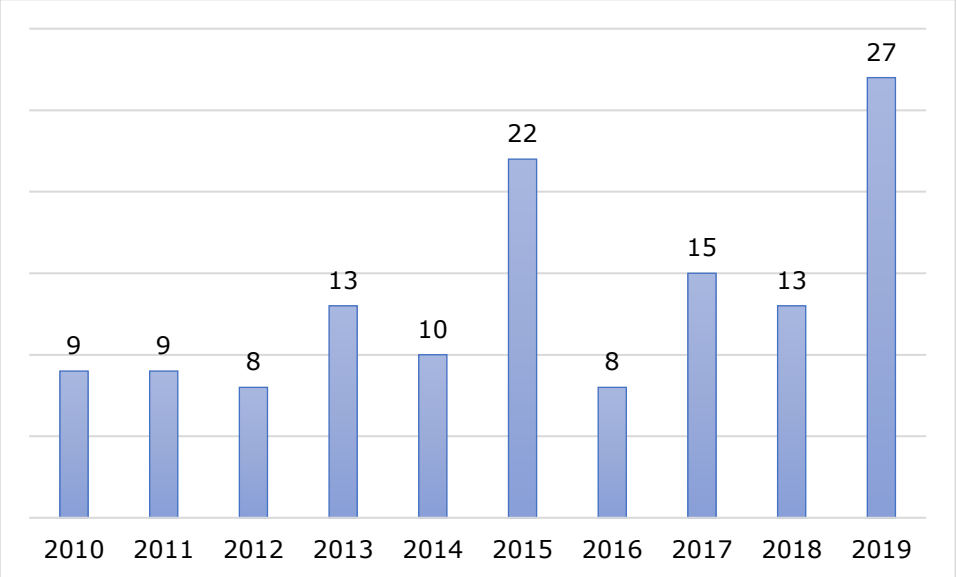
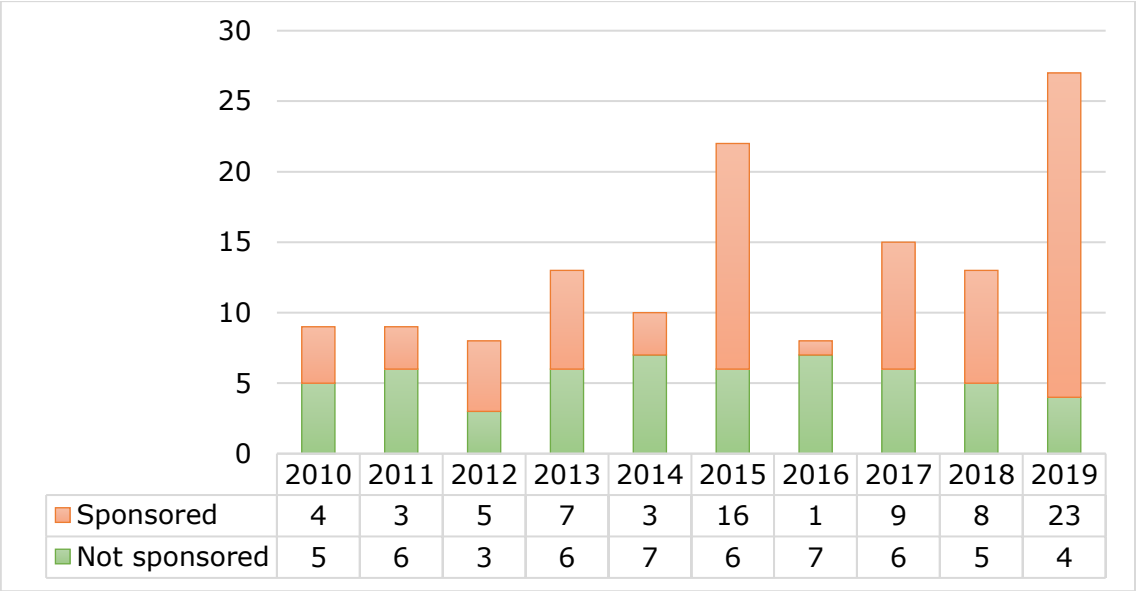


FIGURE 15 Number of cars tested every year. Own elaboration based on data from Latin NCAP

The analysis revealed that every year Latin NCAP has tested between 3 to 7 cars using their own funds (this are the tests not sponsored by the companies) however the increase in the number of cars tested in 2015 and 2019 is caused mainly by the large number of tests sponsored by the car manufacturers in these years. In 2015 the number of cars sponsored compared to the not sponsored were almost 3 times higher while in 2019 were almost 4 times higher. In the next figure is possible to notice also that the lowest number of sponsored tests was in 2016, the year that a new protocol was implemented.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Sponsored	4	3	5	7	3	16	1	9	8	23
Not sponsored	5	6	3	6	7	6	7	6	5	4

FIGURE 16 Tests sponsored and not sponsored every year. Own elaboration based on data from Latin NCAP

A further analysis of the relation between sponsorship of the cars tested and their safety performance reveals that cars tested that were sponsored by the car manufacturers achieved considerable higher scores than the cars tested not sponsored by the car manufacturers.

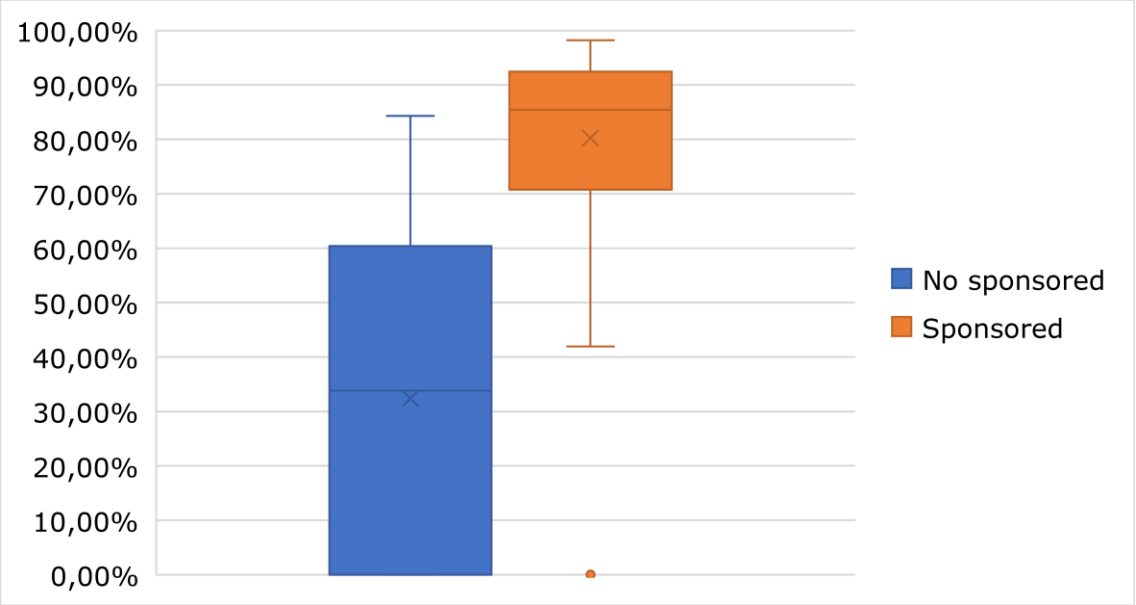


FIGURE 17 Sponsorship of the car tests vs Adult protection score (as percentage of the maximum possible score). Own elaboration based on data from Latin NCAP

This may imply that car manufacturers sponsor the tests of their safer cars or the cars that they expect are going to achieve higher ratings. Maybe this is driven by marketing reasons considering that a high score in the ratings may result in a better image of the car and consequently in greater sales o

f that model. This is something notice also by Domingues & de Lucinda (2018).

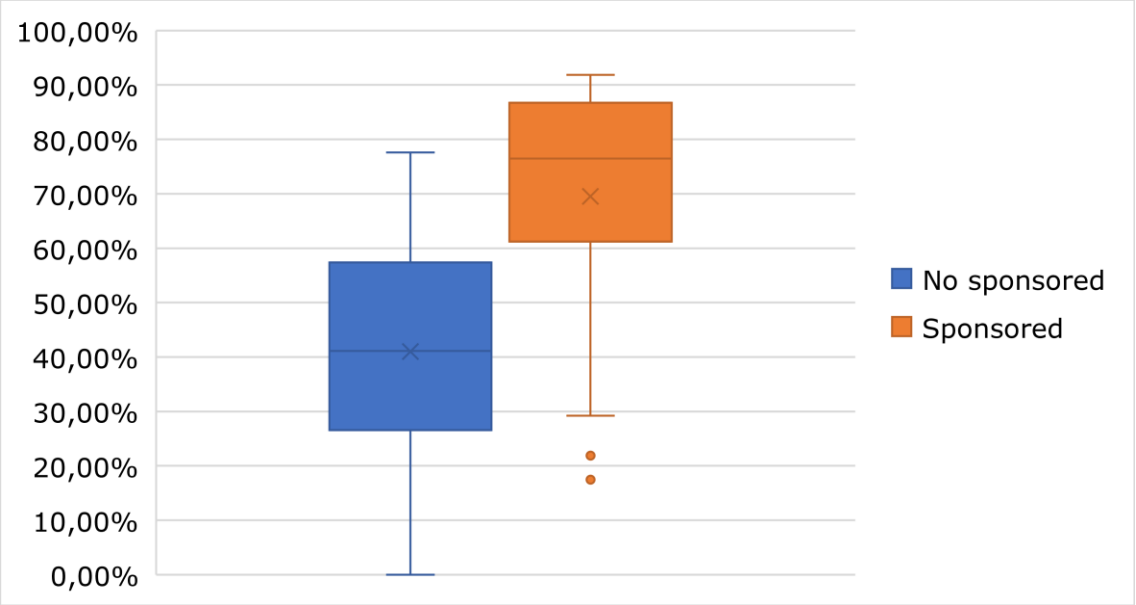


FIGURE 18 Sponsorship of the car tests vs Child protection score (as percentage of the maximum possible score). Own elaboration based on data from Latin NCAP

Regarding the number of cars tested by type, almost the half of all the cars tested are from the type Hatchback, other types with a significant proportion are the Sedan and the SUV with 29 and 16% of the total. There were two specific cases categorized as Compact and Monovolume, however they also present common characteristics of the Hatchback type, therefore they were included in this category. Considering the fact that Latin NCAP test the best seller cars in the region, that 59% of all the cars tested were sponsored by the car manufacturers and that 48% of the cars tested are from the type Hatchback, it is easy to notice a clear dominance of Hatchback cars in the Latin American market.

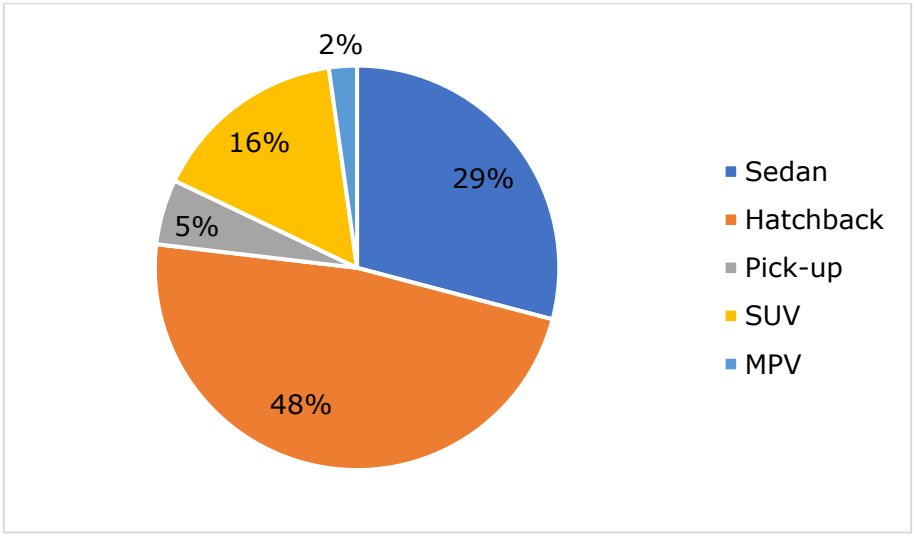


FIGURE 19 Cars tested by type. Own elaboration based on data from Latin NCAP

6.2 Evolution of the safety ratings for adult and child protection

The annual distribution of the number of stars achieved for adult protection shows interesting findings and a drastic effect of the new protocol implemented in 2016 on the number of starts achieved by the cars tested. The ratings were improving gradually since 2010 until 2015, year where around to 70% of the cars tested achieved 4 or 5 stars, however the ratings felt down suddenly in 2016 where there no cars achieving 4 or 5 stars. This is caused by the new protocol implemented in 2016 that is more complete and more exigent than previous one applied until 2015. For instance a car with no ESC, tested with the previous protocol (2010-2015) and rated with 5 stars, would receive maximum 3 stars as in 2016, because the new protocol implemented in that year required ESC to rate a car with 4 or 5 stars (Domingues, 2016).

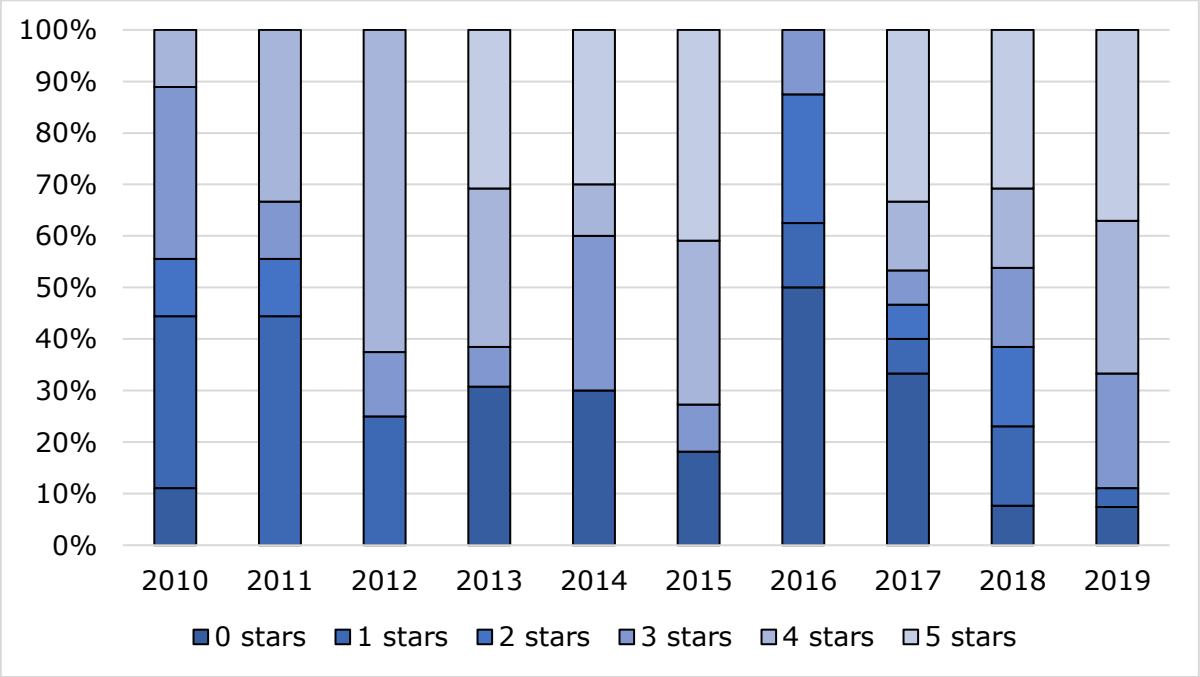


FIGURE 20 Annual distribution of the safety stars for adult protection. Own elaboration based on data from Latin NCAP

Since 2016 the ratings stared to increase again and gradually until 2019, this may suggest that car manufacturers require an adaptation time of 1 or 2 years to adequate their cars to the new requirements so they can achieve higher safety ratings after the implementation of a new protocol. The improvement in the ratings is evident compared to 2010, however there are still cars with 0 stars.

Concerning child protection there is also a gradual increase in the ratings from 2010 to 2015 although not as remarkable as it happens with adult protection and the impact of the new protocol in 2016 was not so drastic neither. The new protocol of 2016 was considerable stricter for adult protection (like the inclusion of the side impact test as mandatory requirement) however for child protection the new protocol consisted on a redistribution of the weights of the different criteria instead

of new and more stricter tests, maybe that's the reason why the new protocol of 2016 didn't produced such a drastic reduction of the safety rating for child protection. Posterior to 2016 there is evident and also gradual increase in the star obtained for child protection, reaching their maximum values on 2019, year where close to 75% of the cars tested achieved 4 or 5 stars.

