Applications and Challenges of Adopting Internet of Things (IoT) in Reducing Road Traffic Accidents

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Abstract

Road traffic accidents is one of the leading causes of non-disease fatality in the Philippines. Globally and reported by WHO, there are about 1.35 million people annually are counted as the result of the road traffic accidents. In Metro Manila alone, accidents were doubled from 2005 to 2019 based from MMARAS (Metro Manila Accident Recording and Analysis System) report which was annually released by MMDA (Metropolitan Manila Development Authority). This study was organized to determine the risk factors and the nature of accident which is discussed in this paper and identify the causes that leads to fatality, non-fatality of injuries and damage to property classifications of road traffic accidents. The use of ANOVA and Multiple Regression statistical tools were performed to test the hypotheses and use its results as input to formulate and adopt IoT application in reducing the road traffic accidents.

Keywords
Road traffic accidents, ANOVA, Multiple Regression, IoT, Nature of Accidents

1. Introduction
Vehicular road traffic accidents are considered one of the major cause of deaths after disease. According to the 2020 WHO Report on Road Traffic Injuries, the lives of almost 1.35 million people every year are at risk as a result of a road traffic accidents. This means that between number of 20 and 50 million more people suffer non-fatal or injuries, with many acquiring disabilities as injury results. Road traffic injuries and crashes cause contributable economic losses in terms of cost of treatment, decreased productivity, and lost man-hours at work, to the tune of 3% of gross domestic product in most countries. A study from World Bank provides that reduction on road traffic fatalities and injuries could have a valuable gain for long-term income both for the low-income and middle-income countries (Azeredo, 2018).

The same report from WHO cited human error as the main risk contributor together with the following; not using motorcycle helmets, car seatbelts and child restriction; unfocused or distracted driving; issues on road infrastructure; unsafe vehicles, negligence on post-crash repair, and unimpeded law enforcement on traffic. With a global acknowledgment for road accidents, injuries and deaths, the World Bank study mentioned earlier considered road safety investments as a human capital investment. Additionally, countries that are not investing on road safety could led to decrease anywhere between 7 to 22% in getting the per capita gross domestic product growth over more than 24-year period, requiring government to put priority and improve road safety investment. The cost of neglecting this issue could led to more than 1.25 million deaths annually and globally, with reduced and enhanced growth prospects and diminished productivity. Over said period, establishing at least eliminating deaths and injuries due to road traffic could potentially grow its GDP per capita in most Asian countries like 15% Thailand, 15% in China, 14% in India, 7% in Tanzania and 7% in the Philippines (Azeredo, 2018).

The Philippines, with a total of 29.67 million vehicles registered with the Land Transportation Office, saw an increasing trend in road accidents. In Metro Manila alone that consists of 16 cities and 1 municipality, with a population of 13.9M and 6.68M registered vehicles, the number of road accidents doubled from 63,072 in 2007 to 116,906 in 2018, resulting in a yearly average of 566 fatalities based on Metro Manila Accident Reporting and Analysis System (MMARAS) 2018 report on situation on road accidents in the Philippines. This led the Philippine Department of Health (DOH) tagged that road accidents as major leading causes of death overtaking other health and deadly diseases, including dengue, in the list of causes of deaths (PhilKotse.com, 2020).

Also reported in MMARAS (2019) was the classification of accidents in Metro Manila into Fatal with 372 cases, Non-Fatal with 20, 466 cases and Damage to Property with 100,933 cases. The most common nature of road accidents was collision with the following types: side-swipe, rear-end, angle impact, hit and run, multiple collision, self-accident, hit parked vehicle, head on and hit object.

The most leading road accident cause was human interface errors, such as, lack of experience on driving, unfamiliar road signs and locations, fell asleep, lost control and drive under the influence of alcohol. Another cause was due to mechanical defects, namely: electrical problem, loose brake, loose propeller, exploded tire and flat tire (PhilKotse.com, 2020). Other factors that led to casualties to pedestrians, drivers and passengers included environmental related and road issues and vehicle traffic involving driver’s over speeding, driving under the influence of alcohol, not good in overtaking, improper turning of the wheel and even pedestrian’s jaywalking.

Various improvements and plans to address these road accidents in Metro Manila included development of policies and implementation of programs on road safety, formation of a road safety task force, and harmonizing and modernizing of land transportation and related laws (Tanggol, 2018). In the course of making progress in the areas of safer roads and mobility and having available regular data on road traffic fatalities, legislations were strengthened on managing car speed, drinking while driving, use of helmet among motorcycles, car seatbelt use, and anti-distracted driving (mobile phone use while driving). However, issues remained on the effective enforcement of road safety laws, lack of national vehicle standards, to ensure use of safer vehicles, and building transport and road infrastructure.

Notwithstanding the above, the trend in road accidents has been increasing for the past several years, hence a need for additional prediction and anticipation, and probably enhancing road traffic system and automation using Internet of Things (IoT), an emerging technology has been adopted in developed countries in addressing road traffic issues of increasing complexities (Vijayaraman & Jayarin, 2019).

The Internet of Things or popularly called IoT is simply defined as a collection of sensors and software with the primary purpose to connect and exchange data over the internet (Oracle, n.d.). The 21st century saw an important role of the IoT platform resulting in collection and exchange of real-time data with minimal human intervention for processing into more meaningful information of decision making. IoT is an affordable low power easy-to-use sensor technology with high reliability brought about by cloud embedded computing platforms, equipment learning and predictive analytics and even communicative artificial intelligence (AI) like Apple Iphone’s Siri.

The automotive industry was one of the first adopters of IoT in incorporating its applications in vehicle design and manufacture, most common of which are sensors that detect failures in vehicle performance and anticipate mechanical failure while on the road. Another widely used IoT application is the vehicle monitoring system using a platform like IBM Blue Mix and cloud data computing) that provides the overall condition of the vehicle in road worthiness and driving performance which are both of interest in the discussion of road accidents. Another development using IoT in vehicles is Advanced Driver Assistance Systems (ADAS) increases road safety by a safe human and machine interface as it has sensors, cameras in order to detect any traffic obstacles, the man driving errors on which it automatically corresponds and adjust to the events or situations (Moller & Haas, 2019).

According to Sharma, M, (2020), the IoT and connected embedded technologies can improve vehicle safety, efficiency, convenience and user experience. The head of programs, research, and advanced engineering at Continental North America, Jonathan Stone says the collected data from these technologies can improve road safety by helping the users or drivers in their driving decision making plus having automation of driver control functions. Systems like ADAS were developed to enhance and automate aspects of the driving or user experience to enhance safe driving habits. These systems have been proven to reduce the number of deaths on the road which led to anticipating and reducing the chance for human error. The purpose of these safety features is to increase and reduce road safety, improve and reduce vehicular injuries by decreasing the total number of traffic accidents (Hearst Autos research, n.d.).

Given the applications and benefits of the Internet of Things (IoT) in the automotive industry and its increasing popularity in IoT implementation in developed and developing countries in traffic management, it will be of interest to seek an answer to the question, "What are the applications and challenges of adopting IoT in reducing road traffic accidents in Metro Manila, Philippines?" The study proposes to identify the major causes of traffic accidents where IoT applications can be viable to reduce the risks of vehicular accidents. The study also aims to come up with an IoT implementation platform in adopting IoT considering the vehicle-driver interface, infrastructure conditions and environmental factors.

The objectives of the study are: (1) to determine the significant and risk factors affecting different nature of vehicular road and traffic accidents; (2) to determine the focal areas of improvement where IoT can be implemented to reduce road accidents; and (3) to propose implementation of strategy in the reduction of road accidents, and to identify whether IoT adoption is applicable to Metro Manila, Philippines.

The results of the study will benefit the road users – drivers, vehicle owners, pedestrians and the policy makers and law enforcement. Stakeholders in the road system and traffic ecosystem will stand to gain from the advantages of IoT-enabled vehicle-related systems and traffic management infrastructure and operations in minimizing human-interface errors and consequently reducing road accidents with the use of internet, wireless communications, data analytics and IoT platforms. This study contributes to the field of IoT application in the area of transportation and road safety.

The study will utilize annual reports from 2005 to 2019 publicly released by MMARAS about the road accidents in Metro Manila. The research locale will be limited in Metro Manila, the largest metropolis in the country with the greatest number of registered vehicles and heaviest concentration of businesses and trade, that makes it a suitable focus of the study where data is available in identifying the different nature of road accidents involving almost all types of main vehicles ranging from private cars, transportation buses, express vans to delivery trucks.

2. Methodology

The study will adopt the following conceptual framework "Figure 1" as its logic in finding an answer to the research question of identifying areas where IoT will be viable to introduce and adopt in Metro Manila in view of improving road safety after analyzing road accidents and its causes.

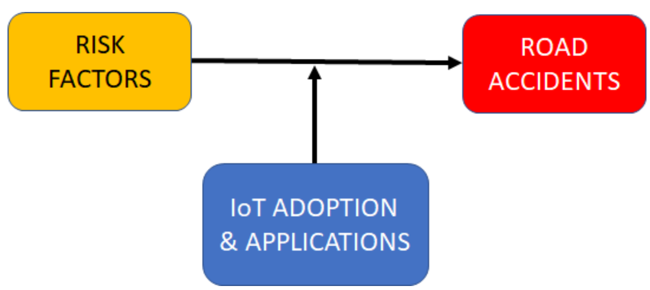

Figure 1. Conceptual Framework

Road accidents are a function of safety risk factors on the road that include the aspects of vehicle, driver, road conditions, environmental driving conditions, information and other stakeholders. The study will look into the moderating effect of IoT between risk factors and road safety relationship, using the number, type and nature of accidents, in view of the study's overall objective of reducing road traffic accidents.

The following hypotheses are hereby posited:

H10: There is no significant relationship between risk factors and road traffic safety.

H1a: There is a significant relationship between risk factors and road traffic safety.

H20: IoT adoption and applications have no moderating effect on the relationship between external factors and road traffic safety.

H2a: IoT adoption and applications have a moderating effect on the relationship between external factors and road traffic safety.

In order to test the above hypotheses, an operational framework shown in "Figure 2" below is drawn together with the variables that will be of interest to the study as indicators of the 3 constructs contained in the conceptual framework.

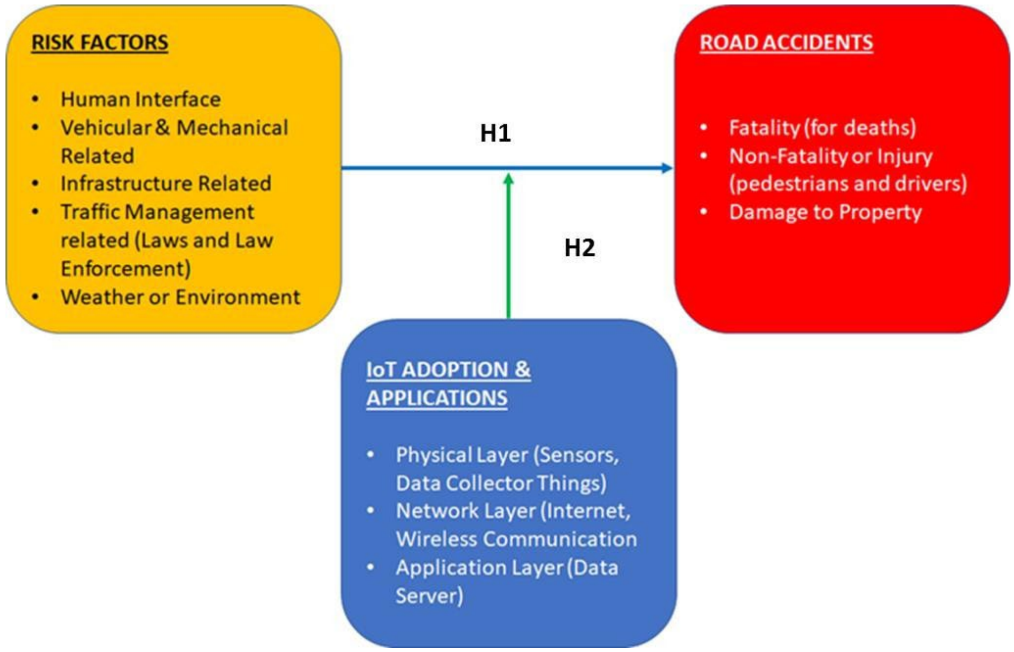

Figure 2. Operational Framework

Below is a tabulated summary Table 1 of the definition of the variables and the corresponding indicators that will be measured for the testing of the above hypotheses:

Table 1. Summary of Constructs and Indicator Variables

CONSTRUCTS	VARIABLES	INDICATORS	Cited Definitions
Risk Factors	Human Interface	Lack of driving experience, Over speeding, Driving under the influence of alcohol, bad overtaking, improper turning.	Human interface is a factor mainly observed on (Sharma M., 2020) as human negligence that leads to the cause of road accidents.
	Vehicular & Mechanical Related	Engine is sputtering, steering wheel is shaking, brake pads are worn, squeaking or grinding, failing alternator, radiator leaking, transmission failures, gearbox issues, electrical problems on lights and so on.	The vehicular problem factors according to (Servicing Master, n.d.) are usually mechanical defects.
		Unfinished or on-going rehabilitation on roads, infrastructure technology	Based from (Polus, Pollatschek, & Farah,

	Infrastructure Related	design concepts are not yet applicable in the Philippines, no improvement on traffic light systems, internet systems are slow, government has no budget to improve infrastructure.	2005), the approach is to identify the high crash-rate roads.
	Traffic Management Related (Laws & Law Enforcement)	Unimproved traffic system, lack of imposing traffic rules and regulations, inappropriate government traffic solutions.	(Lidasan, Espada, & Richmund, 2009) study illustrate the need of improving capacity in transport and traffic planning management.
	Weather or Environment	Floods, typhoons, wet roads, earthquakes, fog, fires, rainy, road re-routing.	(Hamdar, Qin, & Talebpour, 2015) study measures the driver behavior with different road locations and environment.
	Physical Layer	Data collector things or sensors, RFID, raw data, and real-time information	Jain, S., Choudhari, P., & Srivastava, A. (2021) study gives fundamentals of IoT using its applications and embedded technologies.
IoT Adoption & Applications	Network Layer	Internet and wireless connections, network infrastructure, main functioning units of the architecture.	
	Application Layer	Smart computer technology, service management and authorization.	
	Fatality (for deaths)	372 total number of fatal or deaths.	The fatality, non-fatality or injury
Road Accidents	Non-Fatality or Injury (pedestrians & drivers	20,466 total number non-fatal or injury.	and damage to property is based on MMARAS 2019 report. Total of 121,771.
	Damage to Property	100,933 total number of damages to property.	