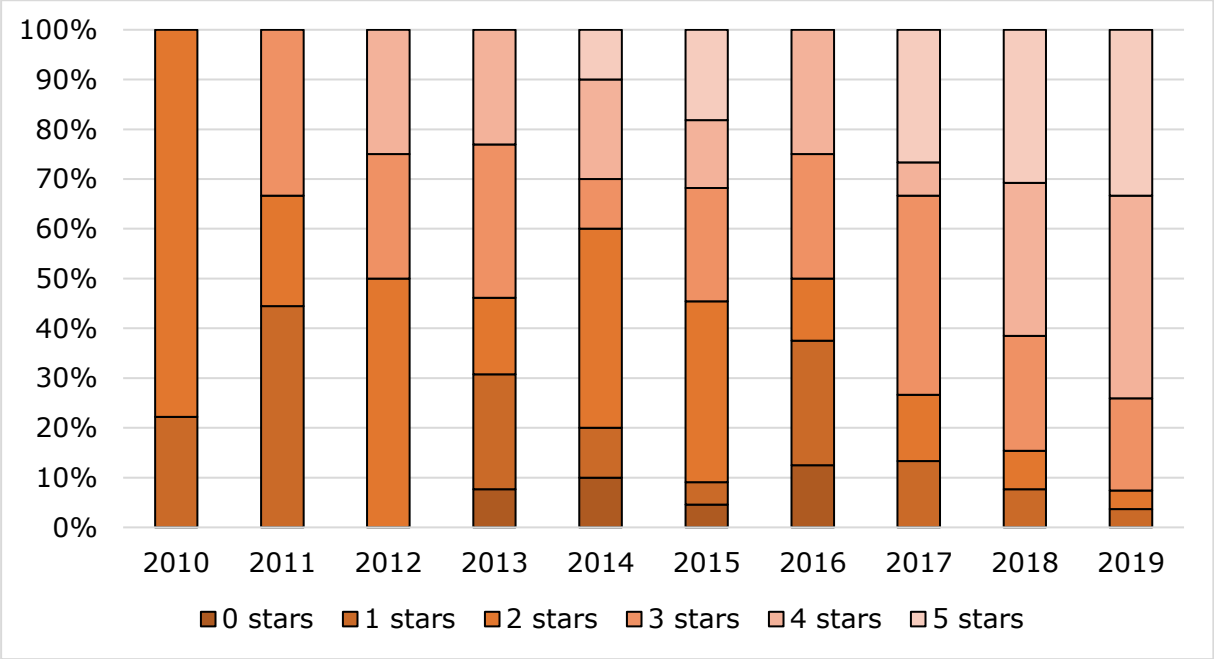


FIGURE 21 Annual distribution of the safety stars for child protection. Own elaboration based on data from Latin NCAP

It is important to notice the importance of the number of sponsored cars by year in the distribution of the safety ratings. This is more evident in the case of adult protection where the years with higher start ratings (2015 and 2019) are the same years with the higher proportion of cars sponsored by the car manufacturers, 73% and 85% respectively.

The visualization of the evolution of the safety rating can be done also using classes or ranges adopting the same type of graph used by Van Ratingen (2016). The figure shows the same patterns for adult protection: a gradual increase of the ratings from 2010 to 2015, a sudden fall of the rating in 2016 followed by a new gradual improvement until 2019.

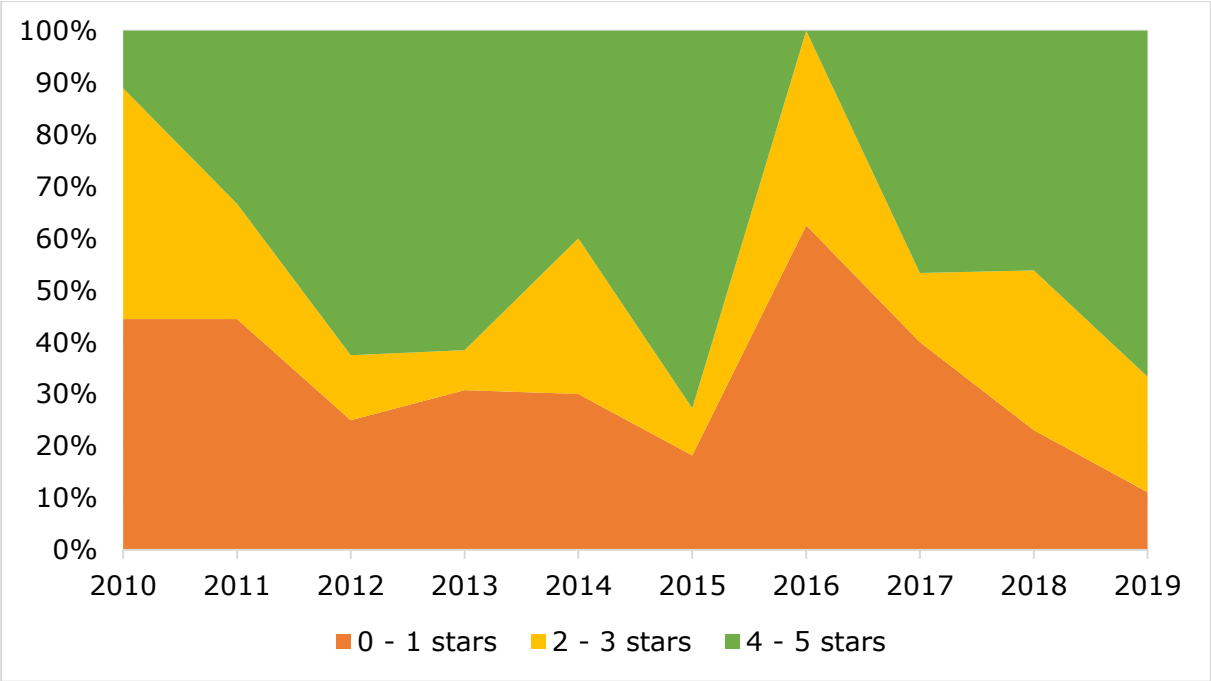


FIGURE 22 Evolution of the safety ratings for adult protection. Own elaboration based on data from Latin NCAP

In the case of child protection, the next evolution graph shows a evident gradual increase in the ratings since 2010, that becomes more remarkable since 2017 until reaching the higher ratings in 2019.

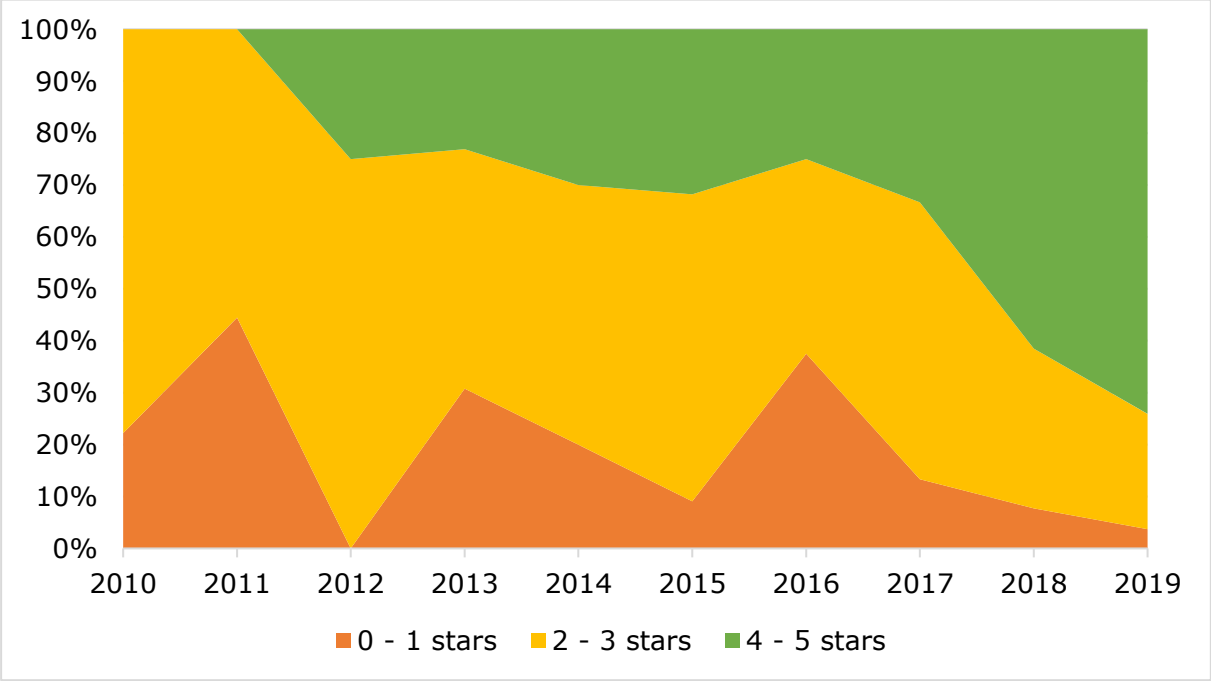


FIGURE 23 Evolution of the safety ratings for adult protection. Own elaboration based on data from Latin NCAP

Calculating the average annual rating to compare adult and child protection performance may not be most adequate because the ratings (number of stars) are expressed in discrete and not continuous values. For that comparison is more coherent to use the adult and child protection scores achieved by the cars tested. Instead of expressing the scores in points they will be expressed as percentage of the maximum value possible to be achieved so adult and child scores can be compared in the same scale.

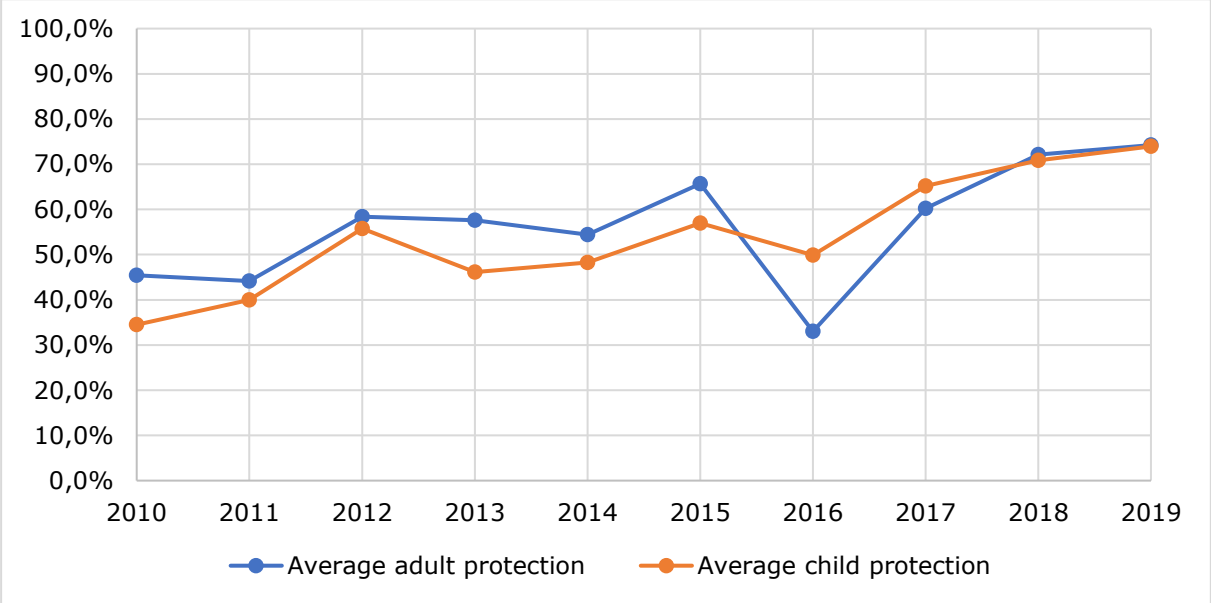


FIGURE 24 Comparison of the average adult and child protection scores as percentage of the maximum points possible to achieve. Own elaboration based on data from Latin NCAP

The comparison reveals interesting findings like the fact that in 2010 the cars tested stared achieving child protection scores 10% lower than the adult protection score, however after 10 years, adult and child protection scores increased to reach basically the same proportion of the maximum achievable score, close to 75%. Is quite interesting to analyze the impact of the new protocol implemented in 2016 producing a reduction of 33% for the adult protection scores and just a reduction of 7% for the child occupant protection.

6.3 Cars tested and safety performance by brand

An analysis of the brands of the cars tested by Latin NCAP along the last decade is going to help to answer questions like what brands are more popular for the new vehicle market in Latin America? And what brands are performing better and what brands are performing worse for adult and child protection? For instance, a comparison of the number of cars tested by brand showed that popular brands like Chevrolet and Volkswagen have been tested in several occasions while at the same time companies like Citroen, Jeep and Mazda have been tested only in 1 occasion during the last decade. The other brands that have been tested just in 1 or 2 opportunities are not that popular and they are from China.

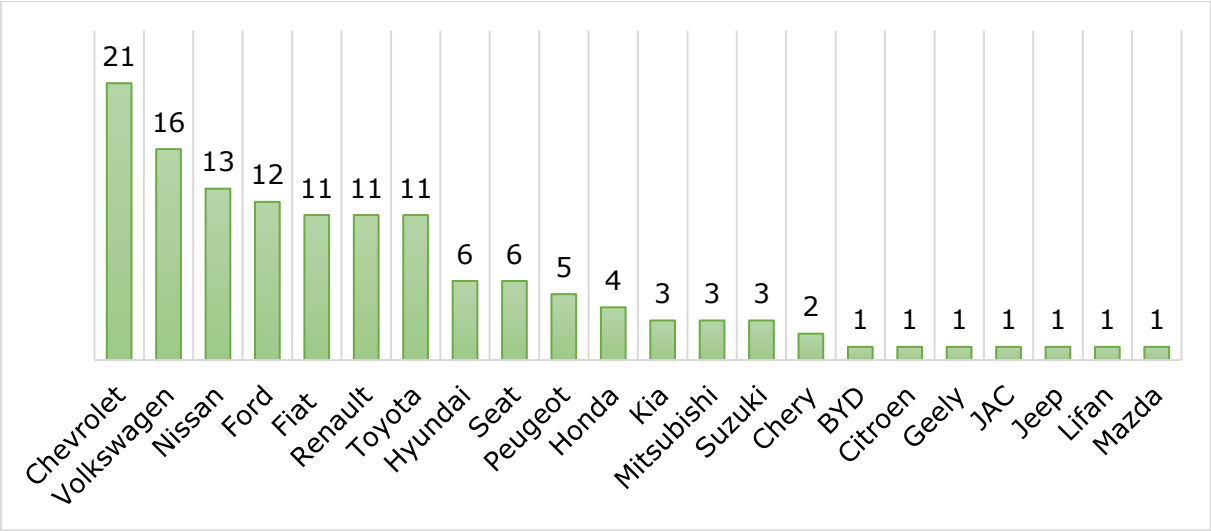


FIGURE 25 Number of cars tested by brand. Own elaboration based on data from Latin NCAP

A pie chart of the number of cars tested by brand shows that Chevrolet is the brand that has been submitted to tests in more opportunities comprehends a 16% of the total number of cars tested. The first 7 brands from the previous figure comprehend the 71% of the whole universe of cars tested by Latin NCAP and this because these brands are very popular in Latina America, reason why their cars are above the top sellers every year, and also because many of these brands decided to sponsor a second test of their models that received a bad rating.

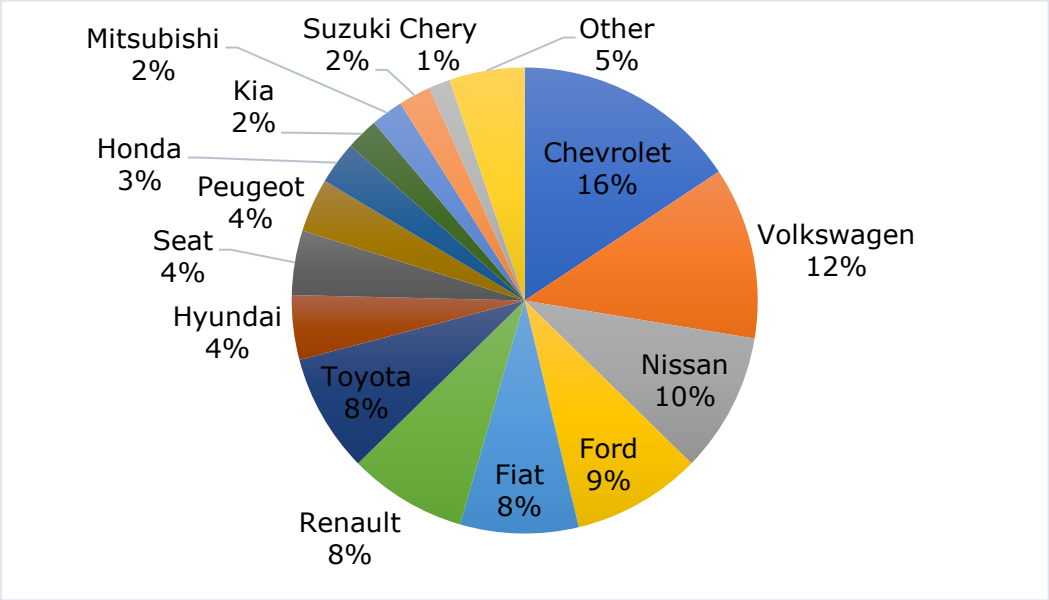


Figure 26.- Cars tested by Brand. Own elaboration based on data from Latin NCAP

A clustering of the average adult safety scores by brand remarked that 6 brands obtained 80% or more of the maximum adult protection score. Two of those brands (Jeep and Mazda) were tested only in 1 opportunity. It is quite amazing to find

that the 5 brands that are performing worse reading adult protection are from the same country, china.