2.1 Data Gathering

The study will mainly use secondary data that will come from MMDA via their official MMARAS annual report. Said report is a compilation of road accidents since 2009 categorized into fatal, non-fatal and damage property road crashes in Metro Manila. These data will be relevant and important in the analysis of the nature and causes of road traffic incidents, from which areas of potential IoT applications can be identified in view of the primary aim of the study to reduce risks leading to traffic accidents.

A survey (using Google forms) will be conducted to gauge the perceived effects of potential IoT elements on the identified risk factors that can cause road accidents. The respondents of this survey are individuals who have driving skills and knowledge of traffic rules, and better yet, with the ability to express their thoughts on the risk factors affecting driving performance. The target number of respondents will be 330 and validation of responses will be conducted with a pilot run with a small subset sample to see if questions are easily understood and provided via a chi-square test of goodness of fit. To ensure that responses are usable, a set of demographic profiling questions will precede the main sets of questions related to the constructs. The questionnaire can be found in Appendix A and questions were drawn according to constructs and definition of variables tabulated above.

2.2 Data Analysis

The use of secondary data from the annual MMARAS reports will be the basis of root cause analysis and will warrant the consequent use of ANOVA when these causes are translated into risk factors after a thorough classification of the nature and causes of accidents. The use of ANOVA and Multiple Regression will enable testing of the first hypothesis on the significant relationship of different risk factors and road accidents, with the p-value of 0.05 or a confidence level of 95%. Multiple regression allows us to look at the relationship between the variables, while holding other factors equal and estimate the strength and significance of the relationships between the dependent variable of road accidents and the independent variables of the risk factors. The multiple regression will be used to check if the road accidents can be predicted based on the risk factor's variables.
The second hypothesis will be tested using the survey responses to the questions of how different IoT applications if adopted will mitigate the risk factors identified to have a significant relationship with road accidents. Since IoT applications cannot be observed directly and measured with actual data, it will be best to do a confirmatory factor analysis to determine if there is a perceived moderating effect of potential IoT applications in reducing traffic accidents. Said statistical tool will be helpful in to testing whether measures of a construct of IoT Adoption & Applications are consistent with the researcher's knowledge of the that nature construct (or factor) since the premise taken is that IoT platform applications, based on literature review, have a moderating effect, i.e., risk factors mitigation and reduction leading to road traffic accidents. This is important in recommending an IoT platform implementation approach in terms of those of measures.

2.3 Interpretation

The results of the two (2) hypotheses tests will mainly be used in crafting an IoT platform implementation strategy together with the results of the literature review of IoT technology developments and applications in the transport industry and traffic management. The platform strategy elements will be grounded in the context of Philippine land transportation policies and infrastructure, more particularly in Metro Manila with the most number of registered vehicles, with the heaviest density of population among urban centers across the country, and with an alarming increase in road traffic accidents resulting in fatal and/or non-fatal injuries and damage to property.

This will mean using the significance of corresponding risk factors to the nature and cause of road accidents as well as the appropriateness of IoT application in mitigating the type of risk. Appropriateness will pertain to the results of the confirmatory factor analysis that will show the agreement between the perception of the respondents' interpretation of an IoT application as a risk reduction factor and the researcher's understanding of the IoT application in mitigating the risks strongly associated with a nature and type of road accident.

This step will reconcile the results of achieving the first and second objectives to wit: identifying the causes and nature of accidents; and determining the areas of IoT application to reduce road traffic accidents. Drawing the implementation platform will lay the foundation of adopting IoT in traffic management, specifically in reducing risk factors and consequently minimizing road accidents. The proposed implementation platform will have to include the challenges in IoT adoption since many stakeholders are involved especially government agencies, riding public, vehicle owners and infrastructure developers and ICT service providers. The proposal will come up with a holistic framework with a systems approach based on key success factors and significant areas of IoT applications in reducing risk factors and road accidents. It will include, as challenges, need for policy reviews, minimum requirements on providing ICT services like mobile apps, internet and IoT hardware and system interconnection, and traffic regulations, law enforcement, and traffic management infrastructure (such as signage, GPS, communication and education).

There are also challenges implementation of IoT in terms of Philippines readiness on said technology. The study will be geared in looking at Metro Manila as a pilot model for IoT applications for traffic management and accident reduction so that it can be emulated by other urban centers throughout the country and eventually throughout regional areas and the rest of the countryside. The budget will not be tackled but will of course be considered as one of the major challenges that will presented as an initial hurdle that will produce long term benefits and sustainable efforts in reducing road accidents.

A stakeholder view and a system approach will be adopted in this final step not only to achieve the third and final research objective but to contribute to the body of existing knowledge of IoT applications particularly in the field of traffic management and risk reduction for a developing country with unsolved traffic issues and increasing road accident rates that go with the pursuit of economic growth with technology advancement in improving the lives of its citizens.

3. Results

This chapter will provide all gathered data from MMARAS annual report from 2015 to 2019 to show the statistical trend of traffic road crashes in Metro Manila, determine the nature and its road traffic accident causes which are the stated as the risk factors: Human Interface, Vehicular and Mechanical Related, Infrastructure Related, Traffic Management Related (Laws and Law Enforcement), and Weather or Environment.

For the last fourteen years (2005 to 2019), the 2019 MMARAS report shows the increasing trend of road traffic accidents as shown in "Figure 3". This means that from year 2005 (65111 cases) the reported cases were doubled in 2019 (121771 cases).

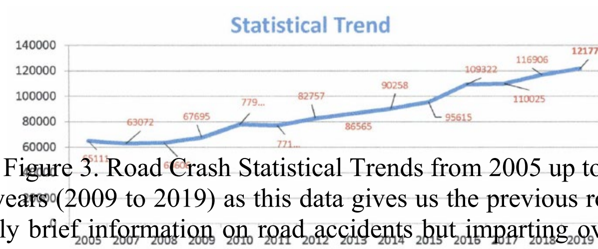

Figure 3. Road Crash Statistical Trends from 2005 up to 2019

The study focuses on the last 11 years (2009 to 2019) as this data gives us the previous road traffic accident history cases. The report gives us not only brief information on road accidents but imparting overall demographic data of accidents involved, circumstances of road crashes and to know the need of enforcement intervention on the identified areas called "Blackspot". The source of their data comes from Traffic Engineering Center – Road Safety Unit (TEC-RSU) wherein they have 8 researchers who gathers road crash data from Police Traffic station within Metro Manila. In the latest 2019 report, from January to December the statistics are 100,933 Damage to Property, 372 Fatal and 20,466 Non-Fatal or Injury summing up total of 121, 771. The greatest number of vehicles involved on road accidents is the use and driving a Car with 50.28%. This is because Cars have the highest number of vehicle types seen all over the Metro Manila while the age bracket that gains the highest number on accidents is between 35 to 51. The top three collision accidents are Side Swipe, Rear-End and Angle impact. Pedestrians, drivers and passengers are the most vulnerable road users. The top 7 areas are EDSA, C-5 Road, Commonwealth Avenue, Quezon Avenue, Roxas Boulevard, Marcos Highway and Radial Road-10.

3.1 Classification of Accidents

The MMARAS report maintains the database of accidents for road accidents into Fatal, Non-Fatal Injury and Damage to Property. Based on the report definition, the types of persons involved are drivers who are riding a pedal cycle, passengers who inside a vehicle, and pedestrians who are anyone passing by. The classification of vehicle types involved are Cycle/Pedicab, Motorcycle, Motor Tricycle, Car, Jeepney/Taxi/AUV/Bus, Van and Truck. "Figure 4 to 6" shows the overall trend from 2009 to 2019.

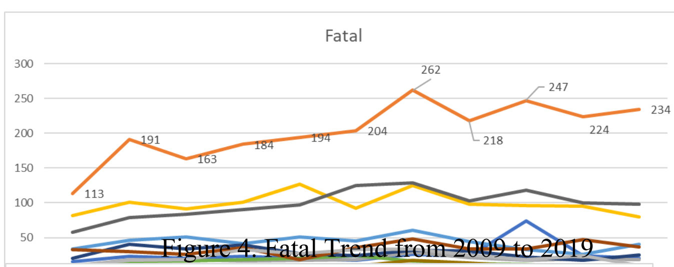

Figure 4. Fatal Trend from 2009 to 2019

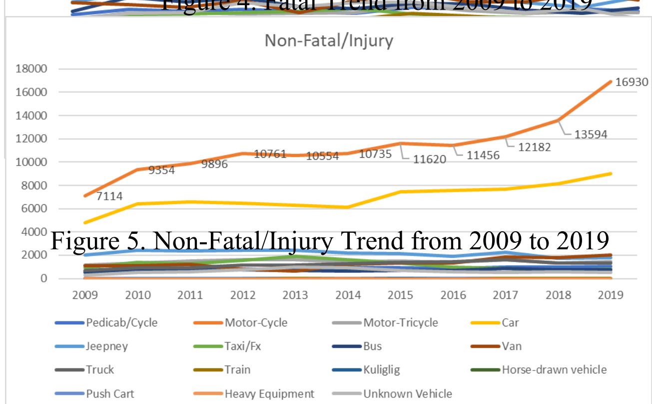

Figure 5. Non-Fatal/Injury Trend from 2009 to 2019

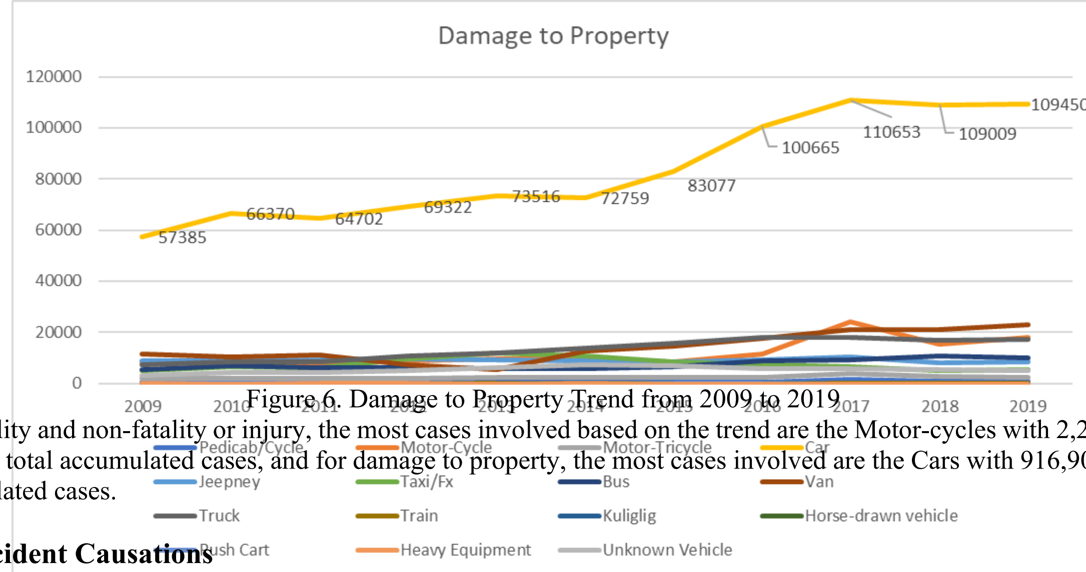

Figure 6. Damage to Property Trend from 2009 to 2019

For fatality and non-fatality or injury, the most cases involved based on the trend are the Motor-cycles with 2,234 and 124,196 total accumulated cases, and for damage to property, the most cases involved are the Cars with 916,908 total accumulated cases.

3.2 Accident Causations

There are five identified categories of accident causations that contributes to the fatality, non-fatality and damage to property. These are human interface error, vehicular and mechanical related, infrastructure related, traffic management related (law and law enforcement) and weather or environment. "Table 2" shows the overall number of accident cases from 2009 up to 2019.

Risk Factors	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Human Interface	8755	4674	3187	2795	2549	11196	2350	3528	2243	40	108
Vehicular & Mechanical Related	294	20	54	68	45	31	32	49	984	1	7
Infrastructure Related	4	1	2	8	6	23	7	1	1	0	3
Traffic Management Related (Laws & Law Enforcement)	8	24	10	4	12	9	1	0	0	0	0
Weather or Environment	1	4	12	1	6	3	4	10	2	0	0

Table 2. Risk factors data matrix

Human interface includes human errors like alcohol suspected, avoid hitting animal, another vehicle, or hitting pedestrian, driver error, lost control, moving backwards/backing inattentively, tired asleep and too fast. Vehicular and mechanical related are vehicle defects like detached wheel, electrical, lost brakes, sudden unintended acceleration and tire broke. For infrastructure related, these are due to humps, manhole/path hole and other road conditions. Infrastructure involves the lost or malfunction of traffic lights causing traffic jams, poor lane markings, unclear traffic or road signs, poor road surfaces like unfinished road rehabilitation. The traffic management related cause is the implementation of the traffic rules and policy which makes it confusing to road users. Lastly, the weather or environment causes are the slippery wet road due to rain or typhoon, runover a scattered sand, fog, earthquakes and fire. In order to test the first hypothesis (H1) on the significant relationship of risk factors and road accidents, ANOVA test is used using the data in Table 2.