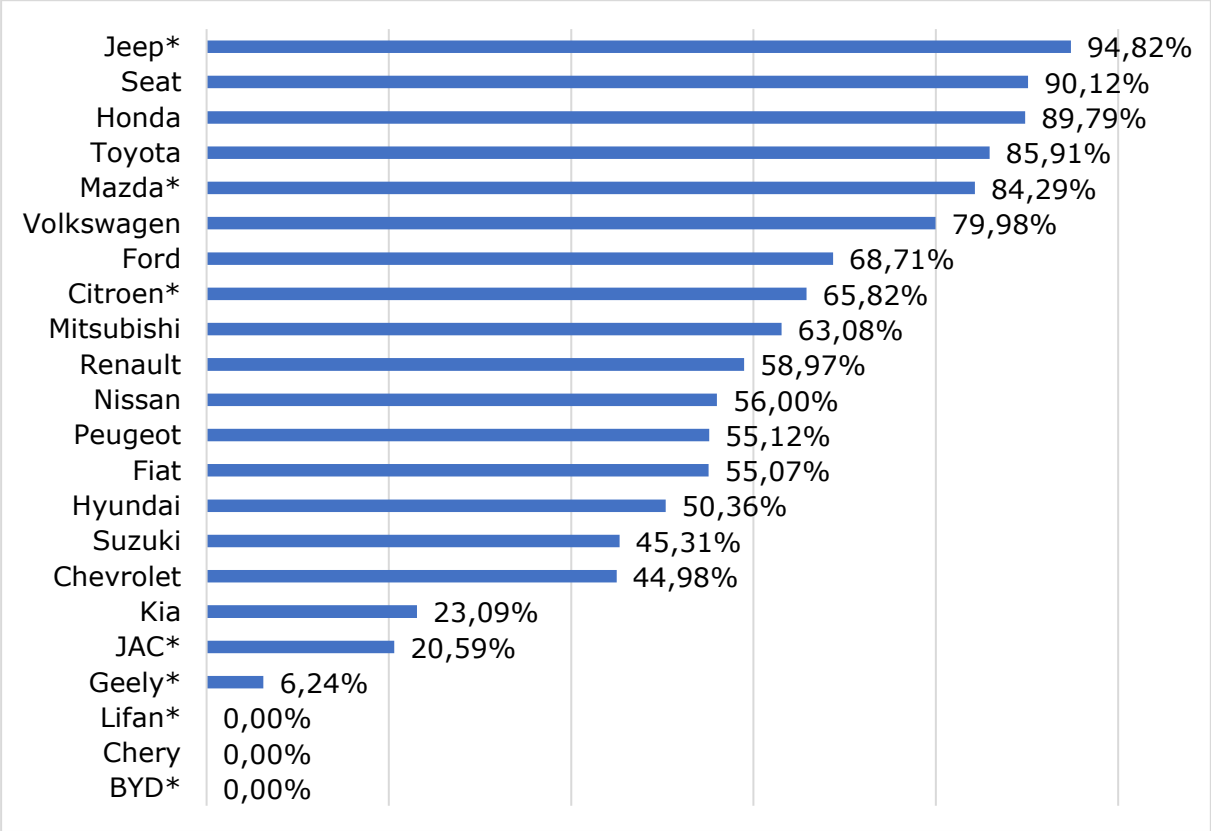


FIGURE 27 Average adult protection scores by brand as percentage of the maximum score. (*) Refer to brands that have been tested just in 1 occasion. Own elaboration based on data from Latin NCAP

The previous figure may lead to interesting affirmations because if we exclude the two best performing brands that were tested only in 1 occasion (considering that 1 test is not enough to represent the average performance of the brand) and if we assume that the sample of cars tested by Latin NCAP is good representative of the Latin American vehicle market, we can affirm that SEAT, Honda and Toyota are the safest brands for adult passenger in Latin America. Latin NCAP tested close to 23% of the models of new cars offered in the market (Oviedo-Trespalacios & Scott-Parker, 2018), representing almost 60% of the volume sales of the largest markets in the region (Latin NCAP, 2017).

Until 2016 companies like Chevrolet use to be identified as "the leading manufacturer of zero stars cars in Latin America" (Consumers International, 2016), however since 2018 the safety performance of the cars produced by this brand had improved considerable, to the point that in 2019, 3 cars tested form this brand obtained 5 stars for adult protection while 2 cars obtained 5 stars for child protection.

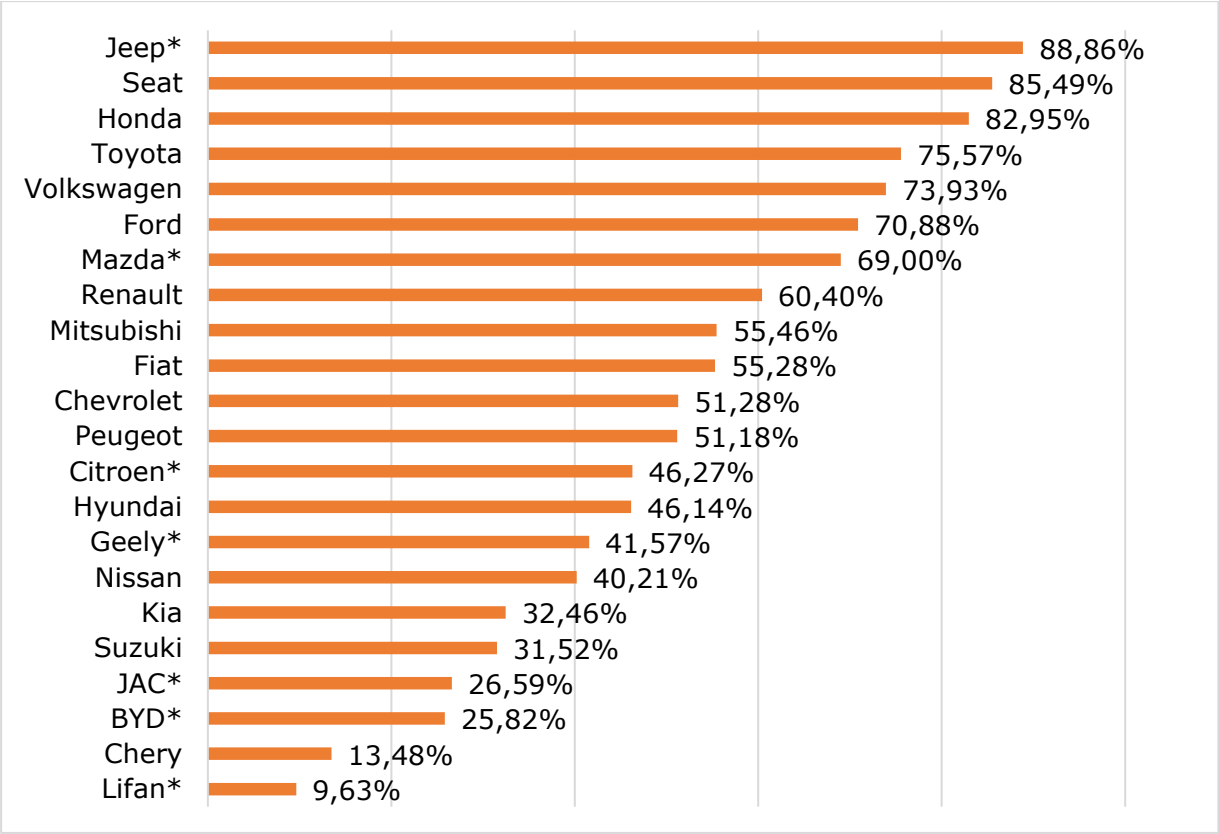


FIGURE 28 Average adult protection scores by brand as percentage of the maximum score. (*) Refer to brands that have been tested just in 1 occasion. Own elaboration based on data from Latin NCAP

Concerning child protection, Jeep is also the brand that achieved the highest score however this brand was tested just in 1 opportunity. If we exclude this brand from the ranking, we obtain the same results obtained in adult occupant protection, that SEAT, Honda and Toyota are the safest brands for child occupants in Latin America. In contrast to adult occupant protection, in average none of the brands achieved more than 90% of the maximum child protection score.

The results are at least convincing considering that the scores for adult and child protection are obtained in different manner and considering different aspects. In this scenario it is possible to affirm that the safest popular brands in Latin America for the protection of adult and child occupants and Seat, Honda and Toyota, and that in general, brands like Volkswagen, Ford and Mitsubishi are also performing well however they are one scale below the other brands. On the other hand, the brands of the Latin American market that showed the worst performance for adult and child protection were all the Chinese brands tested and KIA.

6.4 Cars tested and safety performance by country/region of production

For the most of the cars tested there is specified the country or countries of where they were produced. With that information was elaborated the next pie chart that shows that two thirds of the tested (68%) by Latin NCAP were produced in Latin

America with Brazil as the main producer comprehending 36% of the cars tested. Cars tested that didn't have specified the country of origin were excluded for the elaboration of this pie chart.

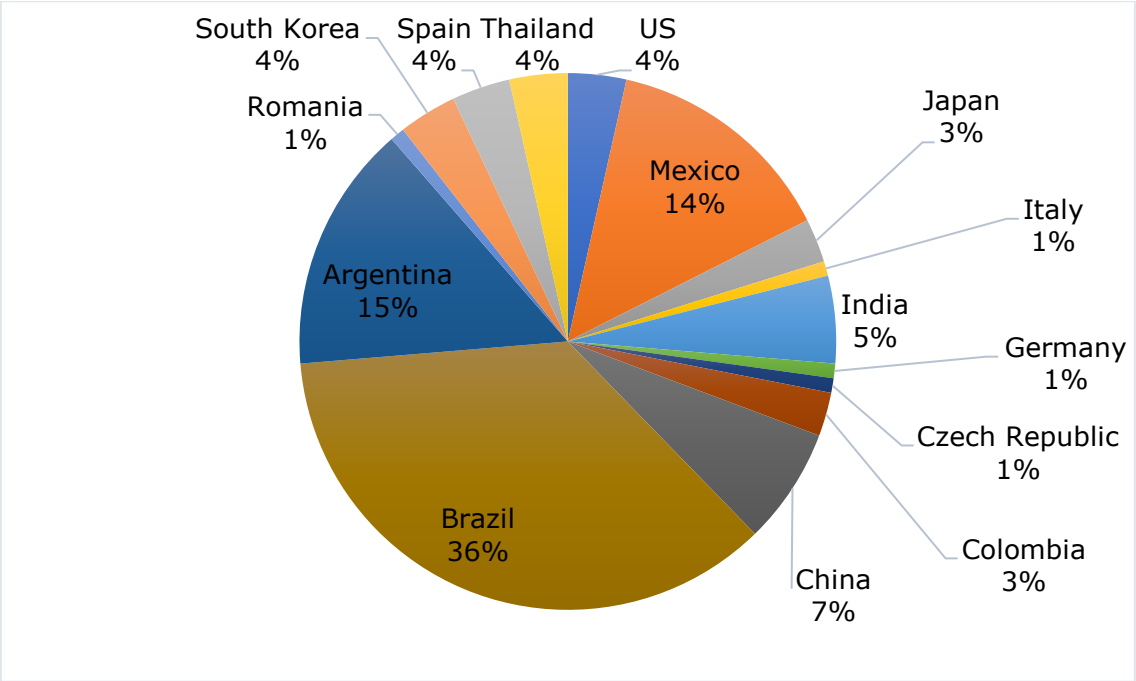


FIGURE 29 Cars tested by country of production. Own elaboration based on data from Latin NCAP

A comparison of the safety performance of the cars tested by country of production will help to identify the countries with weak or strong vehicle production normative. The comparison of the average adult protection scores by country of production shows that the best performing cars are the one produced in European countries, Japan and US, this means the cars that were produce in developed market were the vehicle production normative is more exigent and where the UN vehicle safety standards have been introduced in the local/regional normative. In the middle of the ranking there are located the Latin American countries besides and Thailand while at the bottom of the ranking there are located only countries from Asia. Excluding Colombia, the cars produced in the other Latin American countries achieved in average between 65% to 70% of the maximum adult protection score.

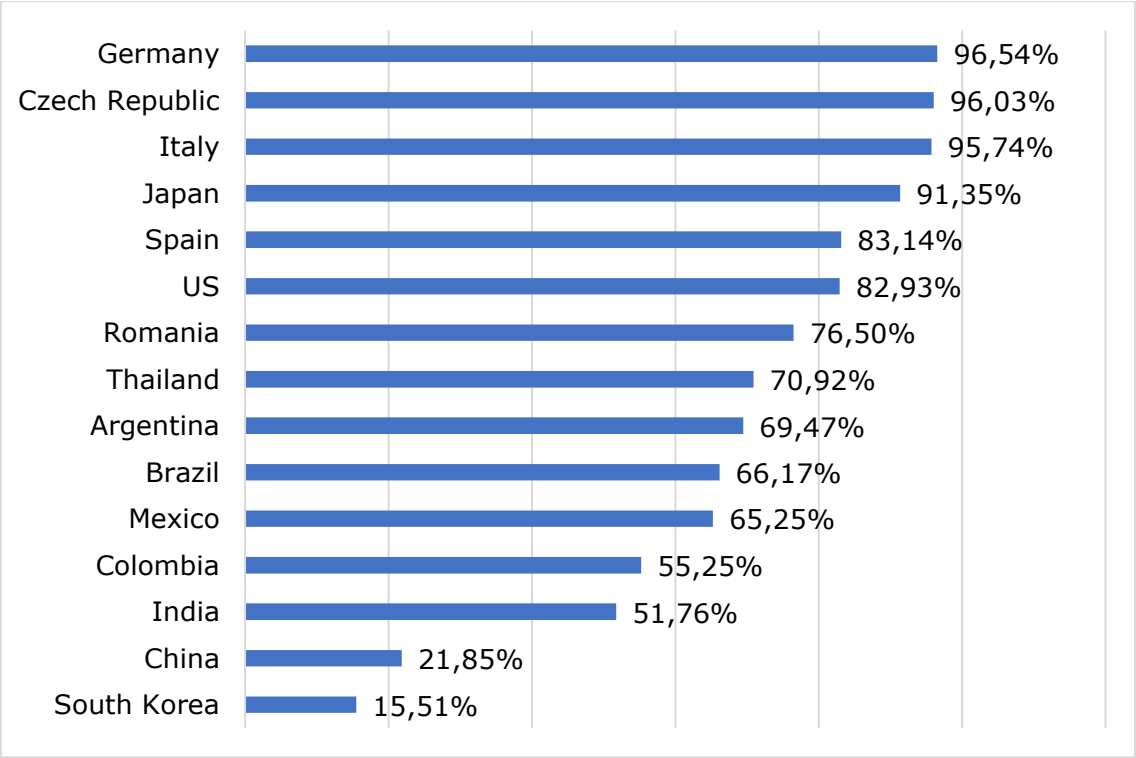


FIGURE 30 Average adult protection scores by country of production as percentage of the maximum score. Own elaboration based on data from Latin NCAP

The graph for child occupant protection score shows that five European countries occupy the highest average scores, followed by US and Japan. Again, the best score is form cars produced in developed countries with strong vehicle production normative. Thailand and the Latin America countries occupy the middle of the ranking and the bottom is composed by the rest of the Asian countries. Countries of the region, like Mexico and Brazil should give more attention to provision of safer cars for children considering that they account for the 50% of all children death in traffic accidents in the region (Gallego Galenao et al., 2015).

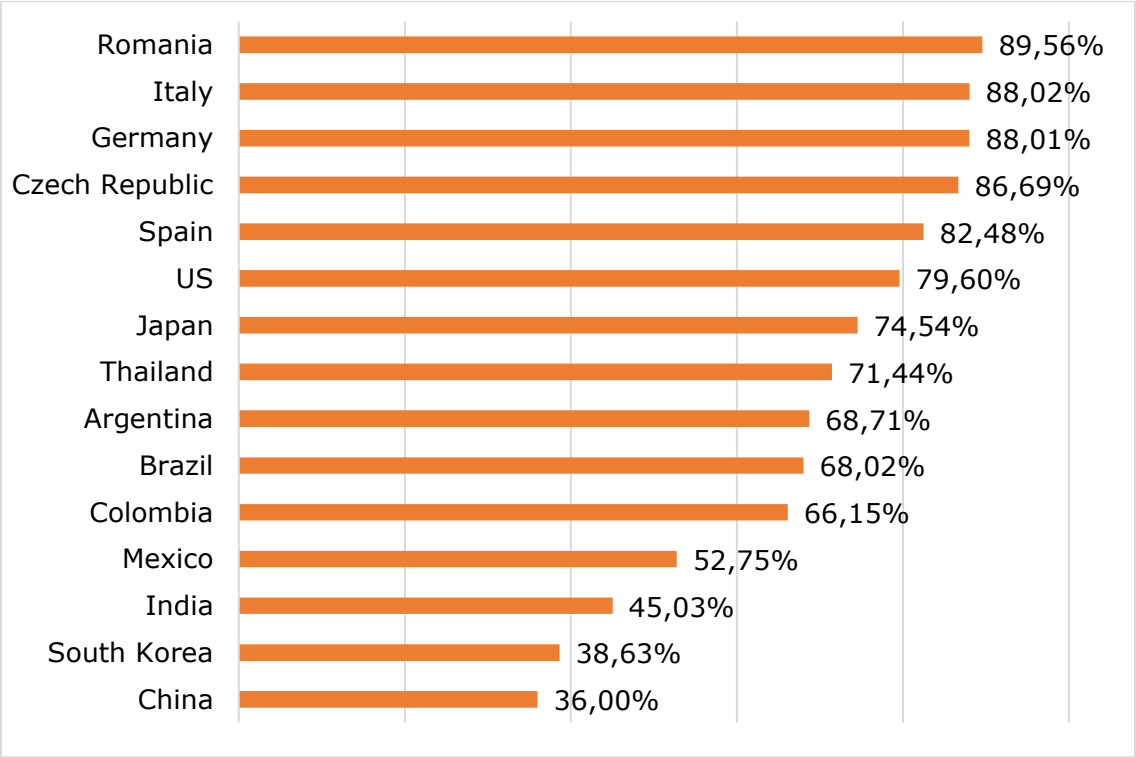


FIGURE 31 Average child protection scores by country of production as percentage of the maximum score. Own elaboration based on data from Latin NCAP

There is trend that is repeated in both rankings:

- The cars produced in 4 European countries (Germany, Italy, Czech Republic and Spain) are located in the top five for adult and child protection. This is something that could be expected considering that Euro NCAP has stricter protocols and that the cars produced in Europe must be submitted at more rigorous tests.

- Cars produced in Latin America are located in the middle of the rankings, and although they achieve at least 50% of the maximum adult and child score, they could improve their safety performance if those countries apply stricter vehicle production normative like the UN vehicle safety standards.

- The worst performing cars are the one produced at India, China and south Korea. The situation of China is not a surprise Taking into account that all the chinses brands achieved the lowest score for adult and child protection, as demonstrate in the previous section, however the presence of South Korea in the bottom of both rankings is quite interesting considering that south Korea is a developed country with a strong car production industry.

The results may suggest that cars produced for Latin America but constructed in developed countries or regions are safer than the ones produced in developing regions. A comparison of the safety ratings based on the region of the cars were produced helps to confirm this hypothesis.

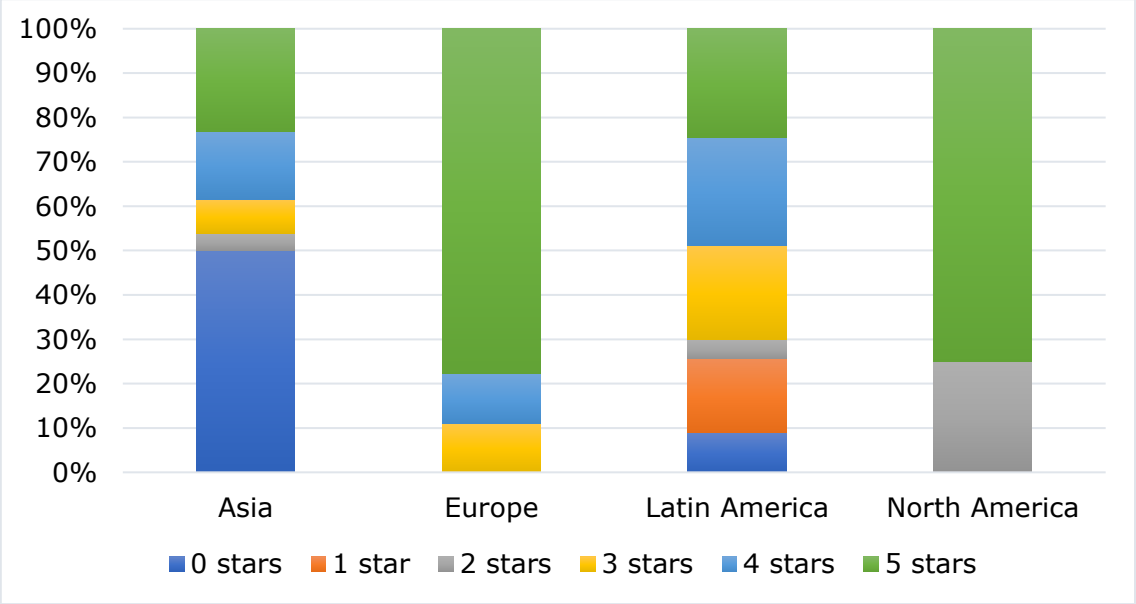


FIGURE 32 Average adult safety ratings by region of production. Own elaboration based on data from Latin NCAP

Cars produced in developed regions like Europe or North America, are achieving the highest ratings. More than 70% of the cars produced in these regions achieved 5 stars, while only 24% of the car produced locally in Latin America and only 23% of the cars produced in Asia achieved the same number of stars.

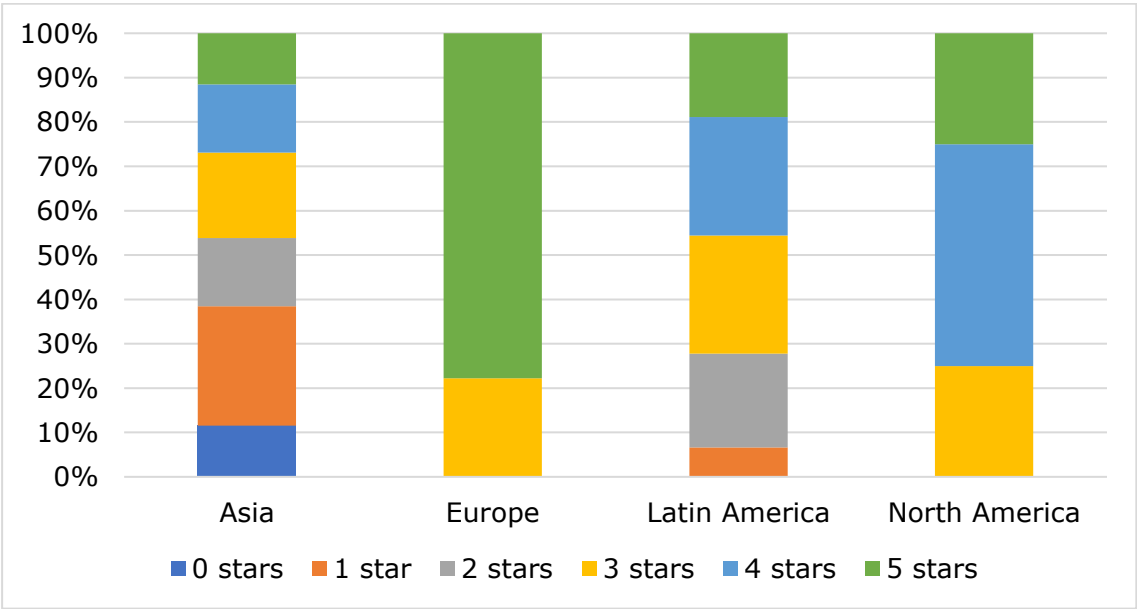


FIGURE 33 Average child safety ratings by region of production. Own elaboration based on data from Latin NCAP

Regarding child protection again the cars produced in Europe and North America are the ones that highest rating, while the cars produced in Latin America have a more balanced distribution between good and bad ratings. For child protection, Asia presents the lowest ratings and the few good ratings from cars produced in this region are from cars built in Japan and Thailand.

6.5 Bodyshell integrity of the cars tested along the years

Another aspect that can be analyzed in order to measure the impact of Latin NCAP on the safety performance of the cars produced for Latin America is the bodyshell integrity of the cars. Since 2013, every time Latin NCAP test a car they also measure the impact on the structure of the cars to see if the bodyshell is enough rigid to support strong forces or if it is weak that occupants can be damaged seriously because of the intrusion of structure if the car during the crash. Latin NCAP classify the bodyshell integrity as Stable and Not stable. This aspect is very important considering only at the beginning of the decade, the cars with unstable structures use to sell more than 650 000 units per annually (Furas, 2013).

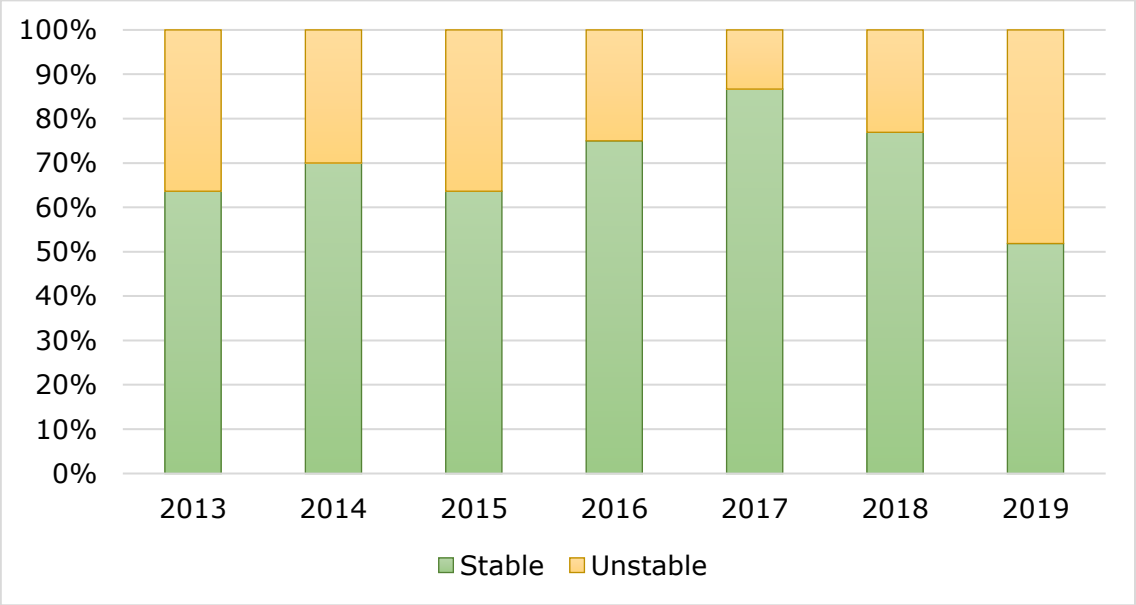


FIGURE 34 Bodyshell integrity of the cars tested. Own elaboration based on data from Latin NCAP

The series starts in 2013 with 64% of the cars tested built with a stable bodyshell, reaching a peak of 87% in 2017 and a minimum proportion of cars with stable bodyshell of 52% in 2019. There is no a clear pattern or tendency regarding the proportion of cars with a stable bodyshell. It seems like the implementation of a new protocol in 2016 didn't have an evident positive or negative effect concerning the bodyshell integrity of the cars tested posteriorly.

6.6 Safety devices and vehicle control systems

Airbags are common safety devices in car industry because they are very effective at the time to protect the car occupants. The positive impact of Latin NCAP is more evident on the provision of safety devices in the cars. It seems that "manufacturers appeared to have made changes to the availability of safety options following the publication of the results" (Consumers International, 2016). The provision of airbags is a clear example of this aspect.

Even in developing regions, most of the cars have at least 1 frontal airbag for driver seat however this is not the case always and Latin America use to be a clear example. In 2010 and 2011, during the first years of Latin NCAP, many of the new cars tested did not include an airbag at all, and as a result the average number of airbags per car tested was only 1.1 and 1 respectively. With the time the car manufacturers realized that airbags were important to achieve better scores and ratings therefore they started to install more airbags in their cars. The next figure shows the evolution of the average number of airbags per car tested on an annual basis:

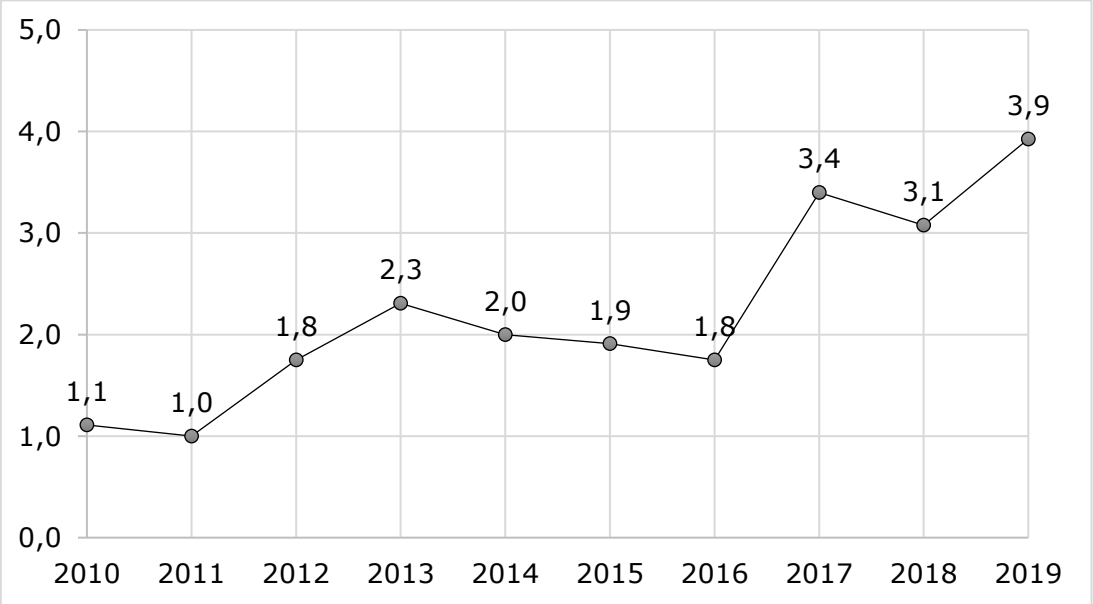


FIGURE 35 Average number of airbags per car tested. Own elaboration based on data from Latin NCAP

In the figure it is possible to appreciate the great impact of Latin NCAP in the provision of airbag in the new cars of the Latin American Market, going from 1.1 airbags per car in 2010 until 3.9 airbags per car in 2019, almost four times higher. The effect of the new protocol implemented in 2016 is clear in the previous figure. It is easy to notice a sudden increase in the number if airbags since 2017. It seems like the car manufacturers perceived that the number of airbags installed until 2016 were not enough to achieve great ratings like in the past, so that they decided to increase the number of airbags and this resulted in greater results as expected. The cost of airbags have decreased close to 60% in the last years (GLOBAL NCAP,

2015), and this may also one of the reasons of the notable increase in the number of airbags in the new cars offered in the region.

Another device that demonstrated to be very effective is reducing the damage to car occupants during a crash are the seat-belt pretensioners. These devices adjust the seat-belt at the moment the car receives a strong impact so the occupants can stay fixed in their seats and they don't smash their heads or bodies against the structure of the car.

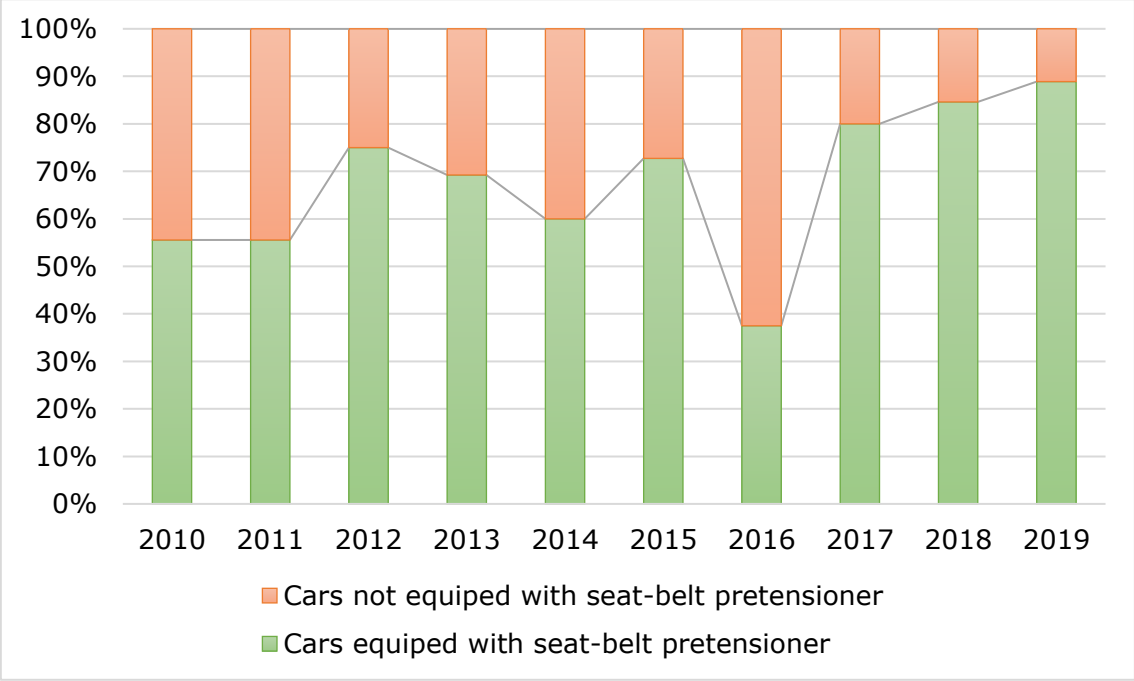


FIGURE 36 Seat-belt pretensioners in the cars tested. Own elaboration based on data from Latin NCAP

The impact of Latin NCAP on the installation of Seat-belt Pretensioners is also evident. Excluding the year 2016, is it possible to notice a gradual increase in the proportion if cars tested equipped with seat-belt pretensioners, going from 56% in 2010 to 89% in 2019. The sudden fall in the proportion during the year 2016 maybe related to the low number of the tests sponsored by the car manufacturers during this year. As stated previously, car manufacturers sponsor the test of the cars their safest cars as a marketing strategy. Similar to what happened with the number of airbags, the sudden increase in 2017 maybe related to the introduction a new stricter protocol in 2016.

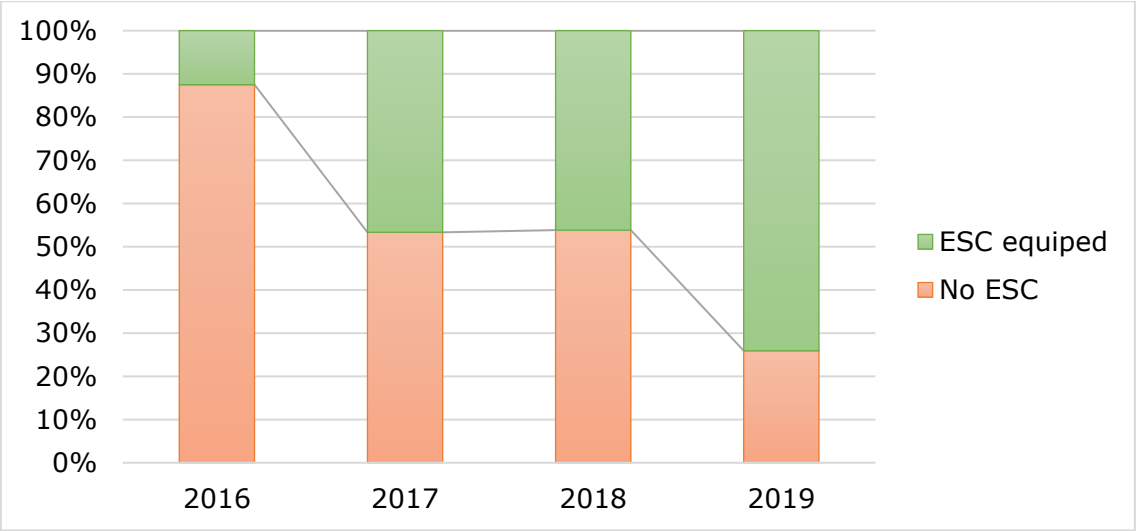


FIGURE 37 Electronic Stability Control (ESC) in the cars tested in the period 2016 – 2019. Own elaboration based on data from Latin NCAP

The installation of ESC is controlled by Latin NCAP only since 2016 as a mandatory requirement to achieve 5 stars. Latin NCAP crash tests had a great positive impact in the provision of ESC in the standard version of the cars tested. In 2016 only 12% of the cars tested were equipped with ESC while in 2019, close to 75% of the cars tested were equipped with ESC, this means that 3 out of 4 cars tested included ESC in their standard versions. This increase follows a similar tendency than the proportion of tests sponsored by the car manufactures during these years. The increase in the number of cars equipped with ESC can have a great impact in some countries of the region like Chile, where close to 20% of the crash fatalities were caused by loos of control of the vehicle (Caroline Wallbank et al., 2019).