H10: There is no significant relationship between risk factors and road traffic safety.
H1a: There is a significant relationship between risk factors and road traffic safety.

3.3 ANOVA Test Result and Interpretation

"Table 3 and 4" provides the ANOVA testing and summary results using simulation from simple MS Excel tool data analysis. The parameters set are p-value of 0.05 or a confidence level of 95%.

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Human Interface	11	41425	3765.909	11532392
Vehicular & Mechanical Related	11	1585	144.0909	84070.89
Infrastructure Related	11	56	5.090909	42.49091
Traffic Management Related (Laws & Law Enforcement)	11	68	6.181818	56.16364
Weather or Environment	11	43	3.909091	15.89091
2009	5	9062	1812.4	15078143
2010	5	4723	944.6	4346481
2011	5	3265	653	2007022
2012	5	2876	575.2	1540614
2013	5	2618	523.6	1282214
2014	5	11262	2252.4	24996367
2015	5	2394	478.8	1094336
2016	5	3588	717.6	2468634
2017	5	3230	646	978182.5
2018	5	41	8.2	316.2

Table 3. Summary of Average and Variance

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	1.22E+08	4	30584132	13.1769	6.18426E-07	2.605975
Columns	23324130	10	2332413	1.004899	0.456045311	2.077248
Error	92841649	40	2321041			
Total	2.39E+08	54				

Table 4. ANOVA Testing Result

The Analysis of Variance (ANOVA) is to test the differences among the means of the risk factors by examining the amount of variation within each sample, relative to the amount of variation between samples. In this case, the essence of ANOVA is to determine the total amount of variation among the relationships of the risk factors to the road accidents which can be attributed to specified road accident causes. The setting of the F-crit (critical) is determined by getting the degrees of freedom between the risk factors (df1 = 4) and degrees of freedom within risk factors (df2 = 40). Using the standard table of F-statistics P = 0.05, the F-crit is 2.61. The set-up decision rule is F $\geq$ 2.61. The computed value F is 13.18. Thus, 13.18 $\geq$ 3.48 means that H10 is rejected and accept H1a that there is a significant relationship between risk factors and its variables to the road traffic safety.

3.4 Multiple Regression and Interpretation

To test the first hypothesis (H1) using another statistical test, the multiple regression is used to determine the relationships of the dependent variable of total road accidents and independent variables of the risk factors. The independent variables are the actual distribution of number of vehicles involved attributed to the risk factors that are categorized and sum up as the fatality, non-fatality and damage to property. The data used are shown in "Table 5".

		Actual Distribution of Vehicle Types Involved		
Year	**No. of Accidents (Y)**	**Fatality (X1)**	**Non-Fatality (X2)**	**Damage to Property (X3)**
2009	67695	380	19226	107914
2010	77946	567	25076	121983
2011	77110	528	25981	119680
2012	82757	587	27114	128264
2013	86565	600	27143	135852
2014	90258	628	27178	144007
2015	95615	745	28440	147583
2016	109322	599	27712	175822
2017	110025	662	29947	204368
2018	116906	566	30365	188885
2019	121771	564	35227	194553

Table 5. Summarized accident type for no. of vehicles involved

The elements of multiple regression are explained by the equation (1) according to (Bevans, 2020) . Y as the dependent variable (number of accidents), $\beta 0$ as the intercept (value of Y when all parameters are set to 0), $\beta 1X1$ the regression coefficient $\beta 1$ of the first independent variable $X1$ (fatality), $\beta 2X2$ the regression coefficient $\beta 2$ of the second independent variable $X2$ (non-fatality) and $\beta 3X3$ the regression coefficient $\beta 3$ of the third independent variable $X3$ (damage to property). This is the effect that increasing the value of the risk factors (independent variables) has on the predicted Y value (dependent variables as road accidents). The $X1$, $X2$ and $X3$ are summation or composed of the five significant factors as shown in equation (2), (3) and (4) where *a* pertains to the human interface risk factor, *b* is vehicular or mechanical risk factor, *c* is infrastructure risk factor, *d* is traffic management risk factor and *e* is weather or environment risk factor. These data are provided in the MMARAS reports.

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 \quad (1)$$
$$X1 = X1a + X1b + X1c + X1d + X1e \quad (2)$$
$$X2 = X2a + X2b + X2c + X2d + X2e \quad (3)$$
$$X3 = X3a + X3b + X3c + X3d + X3e \quad (4)$$

Based on the regression simulation from MS Excel data tool analysis using the Table 5 data, the resulting road traffic accident predictable formula is shown in equation (5). The regression statistics simulation result is shown in "Table 6 and 7".

Regression Statistics	
Multiple R	0.980156729
R Square	0.960707213
Adjusted R Square	0.943867447
Standard Error	4251.68107
Observations	11

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	3093838337	1031279446	57.04991518	2.7566E-05
Residual	7	126537543.4	18076791.92		
Total	10	3220375881			

Table 6. Regression Statistics Results

The correlation coefficient or Multiple R means the measurement of the linear relationship between the independent and dependent variables. It is an any value between -1 and 1 indicating that the larger the value, the stronger relationship. 1 means strong positive relationship, 0 means no relationship and -1 means strong negative relationship. The multiple R value obtain from Table 6 is 0.9802 that is close to 1. Thus, we can say that there is a vigorous positive relationship between the risk factors and road accidents. The coefficient of determination R square (R2) serves as the gauge of goodness of fit. If the R2 is 95% or more, it is considered a good fit. The R2 is 0.9607 and that is 96.07%. This means that many points fall on the line regression graph. Adjusted R square means R2 of the independent variable while standard error provides the goodness of fit measure how precise is the regression analysis (Cheusheva, 2021).

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1419.091186	10831.50027	0.131015201	0.899449154	-24193.33704	27031.51941
Fatality (X1)	-8.737607784	18.05568656	-0.483925535	0.643210665	-51.43252209	33.95730653
Non-Fatality (X2)	1.357350337	0.649570986	2.089610474	0.075013157	-0.178640971	2.893341644
Damage to Property (X3)	0.398269025	0.069399226	5.738810722	0.000706497	0.234165931	0.562372118

Table 7. Regression Analysis Output Coefficients

$$Y = 1419.0912 - 8.7376X1 + 1.3574X2 + 0.3983X3 \quad (5)$$

The interpretation of this simulation is focused on the p-values to know the relationship of the variables. The p-values for each coefficient provides if the relationships are statistically significant. The significance level α=0.05 is a measure of the strength of the evidence present in the data samples. The p-value 0.0462 in fatality (X1) that is less than the significance level means that H10 is rejected and this effect has statistically significant relationship between risk factors and road traffic accidents. However, p-values 0.0889 in non-fatality (X2) and 0.1135 in damage to property (X3) are greater than the significance level which means that there is no significant relationship between risk factors and road traffic safety. This is because non-fatality are injuries only and not proven to be significant to the road traffic accidents unlike fatality that causes major death. Same with the damage to property, these are any injuries to properties that requires repair and not fatality or death.

3.5 Survey Results

The demographic profile is shown in "Table 8" to know the descriptive statistics of the respondents based on the conducted survey.

Table 8. Descriptive Statistics

Demographic	Description	Count	Percentage
Respondents	Total	330	100%
Gender	**Female**	**176**	**53%**
	Male	154	47%
Age / Years of Residence in the Philippines	23 to 26 years old	40	12%
	27 to 30 years old	**120**	**36%**
	31 to 33 years old	28	8%
	34 to 36 years old	8	2%
	37 to 39 years old	4	1%
	40 to 42 years old	40	12%
	43 to 45 years old	32	10%
	46 to 48 years old	8	2%
	52 to 54 years old	20	6%
	55 to 63 years old	30	9%
Nationality	Filipino	330	100%
Residence	Batangas	16	5%
	Cavite	26	8%
	Laguna	104	32%
	Metro Manila	**122**	**37%**

	Other Provinces	62	19%
Highest Educational Attainment	**Bachelor's Degree**	**274**	**83%**
	Master's Degree	14	4%
	Out of School	6	2%
	Ph. D	2	1%
	Student	34	10%
Does employment require driving a transport vehicle?	Maybe	36	11%
	No	**216**	**65%**
	Yes	78	24%
Did you take formal driving lesson?	**No**	**196**	**59%**
	Yes	134	41%
Do you have a driver's license?	No	118	36%
	Yes	**212**	**64%**
How long have you been driving in years?	**3 to 5 years**	**118**	**36%**
	6 to 8 years	34	10%
	9 to 11 years	16	5%
	12 to 14 years	20	6%
	15 to 17 years	52	16%
	No driving experience.	90	27%
Preference Transmission Type	Automatic	76	23%
	Both	**118**	**36%**
	I don't drive.	96	29%
	Manual	40	12%
Rate how well you interpret road signs (from 1 to 10).	1 to 2	12	4%
	3 to 4	0	0%
	5 to 6	58	18%
	7 to 8	114	35%
	9 to 10	**146**	**44%**
Rate how well you understand mechanical side of driving vehicles (from 1 to 10)	1 to 2	36	11%
	3 to 4	54	16%
	5 to 6	**92**	**28%**
	7 to 8	60	18%
	9 to 10	88	27%
Do you think environmental conditions present a significant effect on driving?	No	12	4%
	Yes	**318**	**96%**
As a driver, how would you rate the adequacy of present policies and traffic laws? (from 1 to 10).	1 to 2	14	4%
	3 to 4	62	19%
	5 to 6	74	22%
	7 to 8	**104**	**32%**
	9 to 10	64	19%

	N/A	12	4%
As a commuter, how would you rate the safety features of road infrastructure today? (from 1 to 10).	1 to 2	14	4%
	3 to 4	64	19%
	5 to 6	116	35%
	7 to 8	**124**	**38%**
	9 to 10	12	4%
As a pedestrian, how do you rate safety with the current state of road safety measures? (from 1 to 10)	1 to 2	26	8%
	3 to 4	102	31%
	5 to 6	92	28%
	7 to 8	**110**	**33%**
	9 to 10	0	0%

All the 330 respondents are Filipino on which 53% are female and 47% are male. The highest age and number of year residence in the Philippines is 27 years old and majority living in Metro Manila and Laguna. 65% of the total respondents voted that employment does not require driving a vehicle, 59% did not take formal driving lessons and 64% have driver's license. Based on this survey, 44% rated 9 to 10 on how well they can interpret the road signs, 28% rated 5 to 6 on how well they understand mechanical side of driving vehicles and 96% believed that environmental conditions have significant effect on the driving. As a driver, 32% rated 7 to 8 how adequate the policies and traffic laws. As a commuter, 38% rated 7 to 8 about the safety features of today's road infrastructure. Lastly, as a pedestrian, 33% rated 7 t0 8 about the safety with current state of road safety measures. The meaning and equivalent of rates are 1 to 2 as very poor, 3 to 4 as poor, 5 to 6 as average, 7 to 8 as good and 9 to 10 as excellent.

3.5 Risk Factors of Road Accident and IoT Adoption and Application Survey Results

The second hypothesis H2 is tested based from the survey responses to the six questions of each constructs: Risk Factors and IoT adoption and application. "Table 9" shows the responses of the risk factors and "Table 10" provides the responses of the IoT adoption and application. The questions are understood since the result of the Chi-Square test of goodness of fit is p-value $\leq$ 0.05.

H20: IoT adoption and applications have no moderating effect on the relationship between external factors and road traffic safety.

H2a: IoT adoption and applications have a moderating effect on the relationship between external factors and road traffic safety.

Table 9: Risk Factors Survey Response Result

Risk Factors	Description	Count	Percentage	Chi-square test	Expected
Respondents	Total	330	100%	-	-
1.) For you, what do you think is the most common cause of accidents?	Human Interface	268	81%	8.9624E-167	66.000
	Vehicular & Mechanical Related	22	7%		66.000

	Infrastructure Related	20	6%		66.000
	Traffic Management Related	18	5%		66.000
	Weather or Environment Related	2	1%		66.000
2.) In accidents due to Vehicle Mechanical Problems, which from the list below do you think is the most common cause?	Battery	2	1%	1.8763E-165	47.143
	Faulty Brakes.	220	67%		47.143
	Faulty Headlights and Taillights.	52	16%		47.143
	Faulty Steering System and Suspension.	24	7%		47.143
	Low Maintenance of vehicle	2	1%		47.143
	Tire Blowouts.	26	8%		47.143
	Unmaintained vehicle	4	1%		47.143
3.) In accidents due to Human Interface Problems, which from the list below do you think is the most common cause?	Bad overtaking.	50	15%	2.32695E-31	55.000
	Driving under the influence of Alcohol.	102	31%		55.000
	Improper Turning.	18	5%		55.000
	Jaywalking.	2	1%		55.000
	Lack of Driving Experience.	58	18%		55.000
	Over speeding.	100	30%		55.000
4.) In accidents due to Weather or Environmental Problems, which from the list below do you think is the most common cause?	Earthquakes	8	2%	1.37537E-83	55.000
	Fires	2	1%		55.000
	Floods	116	35%		55.000
	Typhoons	156	47%		55.000
	Wet road	46	14%		55.000
	Fog	2	1%		55.000
5.) In accidents due to Lack of Government's Policy (Traffic Management Related), which from the list below do you think is the most common cause?	Inappropriate government's traffic solutions.	64	19%	2.35749E-31	82.500
	Lack of imposing the traffic rules and regulations.	120	36%		82.500
	Uneducated implementors	2	1%		82.500
	Unimproved Traffic System.	144	44%		82.500
6.) In accidents due to Infrastructure issues in the Philippines, which from the list below do you think is the most common cause?	Government has no budget to improve infrastructure.	34	10%	1.80354E-49	82.500
	Infrastructure technology design concepts are not yet applicable in the Philippines.	62	19%		82.500
	No improvement on the Traffic Lights system.	34	10%		82.500
	Unfinished or on-going rehabilitation on roads.	200	61%		82.500