CHAPTER 7: THE WILCOXON SIGNED RANK TEST

For the Wilcoxon Signed Rank Test there were compared the safety ratings of the years 2015 and 2019, the previous years before the implementation of new and more exigent protocols in 2016 and the current 2020 respectively. The hypothesis for the tests is the next:

Ho: Median_2015 = Median_2019

(There is no significant difference between the two samples)

H1: Median_2015 ≠ Median_2019

(There is significant difference between the two samples)

For all the tests there was assumed a confidence interval of α = 0.05

7.1 First scenario

In this scenario there will be compared safety ratings (number of stars) of the 22 models tested in 2015 and the first 22 models tested in 2019, based on the month/date when the results of the test were published by Latin NCAP

For adult protection

TABLE 14 Wilcoxon Signed Rank Test – First Scenario: Adult Protection

Nr.	2015	2019	Sign	Difference	Absolute Difference	Rank
1	4	4		0		
2	0	3	-1	-3	3	9
3	5	5		0		
4	0	3	-1	-3	3	9
5	4	5	-1	-1	1	2.5
6	5	3	1	2	2	6
7	0	4	-1	-4	4	11.5
8	4	5	-1	-1	1	2.5
9	4	4		0		
10	0	5	-1	-5	5	13
11	4	0	1	4	4	11.5
12	5	5		0		
13	5	4	1	1	1	2.5
14	5	5		0		
15	5	5		0		
16	4	4		0		
17	5	5		0		
18	3	5	-1	-2	2	6
19	3	0	1	3	3	9
20	5	3	1	2	2	6
21	5	4	1	1	1	2.5
22	4	4		0		

∑ ranks (+) = 37.5 N = 13
∑ ranks (-) = 53.5 α = 0.05

Therefore According to tables

W_Statistical = 37.5 W_Critical = 17

W_Statistical > W_Critical

Conclusion. - *The difference is not significant, therefore null hypothesis cannot be rejected. This means that the adult star ratings in the year 2019 are not different enough from the adult star ratings in 2015*

For child protection

TABLE 15 Wilcoxon Signed Rank Test – First Scenario: Child Protection

Nr.	2015	2019	Sign	Difference	Absolute Difference	Rank
1	2	4	-1	-2	2	9.5
2	2	3	-1	-1	1	3
3	5	5		0		
4	0	4	-1	-4	4	15.5
5	3	5	-1	-2	2	9.5
6	5	4	1	1	1	3
7	2	4	-1	-2	2	9.5
8	2	4	-1	-2	2	9.5
9	2	4	-1	-2	2	9.5
10	2	5	-1	-3	3	14
11	3	1	1	2	2	9.5
12	4	5	-1	-1	1	3
13	4	4		0		
14	5	5		0		
15	3	5	-1	-2	2	9.5
16	3	3		0		
17	3	5	-1	-2	2	9.5
18	1	5	-1	-4	4	15.5
19	2	2		0		
20	5	4	1	1	1	3
21	4	4		0		
22	2	3	-1	-1	1	3

∑ ranks (+) = 15.5 N = 16
∑ ranks (-) = 120.5 α = 0.05

Therefore According to tables

W_Statistical = 15.5 W_Critical = 29

W_Statistical < W_Critical

Conclusion. - *The difference is significant, therefore null hypothesis can be rejected. It is possible to affirm that the child star ratings in the year 2019 are different enough from the child star ratings in 2015*

7.2 Second scenario

In this scenario there will be compared safety ratings (number of stars) of the 22 models tested in 2015 with 22 models tested in 2019 that obtained the highest ratings.

For adult protection

TABLE 16 Wilcoxon Signed Rank Test – Second Scenario: Adult Protection

Nr.	2015	2019	Sign	Difference	Absolute Difference	Rank
1	4	5	1	1	1	5
2	0	5	1	5	5	15,5
3	5	3	-1	-2	2	11
4	0	5	1	5	5	15,5
5	4	3	-1	-1	1	5
6	5	4	-1	-1	1	5
7	0	4	1	4	4	13,5
8	4	4		0		
9	4	4		0		
10	0	4	1	4	4	13,5
11	4	3	-1	-1	1	5
12	5	4	-1	-1	1	5
13	5	3	-1	-2	2	11
14	5	5		0		
15	5	4	-1	-1	1	5
16	4	5	1	1	1	5
17	5	5		0		
18	3	5	1	2	2	11
19	3	4	1	1	1	5
20	5	5		0		
21	5	5		0		
22	4	5	1	1	1	5

∑ ranks (+) =	47	N =	16
∑ ranks (-) =	89	α =	0.05

Therefore — According to tables

W_Statistical = 47 — W_Critical = 29

W_Statistical > W_Critical

Conclusion. - *The difference is not significant, therefore null hypothesis cannot be rejected. This means that the adult star ratings in the year 2019 are not different enough from the adult star ratings in 2015*

For child protection

TABLE 17 Wilcoxon Signed Rank Test – Second Scenario: Child Protection

Nr.	2015	2019	Sign	Difference	Absolute Difference	Rank
1	2	4	-1	-2	2	12.5
2	2	5	-1	-3	3	16.5
3	5	4	1	1	1	5
4	0	5	-1	-5	5	19
5	3	4	-1	-1	1	5
6	5	4	1	1	1	5
7	2	4	-1	-2	2	12.5
8	2	3	-1	-1	1	5
9	2	3	-1	-1	1	5
10	2	4	-1	-2	2	12.5
11	3	4	-1	-1	1	5
12	4	3	1	1	1	5
13	4	4		0		
14	5	5		0		
15	3	4	-1	-1	1	5
16	3	5	-1	-2	2	12.5
17	3	5	-1	-2	2	12.5
18	1	5	-1	-4	4	18
19	2	4	-1	-2	2	12.5
20	5	5		0		
21	4	5	-1	-1	1	5
22	2	5	-1	-3	3	16.5

∑ ranks (+) = 15 N = 19

∑ ranks (-) = 175 α = 0.05

Therefore According to tables

W_Statistical = 15 W_Critical = 46

W_Statistical < W_Critical

Conclusion. - *The difference is significant, therefore null hypothesis can be rejected. It is possible to affirm that the child star ratings in the year 2019 are different enough from the child star ratings in 2015*

7.3 Third scenario

In this scenario there will be compared safety ratings (number of stars) of the 22 models tested in 2015 with the 22 models tested in 2019 that obtained the lowest ratings.

For adult protection

TABLE 18 Wilcoxon Signed Rank Test – Third Scenario: Adult Protection

Nr.	2015	2019	Sign	Difference	Absolute Difference	Rank
1	4	0	1	4	4	16.5
2	0	5	-1	-5	5	19
3	5	5		0		
4	0	3	-1	-3	3	13.5
5	4	5	-1	-1	1	3.5
6	5	3	1	2	2	9.5
7	0	4	-1	-4	4	16.5
8	4	4		0		
9	4	4		0		
10	0	4	-1	-4	4	16.5
11	4	0	1	4	4	16.5
12	5	4	1	1	1	3.5
13	5	3	1	2	2	9.5
14	5	3	1	2	2	9.5
15	5	4	1	1	1	3.5
16	4	1	1	3	3	13.5
17	5	3	1	2	2	9.5
18	3	4	-1	-1	1	3.5
19	3	5	-1	-2	2	9.5
20	5	4	1	1	1	3.5
21	5	3	1	2	2	9.5
22	4	5	-1	-1	1	3.5

$\sum$ ranks (+) = 104.5 N = 19

$\sum$ ranks (-) = 85.5 α = 0.05

Therefore According to tables

W_Statistical = 85.5 W_Critical = 49

W_Statistical > W_Critical

Conclusion. - *The difference is not significant, therefore null hypothesis cannot be rejected. This means that the adult star ratings in the year 2019 are not different enough from the adult star ratings in 2015*

For child protection

TABLE 19 Wilcoxon Signed Rank Test – Third Scenario: Child Protection

Nr.	2015	2019	Sign	Difference	Absolute Difference	Rank
1	2	1	1	1	1	6
2	2	4	-1	-2	2	13.5
3	5	5		0		
4	0	4	-1	-4	4	19
5	3	5	-1	-2	2	13.5
6	5	4	1	1	1	6
7	2	4	-1	-2	2	13.5
8	2	4	-1	-2	2	13.5
9	2	3	-1	-1	1	6
10	2	3	-1	-1	1	6
11	3	2	1	1	1	6
12	4	4		0		
13	4	3	1	1	1	6
14	5	4	1	1	1	6
15	3	3		0		
16	3	4	-1	-1	1	6
17	3	4	-1	-1	1	6
18	1	4	-1	-3	3	17
19	2	5	-1	-3	3	17
20	5	4	1	1	1	6
21	4	3	1	1	1	6
22	2	5	-1	-3	3	17

∑ ranks (+) = 42 N = 19

∑ ranks (-) = 148 α = 0.05

Therefore According to tables

W_Statistical = 42 W_Critical = 46

W_Statistical < W_Critical

Conclusion. - *The difference is significant, therefore null hypothesis can be rejected. It is possible to affirm that the child star ratings in the year 2019 are different enough from the child star ratings in 2015*

7.4 Findings from the Wilcoxon signed rank tests

The Wilcoxon signed rank tests conducted for the different scenarios gave the next results:

TABLE 20 Results of the Wilcoxon signed rank tests conducted

Comparison of safety ratings 2015 - 2019: Adult protection	
First scenario	The hypothesis cannot be rejected
Second scenario	The hypothesis cannot be rejected
Third scenario	The hypothesis cannot be rejected
Comparison of safety ratings 2015 - 2019: Adult protection	
First scenario	The hypothesis can be rejected
Second scenario	The hypothesis can be rejected
Third scenario	The hypothesis can be rejected

According to the results of the tests, in the three scenarios, the distribution of the safety ratings for adult protection in 2015 and 2019 are similar because there is no significant difference between the 2 samples. This suggest that in 2019 the cars tested were achieving in general the same high ratings for adult protection than in 2015 (both years count with the largest proportion of cars rated with 4 and 5 stars).

Concerning child protection, the results of the Wilcoxon signed rank tests in the different scenarios confirm that the child protection safety ratings achieved in 2019 are considerable higher than ratings obtained by the cars tested in 2015. According to the tests there is a significant difference between the distribution of the ratings in 2015 and 2019, and this is also evident in the figures that represent the evolution of the ratings along the years. In the case of child protection, there is an evident gradual increase in the safety rating since 2010 and reaching the highest values in 2019.

These results give support to the decision of Latin NCAP about implementing a new and more exigent protocol in the current year 2020 and not wait another for another couple of years. As explained previously, the vehicle safety in Latin America is several years behind than the vehicle safety in develop regions like Europe, therefore there is no time to lose extending a phase/protocol for several after a period where most of the cars tested are already achieving high scores. As stated by (Van Ratingen et al., 2016): "sufficient time does not always have to mean years, as many manufacturers have responded very quickly to new challenges in the past".

It is important to remark that this doesn't suggest that the safety performance of the cars did not improve from 2015 to 2019. The protocol implemented in 2016 was more stricter than the previous one, especially for adult protection, this suggest that a car that use to achieve 4 or 5 stars with the old protocol between 2010 and 2015, would achieve a safety rating 1 or 2 starts lower with the new protocol from 2016 because their requirements were more strict, for instance since 2016 the side impact test became mandatory for all the car tested. This is reflected in the fact that in 2015, 32% of the cars tested achieved 4 or 5 stars while in 2016 none of the cars tested achieved 4 or 5 stars.

This hypothesis is also supported by the fact that Latin NCAP have encouraged the car manufacturers to equip their vehicles with more safety devices. The average number of airbags per car tested increased almost 4 times from 2010 to 2019. In the same period the number of cars tested and equipped with seat-belt pretensioner increase in 33%. The protocol implemented in 2016 required the implementation of ESC as a mandatory requirement to achieve 5 stars and this resulted in the fact that during year only 12 of the cars tested were equipped with ESC while in 2019 close to 75% of the cars tested were espied with ESC technology. Taking into account the fact that Latin NCAP select the best seller models in the region for the not sponsored tests and considering that Latin CNAP only tests the most basic version of the car, becomes evident the positive impact of Latin NCAP of the safety equipment of the cars, and consequently on their safety performance.

CHAPTER 8: DISCUSSION OF THE RESULTS

The data visualization in the previous chapter revealed interesting facts about the impact of Latin NCAP on the safety performance of the cars commercialized in Latin America. In this chapter, there will be discussed other related aspects to give more clarity about the finding of the previous chapter.

8.1 Improvement of the performance besides the ratings

The evolution of the safety ratings can lead to misperceptions when they are analyzed without taking into the fact that in 2016 there was implemented a new protocol that was stricter and more exigent that the previous one, therefore it is normal to see a decrease in the number of stages obtained by the cars tested in 2016 compared to 2015. One of the tests that remain mandatory for all the cars tested with both protocols is the average frontal impact test score. Latin NCAP provides the results for all the cars tested by them except, the ones tested in 2016 and 2017. An analysis of the evolution of this average performance of the cars in this test is represented in the next figure:

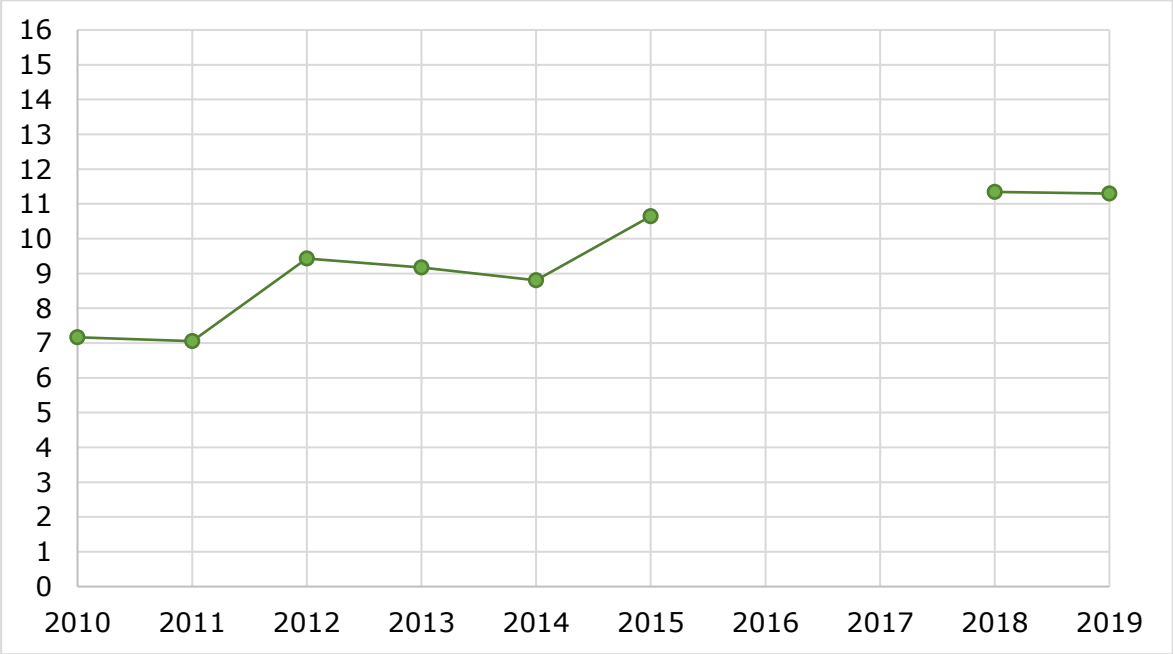


FIGURE 38 Evolution of the average frontal impact test score. Own elaboration based on data from Latin NCAP

It becomes evident the gradual improvement of the performance of the cars tested in this test, which use to be the only mandatory crash test until 2015, since 2016 the side impact test became mandatory for all tests also. The maximum score for this test in both protocols is 16 points. Although there is no data from 2016 and 2017, it is not far from reality to think that the average of those years was raging between 10 and 12 points, like the average in 2015, 2018, and 2019 because this tested remained the same in the new protocol of 2016. This may suggest that in 2015 car manufacturers were equipping their cars to perform relatively well in the

frontal impact test but that design of the car was not enough to perform well also in the side impact test that became mandatory for all cars tested since 2016. For instance, a car equipped with front airbags and a resistant structure was able to perform quite well in the frontal impact test, but if the same car was not equipped with side airbags also, that car certainly performed very badly in the side impact test. Maybe that is another reason why the safety rating of the cars tested in 2016 was considerably lower than the cars tested in 2015.

8.2 The case of Chevrolet cars

Certainly, the car manufacturers are now aware of the impact of the safety ratings on the image of their cars and their brand, and in more or less degree (depending on the company) they are investing to make their cars safer for the users. One interesting case of analysis of this improvement is the company Chevrolet, that in 2016 was identified as "the leading manufacturer of zero stars cars in Latin America" (Consumers International, 2016). At the same time, Chevrolet is the brand with more cars tested (16% of the cars tested by Latin NCAP are from Chevrolet) and in more repeated occasions (9 years).

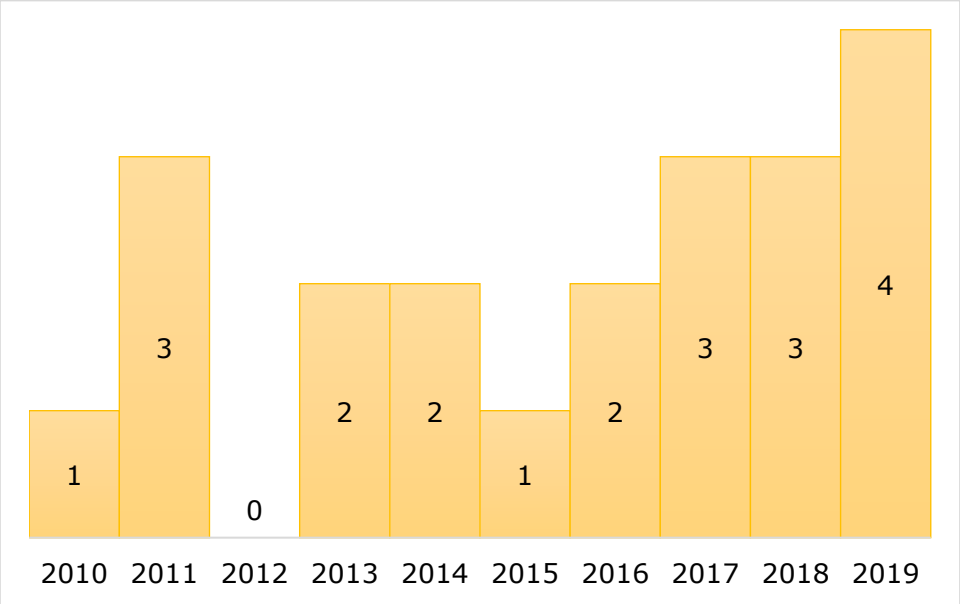


FIGURE 39 Number of Chevrolet cars tested every year. Own elaboration based on data from Latin NCAP

An analysis of the evolution of the average safety ratings of the Chevrolet cars tested may be useful to visualize the improvement of the brand in the last years. The adult star rating initially showed an alarming gradual decrease in the ratings obtained by the cars of this brand. Considering the assumption that a company like Chevrolet was aware of the existence of Latin NCAP and the safety ratings since their implementation in 2010, it becomes even more surprising that Chevrolet did not take seriously the safety performance of their cars until 2017, when the average adult safety performance remained in 0 stars for the third year in a row. It took 8 years to start seeing some improvement of the Chevrolet cars,

years in which Latin NCAP was pushing this brand and all the other brands in the region to improve the safety of their cars. Finally, in 2018 the Chevrolet cars tested started to obtain high ratings, and the improvement was so accelerated that in 2019 some of the Chevrolet cars tested obtained 5 stars for adult protection for the first time.

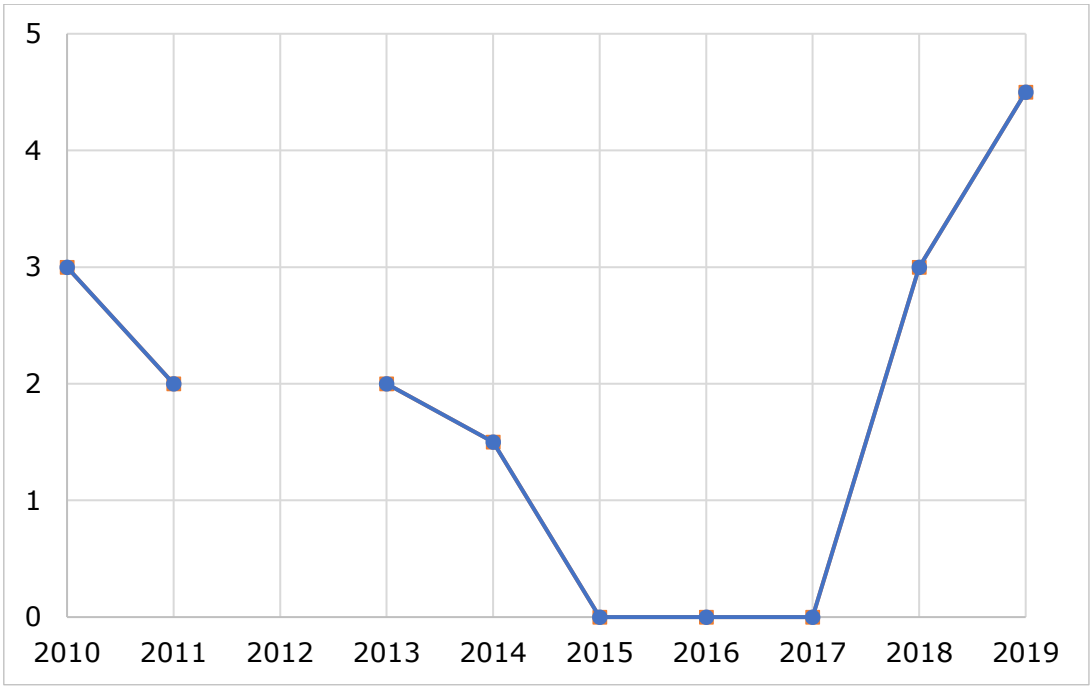


FIGURE 40 Evolution of the average adult safety rating of the Chevrolet cars tested. Own elaboration based on data from Latin NCAP

The evolution was quite different for child protection. From 2010 to 2016 the average safety rating remained low (between 1 star to 2 stars) with an erratic evolution in that period. However, the gradual improvement of the safety ratings of the Chevrolet cars started 1 year before in the case of child protection. Since 2017 the ratings started to improve and similar to what happened with adult protection, in 2019 some of the Chevrolet cars tested obtained also 5 stars for child protection for the first time since the creation of Latin NCAP in 2010.

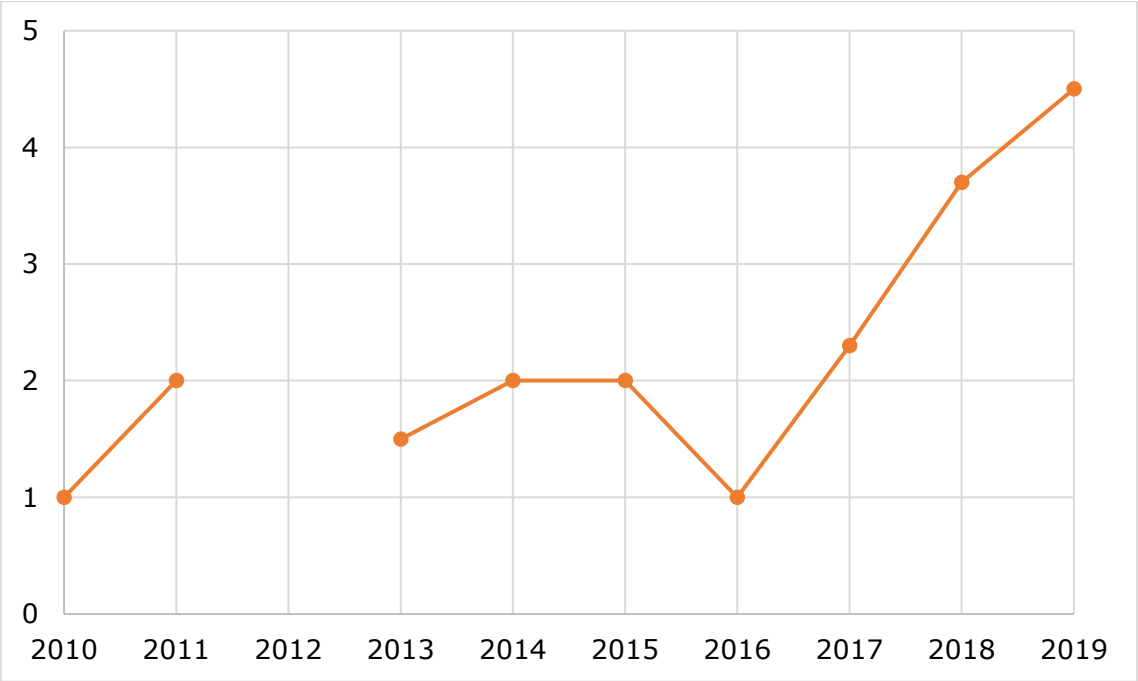


FIGURE 41 Evolution of the average child safety rating of the Chevrolet cars tested. Own elaboration based on data from Latin NCAP

It was in 2019 the first time that a Chevrolet car obtained 5 stars for adult and child protection, and although this improvement took 10 years, finally the company gave up to the external pressure of Latin NCAP, Consumers International, and other voices in the region. The improvement in the ratings of Chevrolet cars since 2017 -2018 period, looks promising for the future and hopefully, this brand will continue working in making their cars even safer for the users so that they can save hundreds and maybe thousands of lives taking into account the popularity of this brand in the region.

The last Chevrolet cars tested are not the best in their class or reaching excellence in safety performance yet, nevertheless the gradual improvement in the safety performance of these cars since 2017 is undeniable. A comparison in more detail of the safety performance of a model that has been tested on repeated occasions may provide a clear image of this improvement. The following table shows a comparison of the safety performance and safety characteristics of the Chevrolet (New) Aveo, a model that has been tested in 4 different years.

TABLE 21 Evolution of the safety performance of a car from Chevrolet tested in 4 different occasions. Own elaboration based on data from Latin NCAP

Model	Chevrolet Aveo	Chevrolet Aveo	Chevrolet New Aveo	Chevrolet New Aveo
Year	2015	2017	2018	2019
Made in	Mexico	Mexico	China	China
Adult occupant protection (Safety rating)	0 stars	0 stars	2 stars	3 stars
Adult occupant protection (Safety score)	0 / 17	17,49 / 34	23,76 / 34	23,76 / 34
Child occupant protection (Safety rating)	2 stars	3 stars	4 stars	4 stars
Child occupant protection (Safety score)	17,93 / 43	30,11 / 49	37,02 / 49	37,02 / 49
Frontal impact score	0 / 16	No data	10,79 / 16	10,79 / 16
Number of airbags	0	2	2	2
Seat-belt pretensioner	No equipped	No equipped	Equipped	Equipped
SBR (Seat-belt reminder)	No equipped	Only for driver	No equipped	Only for driver
ESC (electronic estability control)	No data	No installed	No installed	No installed
Bodyshell integrity	Unstable	Stable	Stable	Stable

8.3 The decrease in the cost of safety devices and technologies

The results of the data processing revealed a clear improvement in the provision of safety devices in the cars produced for the region. Adopting the assumption that car manufacturers decided to equip their cars with more and better safety devices just because of the influence of Latin NCAP may sound very promising but not very realistic. Like any other company, car manufacturers are business-driven organizations that sell a sort of product to generate the largest amount of profit with the lowest possible cost. Therefore the economic cost of the safety devices is something that could affect their sales because these dispositives could increase the final cost of the car and the more expensive the car the less the people in Latin America that will be able to pay for it, taking into account the income level of most of the countries in the region. However, the cost of safety devices and driving technologies has decreased considerably in the last decade and this is another of the factors that propelled the improvement in the safety performance of the cars in Latin America.

TABLE 22 Cost of strengthened bodywork, safety devices technologies in the last years. Consumers International (2016) based on data from Global NCAP.

Equipment	Estimated Cost
Airbag + strengthened bodywork	200 USD
Airbag	50 USD
ESC (to a car with ABS)	50 USD
ABS + ESC	75 USD - 100 USD

According to the previous table, car manufacturer just needs to invest around of 250 USD to equip their cars with a strength bodyshell plus 2 frontal airbags and this may be enough for a car to perform quite well in the front impact test and probably achieve a medium-good safety rating. In the same logic, equipping the car with side airbags (so the car can perform well also in the side impact test) may cost to the car manufacturers and an additional 200 USD. And as ESC is a requirement to achieve 5 stars, the car manufacturers would have to invest another 50 USD to aspire to get that safety rating.

The study from Consumers International is focused in the Latin American case and it is assumed that their results are in great degree applicable to vehicle market in the region therefore if their estimations are accurate, a car manufacturer would require close to 500 USD to equip their cars safe enough (strong bodyshell, front and side airbags and ESC) to perform quite well in the crash tests and even to aspire to get a high safety rating for adult and child protection.

At this point, there must be stated that those prices may not apply to all cars and all companies. Every car is designed and constructed different and this may affect the cost of some element like a safe bodyshell. Some other sources consulted, like Caroline Wallbank et al. (2019), stated that the cost of an airbag is just around 35 USD, while the cost of equipping the car with a resistant side impact structure is 542 USD. Nevertheless is a reality that the cost of safety devices and technologies is decreasing and they are now much more affordable than in the past in a manner that nowadays, "Safety does not need to be an expensive option" (Consumers International, 2016). In other words, equipping the cars to save more lives, is becoming cheaper.

8.4 The impact of safety devices and technologies on the safety performance of the cars tested

Ensembling the cars with a more resistant bodyshell and equipping them with more safety devices and technologies, is going to help to save more lives and to reduce the severity of accidents, nevertheless this result convenient for the car manufacturers too. Safety devices and technologies are helping car manufacturers to perform better in crash tests and therefore to achieve higher ratings. A clear example of this aspect is the number of airbags installed in the car.

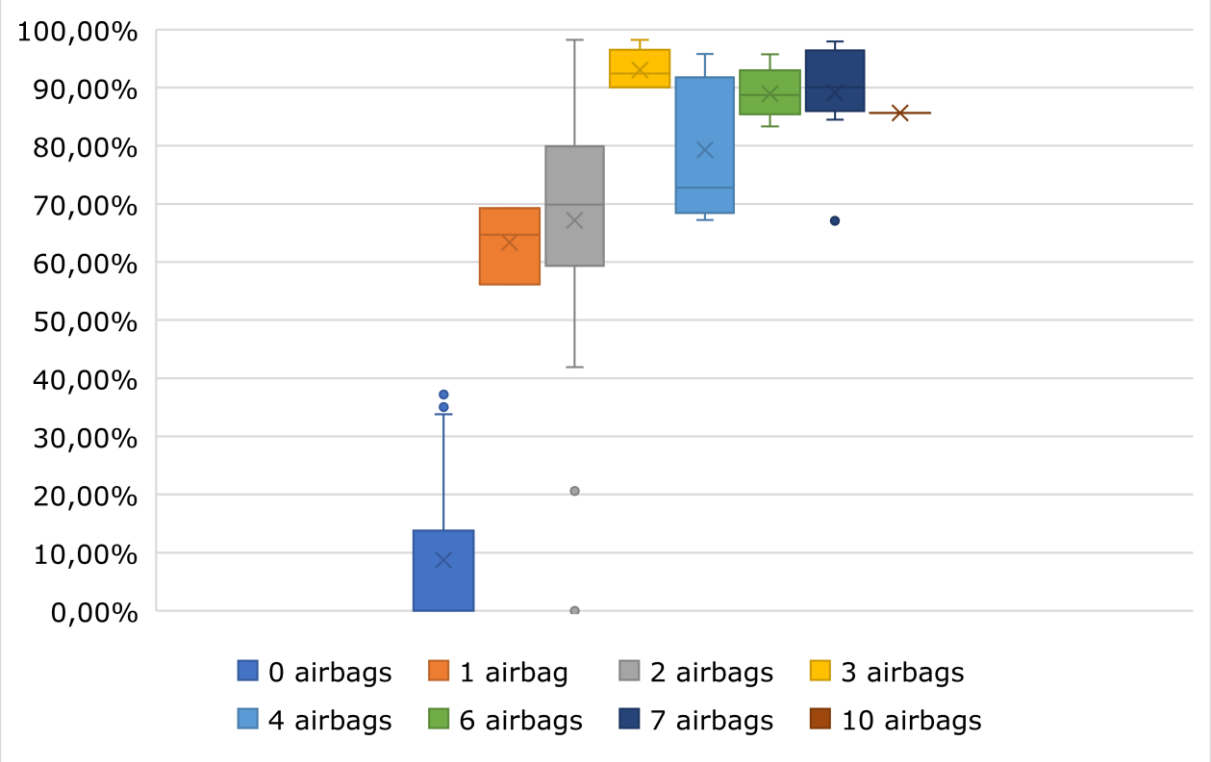


FIGURE 42 Number of airbags vs Adult protection score (as percentage of the maximum possible score). Own elaboration based on data from Latin NCAP

The figure shows a clear positive relationship between the number of airbags and the performance of the car regarding adult protection. The effect of having installed 1 airbag compared to none airbag, is great for the adult protection performance.

Cars without any airbag achieved in average close to 9% of the maximum possible score, however, cars with 1 airbag achieved close to 63% of the maximum possible score. Except by the cases of cars equipped with 3 airbags, there is a clear gradual increase in the safety performance for every increment in the number of airbags installed in the car. Only 1 of all the cars tested was equipped with 10 airbags, and that is the reason why the representation of this category in the boxplot doesn't seem to follow the same positive correlation.