According to the survey the most common cause of accidents is Human Interface error with 81% followed by Vehicular & Mechanical related, Infrastructure Related, Traffic Management Related and Weather or Environment with 7%, 6%, 5% and 1% respectively. Under the human interface, the most common causes are 31% driving under the influence of alcohol and 30% over speeding. Faulty brakes with 67% is the most common cause under vehicular & mechanical related, unfinished or ongoing rehabilitation on roads have 61% as the most common cause under infrastructure related, unimproved traffic system with 44% under traffic management related and typhoons with 47% under weather or environment as the most common causes.

Table 10: IoT Adoption and Application Survey Results

IoT Adoption and Application	Description	Count	Percentage	Chi-square test	Expected
Respondents	Total	330	100%	-	-

1.) Where do you think IoT system can be applied the most?	Human Interface	120	36%	2.26434E-26	66.000
	Vehicular & Mechanical Related	104	32%		66.000
	Infrastructure Related	58	18%		66.000
	Traffic Management Related	38	12%		66.000
	Weather or Environment Related	10	3%		66.000
2.) In accidents caused by Vehicle Mechanical Problems, which from the list of features below do you think IoT can be applied the most?	Faulty Brakes.	153	46%	5.3473E-119	36.667
	Faulty Steering System and Suspension.	76	23%		36.667
	Faulty Headlights and Taillights.	57	17%		36.667
	Tire Blowouts.	26	8%		36.667
	Electrical wirings	6	2%		36.667
	All of the choices.	4	1%		36.667
	No answer	4	1%		36.667
	Faulty sensors and automatic engine brakes	2	1%		36.667
	Vehicle computer system	2	1%		36.667
3.) In accidents caused by Human Interface Problems, which from the list below do you think IoT can be applied the most?	Over speeding.	170	52%	8.51792E-93	47.143
	Lack of Driving Experience.	66	20%		47.143
	Driving under the influence of Alcohol.	48	15%		47.143
	Bad overtaking.	26	8%		47.143
	Improper Turning.	16	5%		47.143
	All of the choices.	2	1%		47.143
	No answer.	2	1%		47.143
4.) In accidents caused by Weather or Environmental Problems, which from the list below do you think IoT can be applied the most?	Floods	136	41%	3.3361E-132	36.667
	Typhoons	124	38%		36.667
	Wet Road	32	10%		36.667
	Earthquakes	22	7%		36.667
	Fog	5	2%		36.667
	Fires	4	1%		36.667
	Rainy	3	1%		36.667
	All of the choices.	2	1%		36.667
	Road Re-routing	2	1%		36.667
5.) In accidents caused by Lack of Government's Policy (Traffic Management Related), which from the list below do you think IoT can be applied the most?	Unimproved Traffic System.	144	44%	5.23131E-56	66.000
	Lack of imposing the traffic rules and regulations.	122	37%		66.000
	Inappropriate government's traffic solutions.	60	18%		66.000
	All of the choices.	2	1%		66.000
	No answer.	2	1%		66.000
6.) In accidents caused by Infrastructure of the Philippines, which from the list below do you think IoT can be applied the most?	Unfinished or on-going rehabilitation on roads.	102	31%	2.44583E-27	55.000
	Infrastructure technology design concepts are not yet applicable in the Philippines.	96	29%		55.000
	No improvement on the Traffic Lights system.	54	16%		55.000
	Internet systems are still slow.	46	14%		55.000
	Government has no budget to improve infrastructure.	30	9%		55.000
	No answer.	2	1%		55.000

From this survey results, 36% and 32% have responded on that IoT application and system can be applied the most addressing the issues on human interface errors and vehicular and mechanical related problems to avoid the road traffic accidents. The other part of the survey is to be a holistic approach considering all the aspects of the risk factors to inject the use of IoT as improvement on the road traffic accidents. Under human interface, IoT is most needed for over speeding (52%). For vehicular and mechanical problems, IoT is needed for the 46% faulty brakes. 41% flood, 44% unimproved traffic system and 31% unfinished rehabilitation on road are the most items to be considered to have IoT and improve these issues to lessen the risk factors.

Both the risk factors and IoT application survey results have commonality. These are addressing the issues on human interface and vehicular and mechanical factors that needs the IoT application to have improvement on the road traffic accidents in Metro Manila. These results of the survey have answered the second hypothesis H2 that IoT adoption and applications have a moderating effect on the relationship between external risk factors and road traffic safety.

The results of the two hypotheses tests achieved the first and second objectives defined in Chapter 1 and will be a basis to recommend and implement strategy on IoT platform and applications in the traffic management. The implementation strategy will be based on the Philippine land transportation policies and considering the current infrastructure especially the telecommunication wherein the internet and cloud platforms are used for the IoT and its devices.

4. Conclusion

This chapter provides summary of findings based on the overall results, recommendation on the improvement and implementation strategy based on the identified risk factors and the conclusion. The researcher was able to meet and present the objectives of this study: determine the significant and risk factors affecting different nature of road traffic accidents; determine focal areas of improvement where IoT can be implemented to reduce the road accidents; and propose implementation of strategy in the reduction of road accidents and identify whether IoT is applicable to Metro Manila, Philippines.

4.1 Summary of Findings

1.) There are five main significant and risk factors that affect the different nature of vehicular and traffic accidents which are proven on the data gathered from MMARAS annual reports (2015 to 2019). The problems that are related to road traffic accidents are Vehicle Mechanical Problems, Human Interface Error Problems, Weather or Environmental Problems, Lack of Government's Policy and Infrastructure issues in the Philippines.

2.) Among the five risk factors, Human Interface error is the most significant risk factor that led to the road traffic accidents. The second most significant risk factor is the Vehicular and Mechanical related problems. The first hypothesis tells that there is a significant relationship between risk factors and road traffic safety. This is based on the results of the ANOVA and Multiple Regression tests.

3.) From the result and analysis of the survey, the second hypothesis shows that IoT adoption and applications have a moderating effect on the relationship between external factors and road traffic safety.

4.) The results from the two hypotheses are used in generating an IoT platform and system, its implementation strategy with baseline on the literature review of latest IoT technology developments especially in the advanced cars, transport industry and traffic management. IoT application helps on mitigating the risk on human interface and vehicular related problems. This is presented and discussed in the recommendation section.