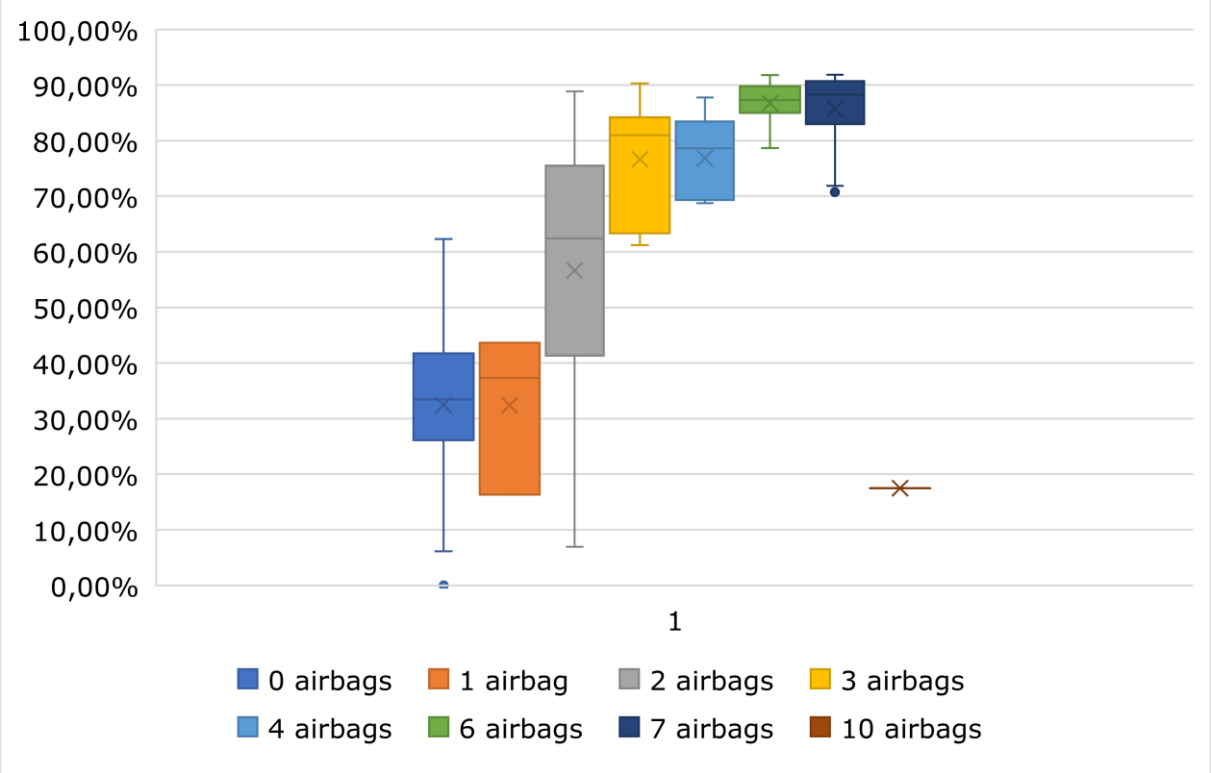


FIGURE 43 Number of airbags vs Child protection score (as percentage of the maximum possible score). Own elaboration based on data from Latin NCAP

Again, there is a positive correlation between the number of airbags installed in the car and the safety performance for child protection, however, in this case, the effect of the airbags become more evident since the installation of 2 airbags and becomes greater since the installation of 3 airbags. This may be caused by the fact that child dummies are located in the rear seats while the cars equipped with 1 or 2 airbags have installed these safety dispositives in the front seats. The category of cars equipped with 10 airbags is presented by just 1 car, therefore it may not be considered as representative of the group. This car is the Chevrolet Malibu tested in 2013, and in the technical sheet of this car on the website of Latin NCAP, it is not specified the reason why this car performed well in adult protection while performed so bad regarding child protection.

The case of the Chevrolet Malibu tested in 2013, reveals that the safety performance of the car not only relies on the airbags, actually the final performance relies on the combination of many aspects of the car, like the strength of the bodyshell, therefore it is normal and excepted to find some outliers in the

previous figures. Therefore, it is convenient to analyze also the relation of other safety devices on the safety performance of the car, for instance, the effect of seat-belt pretensioners.

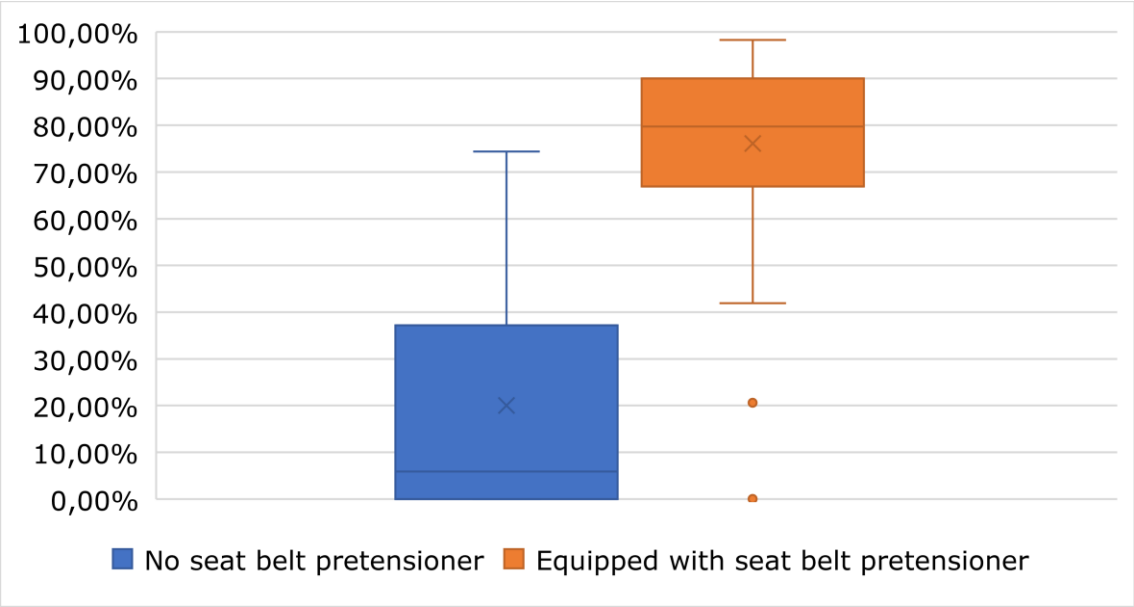


FIGURE 44 Seat-belt pretensioner vs Adult protection score (as percentage of the maximum possible score). Own elaboration based on data from Latin NCAP

Similar to what happened with the airbags, the installation of seat-belt pretensioners have a great positive effect on the safety performance of the cars regarding adult and child protection, increasing the safety performance from close 40% (in cars no fitted with seat-belt reminder) to close to 77% in the case of adult protection and 64% in the case of child protection. This means that in the case of adult protection, the cars with seat-belt pretensioners on average achieved almost twice the score than the cars tested without these diapositives. These findings should encourage car manufacturers to invest more in (the installation of these devices for all the occupants to improve the safety performance of their cars.

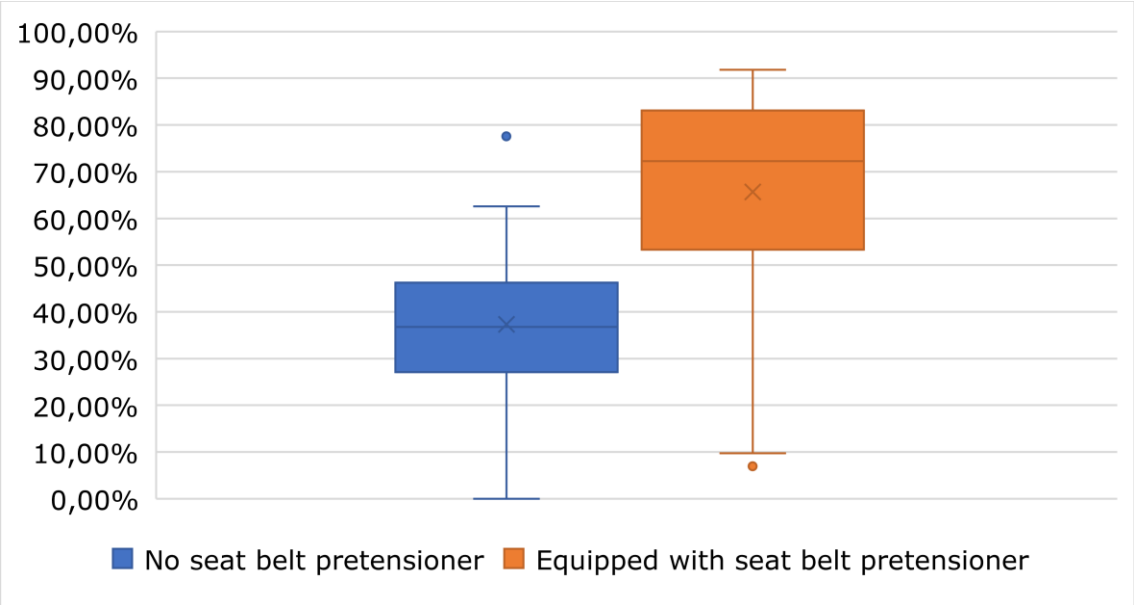


FIGURE 45 Seat-belt pretensioner vs Child protection score (as percentage of the maximum possible score). Own elaboration based on data from Latin NCAP

Concerning the bodyshell integrity, it is interesting to find that the year with the lowest percentage of cars with stable bodyshell (51%) is at the same time the year with the largest proportion of tests sponsored by the car manufacturers (85%). This may suggest car manufacturers consider that the safety performance of the car relies mainly on the safety devices of the car and not in the structure of the car itself. However, many cars equipped with airbags offered very low protection when tested because of their weak structures (Furas, 2014). The following box plot analysis reveals the importance of a stable bodyshell to achieve higher safety scores.

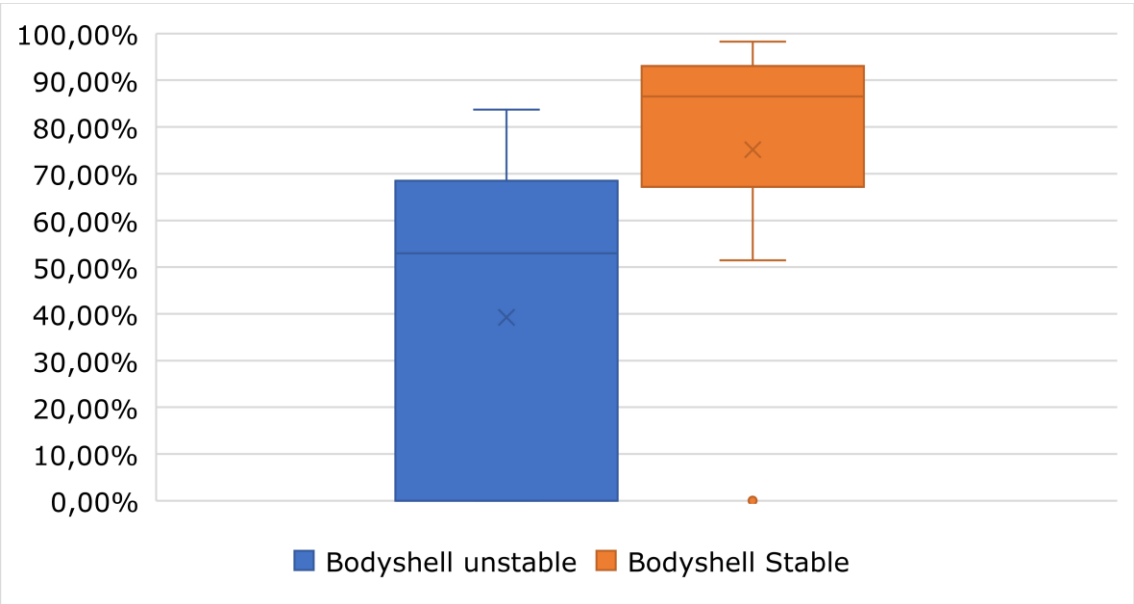


FIGURE 46 Bodyshell integrity vs Adult protection score (as percentage of the maximum possible score). Own elaboration based on data from Latin NCAP

The integrity or strength of the bodyshell plays a fundamental role in the damage that car occupants can suffer especially on their heads and limbs. A weak bodyshell can suffer a lot of intrusion during the impact and consequently damage seriously the occupants, especially when the car is not equipped with enough airbags. The same box plot but using data from child protection demonstrates also the importance of a strong bodyshell to achieve a high child protection score. Both figures show clearly that building the car with a stable bodyshell has an overwhelming positive effect on the safety performance of the car.

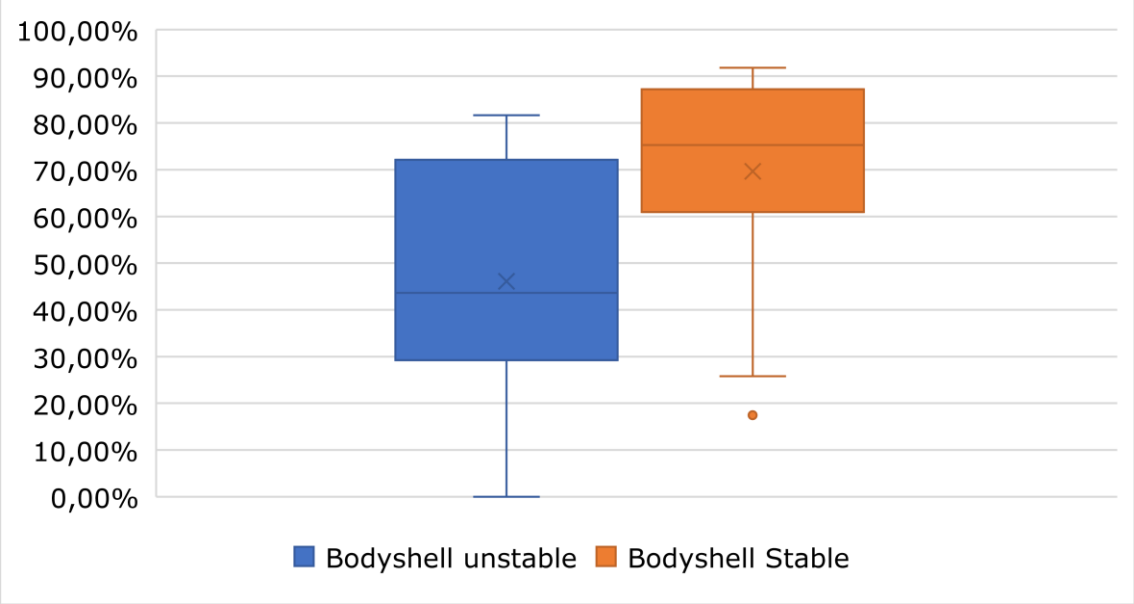


FIGURE 47 Bodyshell integrity vs Child protection score (as percentage of the maximum possible score). Own elaboration based on data from Latin NCAP

8.5 Relation between safety ratings and reduction of crash severity

After an exhaustive research and literature review about the relation of safety ratings and reduction of crash severity in the Latin American context, there was not found any study or report about this aspect. These types of estimations would require complex cross-validation of the best-sellers cars and the new cars registered every year besides detailed traffic accident data based on a common severity scale framework. Maybe the reason why there are no studies about this in the Latin American context is because making these estimations at a regional level is even more difficult considering that most of the countries in the region don't collect crash data on a systematic and standardized manner.

On the other hand, some NCAP programs in developed regions, in cooperation with national authorities and road safety related institutions, took the challenge to make these estimations. Although they are not exactly applicable to Latin America, it is still useful to review them to have a better idea of how much can crash severity gets reduced when a car is rated with a higher number of stars.

The results of the studies conducted for the European case are at least interesting in principle. One of the first studies conducted in 2001 concluded that the risk of fatal or serious injury was reduced by 12% for every star that the car achieved in the Euro NCAP tests (LIE, Kullgren, & Tingvall, 2001). Almost ten years later a new study estimated that 5 stars models use to have a risk of fatal injury 68% lower compared to 2 stars models (Kullgren, Lie, & Tingvall, 2010). The results of that study are interesting cause it is possible to notice a progressive reduction in injury and fatality risk with the increase of the safety ratings of the cars.

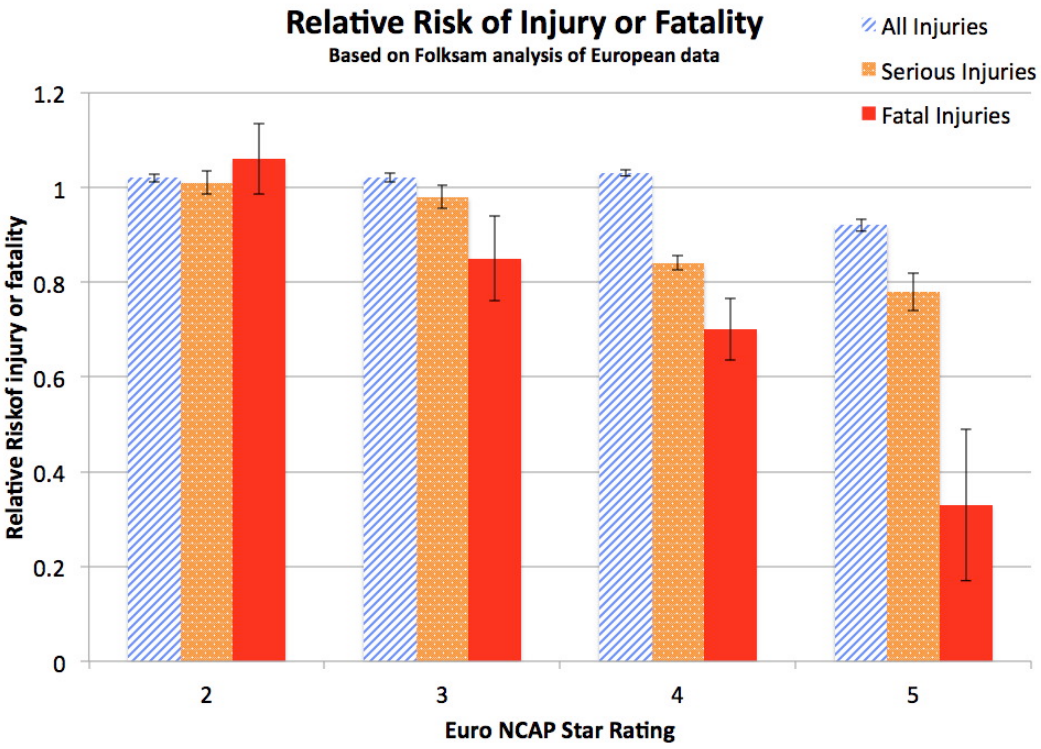


FIGURE 48 Relative risk of Injury and Fatality vs Euro NCAP star rating (Kullgren et al., 2010)

A similar research was conducted for the case of ANCAP ratings and the improvement of the crashworthiness (reduction in the serious injury rate). The study concludes that "On average the crashworthiness improves by 22% when a model improves from 3 stars or less to 4 stars and by 35% when a model improves from 4 stars to 5 stars. The average improvement from 3 stars or less to 5 stars is 49%" (Paine et al., 2013). In this study, there was estimated also the reduction in the serious injury rate for specific models.

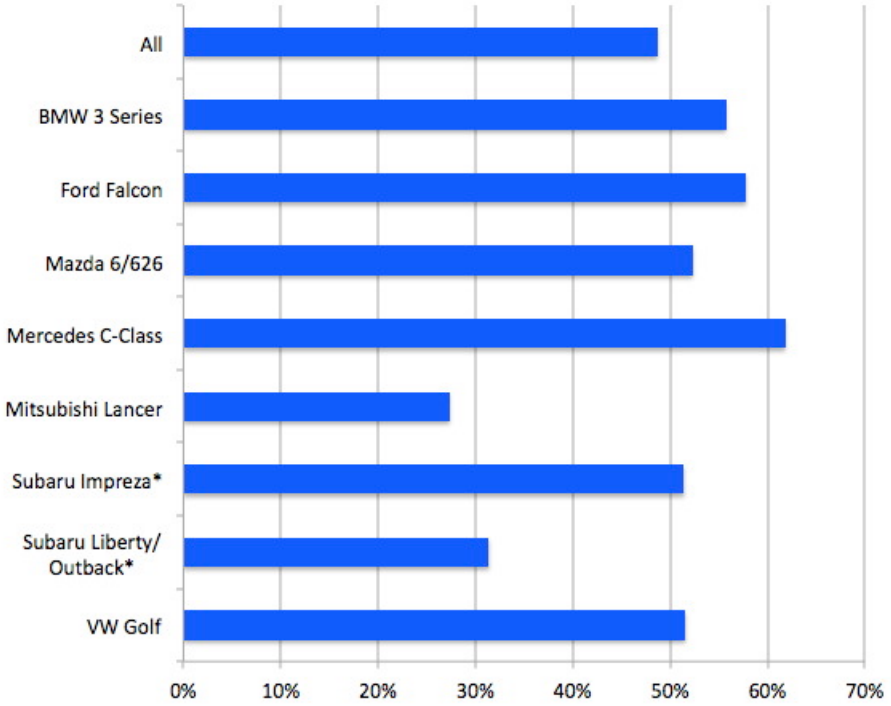


FIGURE 49 Reduction is serious injury rate due to a change from 3 or fewer stars to 5 stars (Paine et al., 2013)

The results obtained for Euro NCAP and ANCAP are promising and they demonstrate that improving vehicle safety can reduce injury and fatality risk in a great magnitude. It is not possible to affirm if the same risk reductions are in a great degree applicable to the Latin American context because the protocols used for the tests in Europe and Australia are more exigent that the protocols used by Latin NCAP. Probably a car that obtained 5 stars in Latin NCAP tests in 2019, would receive a lower score if they were tested with the same protocols used by Euro NCAP and ANCAP nowadays. Nevertheless, the evidence confirms that improvement in the safety rating of car results is considerable serious injury and fatality risk reduction, and this is undeniable. Conducting similar studies but focused on Latin NCAP and the risk reduction in the region may start by first analyzing specific countries where data is collected in efficient and standardized manners, to then create models to estimate a regional impact.

CHAPTER 9: CONCLUSIONS OF THE THESIS

All the research process conducted in this Thesis can be summarized in the next main conclusion that constitutes an answer for the main research question of the thesis: Latin NCAP had a positive impact on the safety performance of the new cars produced for the Latin America market, and although this positive impact may not look so evident when the safety ratings are analyzed (because of the stricter protocol implemented in 2016), the evidence confirms that in the last years, the cars that are being produced for the region are now equipped with more safety devices, they include new safety technologies and they are performing better in the crash tests.

Certainly, the whole research conducted resulted in many other relevant conclusions that provide answers to the secondary research questions and that can be considered as a relevant scientific contribution to this field of road safety that has not been studied in much detail as other aspects of road safety.

9.1 Conclusions from the literature review

All the information consulted in the literature review revealed interesting findings that are useful to understand the context surrounding the problem of unsafe cars in Latin America and the work of Latin NCAP in this region. The main conclusions resulted from the literature review are the next:

- The focus on safer vehicles have become stricter during the last decades, going from just basic requirements of safety devices to submit the new cars to exigent crash tests in order to assess the safety performance of cars in simulated crash scenarios.
- Implementation of NCAP in all the regions of the world is strongly promoted by UN and WHO because the first NCAPs implemented in developed regions, like Europe, demonstrated to be effective to increase the safety performance by new cars beyond minimum requirements.
- The fatalities rates in Latin America easily duplicate and even triplicate the fatality rates of developed countries located in North America like Canada and the US.
- In most of the countries of Latin America car occupants (drivers and passengers) account for the largest proportions of traffic deaths, and in many cases, this proportion is higher than 50%.
- The motorization rates in Latin America are growing faster than the motorization rates in the US and Europe, however the motorization levels still below than in those regions. The average vehicle age in Latin America still being considerably higher than the average vehicle age in Europe.
- The vehicle production is a strong part of the national industry in countries like Argentina, Brazil and Mexico. These two last countries are located among the top ten producers of passenger cars at a worldwide level.

- The accomplishment of the UN minimum vehicle safety standards is poor and almost inexistent in Latin America. It is alarming to notice that countries with a strong car industry like Brazil that accomplishes only 3 out of 7 minimum vehicle safety standards while Mexico just accomplishes 1 out of the 7 minimum vehicle safety standards.
- Some studies already demonstrated that the application of the UN vehicle safety standards in four strategic countries of the region (Argentina, Brazil, Chile, and Mexico) have the potential to save thousands of lives every year and reduce drastically the number of seriously injured victims in the region.
- Latin NCAP is one of the newest NCAPs in the world and is based in the same framework and methodologies used by Euro NCAP in previous phases, however, Latin NCAP started operations with a great disadvantage compared to the European case because the normative in Latin America regarding vehicle safety still being weak compared to the normative in Europe even three decades ago.
- Latin NCAP works independently from the car manufacturers and their tests are based on already proven methodologies that were successfully applied in Europe. At present, Latin NCAP is the only organization in Latin America conducting crash tests to vehicles.
- Latin NCAP implemented the safety scores and the safety ratings for adult and child occupant protection since its creation in 2010. In 2016 it was introduced a new protocol that makes the requirements for the car tested, stricter at the time to obtain a higher safety rating. The tests and most of the safety scores before and after 2016, still being directly comparable.
- The process adopted by Latin NCAP for car selection, testing and publication of results is done in a manner that car manufacturers cannot deceive the process and therefore they cannot manipulate the results of the test or modify the car that will be submitted to the tests.
- Latin NCAP always tests the most basic model of the car using only the safety devices that come in the car from fabric. Car manufacturers must compromise to not reduce the safety specifications of their cars after receive a score form Latin NCAP, especially a good score.

9.2 Conclusions from the data processing and analysis of the results

The data processing, the statistical tests and the posterior discussion of the results provided scientific support for the he following conclusions, which gave a clear insight about the safety performance of the cars in Latin America and the impact of Latin Impact along the last decade.

- Since its creation in 2010, Latin NCAP only tested 3 to 7 cars every year using their funds. Increasing the financial support to Latin NCAP may result in a higher number of tests per year and therefore in a higher impact in the vehicle market.

- Car manufacturers are aware of the fact that every new protocol introduced by Latin NCAP is more exigent than the previous one. This explains why the number of sponsored cars tested is higher in the yeas previous to the introduction of new protocols.
- On average, sponsored cars performed much better than the cars that were not sponsored (close to 48% better in adult protection and close to 29% better in child protection). This implies that car manufacturers sponsor the tests of their best and safer cars.
- The evolution of the distribution of the safety ratings for adult and child protection along the last decade can be misunderstood and lead to wrong conclusions if they are not analyzed taking into account that in 2016 it was introduced a new and more exigent protocol and that is the reason why it seems that there was a great decrease in the performance from 2015 to 2016 (especially for adult protection), when in fact cars in 2016 had a similar safety devices equipment and bodyshell integrity than the cars tested in 2015, year in which the most of the cars tested performed well in the tests. Therefore, it is expected to wait for a decrease in the safety rating of the cars during 2020, because this year was introduced a new protocol that is stricter than the protocol introduced in 2016.
- Regarding the brands of the cars tested, 7 brands comprehend 71% from all the universe of cars tested (134 cars). Chevrolet, Volkswagen, and Nissan are the 3 brands that have been tested on more occasions.
- The progress in the safety performance of brands like Chevrolet during the last years is remarkable and promising for the future. This brand, identified as the "the leading manufacturer of zero stars cars in Latin America" (Consumers International, 2016) was analyzed in more detail to illustrate the impact that Latin NCAP is producing on the main car manufacturers in the region.
- An analysis of safety performance based on the brand of the car revealed that the safest brands in the Latin American new vehicle market, for both adult and child protection are JEEP, SEAT, Honda, and Toyota. However, it must be remarked that just 1 car from the brand JEEP was tested since the creation of Latin NCAP.
- On the other side of the scale, the comparative analysis by brand revealed that the 3 most unsafe brands in Latin America are all Chinese brands and they are BYD, Chery and Lifan.
- Close to two-thirds of the cars tested were produced in Latin America and they had a medium performance when tested. On the other hand, less than 10% of the cars tested were produced in Europe but they achieved the highest scores among all the cars tested.
- An analysis at the regional level shows that cars produced in developed regions like North America and Europe achieve better scores than the cars produced in regions like Asia and Latina America. This shows the importance of an exigent vehicle production regulation and the reality of a weak vehicle production regulation in Latin America.

- The positive impact of Latin Impact gets reflected in the fact that car manufacturers are implementing more safety devices and new technologies in the car they produce for the Latin American Vehicle market. The average number of airbags in the cars tested increased from 1.1 in 2010 to 3.9 in 2019. In 2010, 56% of the cars tested were equipped with seat-belt pretensioners, in 2019 this number increased to 89%. Similarly, the percentage of cars tested equipped with ESC came from 12% in 2016 to 75% in 2019.
- Bodyshell integrity of the cars tested did not show a gradual positive evolution like in the case of the safety devices, instead, there is an erratic evolution reaching the highest percentage in 2017 (close to 87% of the cars tested) and its lowest value on 2019 (around of 52% of the cars tested)
- Concerning adult protection, the Wilcoxon signed rank test, in the 3 different scenarios defined for this thesis, demonstrated that in 2019 the distribution of the safety ratings was similar enough and positive as in 2015. This supports the decision of Latin NCAP about implementing a new protocol since 2020 and do not wait for another few years to do it. In the case of child protection, the Wilcoxon signed rank test, also in the 3 different scenarios, revealed that the distribution of the safety ratings in 2019 was significantly higher than in 2015, confirming the gradual improvement of the child safety performance that started in 2010.
- The frontal impact test remained mandatory for all cars tested since the creation of Latin NCAP. An analysis of the evolution of the performance of the cars tested in this test showed a gradual though not perfect improvement of the average score the cars obtained every year, going from close to 7 out of 16 points in 2010 to 11.2 out of 16 points in 2019.
- Another main reason behind the improvement of the safety performance of cars is the great reduction in the cost of safety devices and technologies during the last years.
- Adopting costs from Consumers International (2016) which are based on data from Global NCAP, it was estimated that a car manufacturer would require close to 500 USD to make their cars safe enough (strong bodyshell, front and side airbags, and ESC) to perform quite well in the crash tests and even to aspire to get a high safety rating for adult and child protection.
- A box plot analysis of the safety performance of the cars based on their number of airbags demonstrated the great positive impact of equipping the car with just 1 airbag (for adult protection performance) and 2 airbags (for child protection performance) compared to installing no airbags in the car. With an estimated cost of airbags of close to 50 USD, car manufacturers don’t have any excuse to install at frontal and side airbags in their cars.
- Seat-belt pretensioners have also a great impact on the safety performance of the car, especially in the case of adult protection. On average, the cars equipped with seat-belt pretensioner achieved an adult protection score 2 times higher than the cars without seat-belt pretensioners.

- Concerning bodyshell integrity, the results may suggest that car manufacturers are not paying to much attention to this aspect of the car and that they are focusing on the provision of safety devices like airbags, however, the results also demonstrated that cars built with a strong bodyshell are performing much better than cars built with a weak structure.
- There was not found studies or reports about the relation between the Latin NCAP safety ratings and the reduction of injury risk of car occupants in Latin America, however, the few studies of this type conducted in developed regions like Europe or Australia demonstrated that every time that a car tested by NCAP protocols, receives a higher star, the injury risk is reduced significantly. In few words, the higher the number of stars achieved by the car, the lower the injury risk for the user, and with a great degree of certainty, this applies also to the Latin American case.

All the conclusions mentioned and many other more specific findings are all explained in detail in the previous chapters and they are intended to summarize the main findings of the second part of the thesis and they are explained in more detail in the previous chapters. They were explained in a manner that any professional or person involved in the area, can understand them and take advantage of them.

These findings will help authorities and policy makers to elaborate adequate measures and policies to address the problem of unsafe cars in the region. Car manufacturers can get also benefited from the findings of the second part of the thesis because they are useful to identify the areas in which their car needs to improve to become safer and to perform better in the crash tests conducted by Latin NCAP.

CHAPTER 10: PRACTICAL RECOMMENDATIONS AND FUTURE RESEARCH

The whole analysis conducted resulted in relevant findings and scientific supported conclusions that are intended to be a contribution from the author to the improvement of vehicle safety in Latin America. This chapter comprehends some important recommendations to apply the findings of this research to improve the safety performance of the vehicles in the region.

10.1 Recommendations for authorities and policy makers

Authorities and policy makers related to the regulation of vehicle safety at the national and regional levels have a great responsibility on the provision of safer vehicles but at the same time, they have a great power to improve the situation. Relevant studies demonstrated that the implementation of the UN vehicle safety standards in the car producer countries in the region is going to saves thousands of lives and to reduce considerable the number of seriously injured victims. Strengthening the car production normative is the best contribution from the part of authorities and transport planners, therefore they must encourage their governments to apply the UN vehicle safety standard, especially in the countries with a strong car production industry (Argentina, Brazil, and Mexico). Countries that are not producing cars may focus on making their new cars importation normative more exigent to ensure that very unsafe cars (0 and 1 star cars) are not allowed to circulate in their roads anymore.

10.2 Recommendations for car manufacturers

Car manufactures should pay more attention to make the bodyshell of their cars more resistant besides the provision of safety devices. This may require to increase the efforts to improve the design and the materials of the bodyshell, but the literature review revealed that this is not something very expensive anymore. The research conducted showed that the provision of safety devices and technologies certainly make the cars safer until some degree, however without a resistant bodyshell,s certainly the car will not perform as safe as expected or will not achieve a high safety rating.

Every day more and more consumers are aware of the existence of Latin NCAP and the safety ratings and if car manufacturers must remain relevant and popular, they should invest also in safety because this aspect of the car is taking more relevance every day. Some companies may try to avoid the safety aspect for some time, but like in the case of Chevrolet, they will certainly reach a point where they would need to invest in the safety performance of their vehicles to keep a good position in the market.

10.3 Recommendations for Latin NCAP and other external organizations

It is pertinent to encourage to Latin NCAP to not reduce the efforts towards the provision of safer vehicles in the region and to continue working independently from car manufacturers. Latin NCAP may increase their efforts towards the propagation of the crash tests and the safety ratings among consumers. Latin America is a large region that comprehends a large and spread vehicle market, and if the safety ratings reach more and more potential buyers in all the countries, this certainly is going to produce a greater impact on the production of safer vehicles.

Other NGO and development organizations interested in the improvement of the road safety situation of Latin America, can support Latin NCAP financially or logistically to allow Latin NCAP to make more tests to more cars every year. Every year, Latin NCAP tests between 3 to 7 cars with their funds (without sponsorship), and if this number increase, the impact on the vehicle market will also be greater.

10.4 Further research

To the knowledge of the Autor, this is the more recent but also the most complete study about the impact of Latin NCAP on the safety performance of the cars in Latin America. There is no several research about the Latin American context, and just a few of them just slightly refers to the evolution of the safety performance of the cars since the implementation of Latin NCAP.

Because of the academic context and the scope of the study, this thesis was focused more on the technical aspect of the car safety and the results of this research could be studied in more detail to estimate the number of fatalities and seriously injured people that could be reduced because of the improvement of the safety performance of the car (reduction for every extra star a car receives). Other studies could focus specifically on the risk reduction of serious injury because of the installation of a safety device (perhaps the number of airbags in the car) or a safety technology (like the installation of ESC).

Further studies will certainly require additional information related to registration of new cars every year, best seller cars, and standardized road accident data. Taking as a study case a large region like Latin America, may overcomplicate the estimations at a regional level, therefore further studies may start analyzing countries with a strong car production industry (Argentina, Brazil or Mexico) or countries that don’t produce cars but that comprehend a large share of the annual number of new vehicle sales in the region (Chile).

There is still much research to be conducted in this field that is relatively new for Latin America, and it is expected that this thesis will encourage the realization of further studies in the are of vehicle safety in the region.

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