4.2 Recommendation and Implementation using IoT

The Internet of Things or IoT is a collection of sensors and software that has a purpose to connect and exchange data over the internet. Over the 21st century, IoT plays an important role whenever there is technology and internet as it collects data with minimal human intervention. Nowadays, IoT is low power sensor technology with low cost which means very affordable and reliable, cloud computing platforms, machine learning and analytics and can be further have conversational artificial intelligence (AI) like Apple Iphone's Siri. IoT applications are intelligent and easy to use. The automotive industry can benefit from IoT applications particularly on production lines and sensors that can detect failures in the vehicles to avoid and anticipate mechanical failure while you are on the road or driving. IoT can be applied on car monitoring system using a platform or tool (e.g. IBM BlueMix, Cloud data computing) that is beneficial to the topic of road accidents. A technology on cars like Advanced Driver Assistance Systems (ADAS) is one of the most system that IoT has been established. ADAS increases road safety by a safe human and machine interface as it has sensors, cameras in order to detect any traffic obstacles, the man driving errors on which it automatically corresponds and adjust to the events or situations.

This was in fact research done in India by the researchers in order to have design and implementation of real time autonomous vehicle by using image system processing and connect it to IoT. The design and model have object detection algorithm and lane prediction. It gives the drivers good awareness and interference of his surroundings in case the driver has loss his attention on driving. The lane detection is also one of the road-safety features to detect and aware the driver for proper view that he is staying on the correct lane to avoid collision with other vehicles (Goyal, Reddy, & Amalyal, 2020).

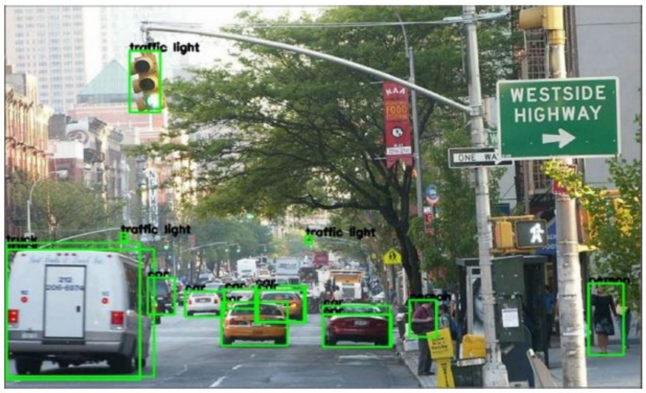

Figure 7. Detection of objects using IoT

In “Figure 8”, variables are the human interface problems that causes road accidents. Internet of Things (IoT) introduced on the framework to use as technology that will help reduce the road accidents and have safer roads while driving. IoT system is placed since the internet is in demand and have anywhere access for transmitting and receiving the data.

IoT will address the identified road accident problems particularly on human interface related issues. The major components of IoT are people, data and things. This technology is needed in order to perform vehicle communication to other objects and detect the driver, user and passenger while driving. These objects are vehicles on the road sensing others vehicles, pedestrians, lane detection, traffic lights, tracking the traffic situations in an area through GPS. Figure 9 gives an overview on how each vehicle will interact to other objects during driving. Since the problem is related to the human interface and user experience, features and specifications will be added to the vehicle as an application also of IoT.

In IoT system process related to vehicle-to-vehicle or device-to-device communication, there are three layers namely Application layer, Network layer and Perception layer. These layers are interrelated to each other and were discussed on the literature review. For instance, the process will start at perception layer wherein the user will navigate the safety feature he wants to do like sensing other vehicles in order to prevent collision, tracking the traffic situation to avoid congestion that may lead to multiple accidents. In addition, an integrated feature is presented on the vehicles like sensors that will automatically connect to the network layer using the internet and process until the application layer. The cloud is a platform used for data storage and processing.

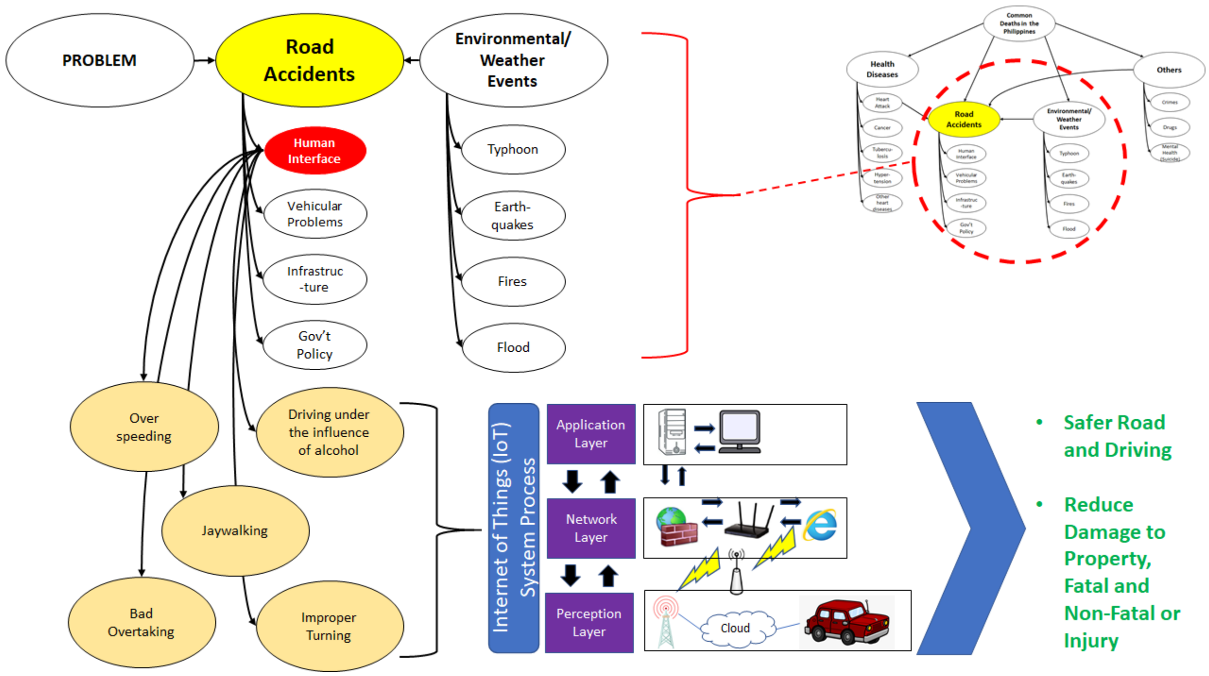

Figure 8. Framework with IoT

Figure 9. Application of IoT among objects

4.3 Conclusion

From the summary of findings, conclusions were derived to restate the study and summarized the main points.
1.) The Human Interface and Vehicular Related risk factors are the two most significant factors to the road traffic safety. These two identified as the most contributor to the accident types: Fatality, Non-Fatality and Damage to Property.
2.) To address the risk factors, IoT will have moderating effect to reduce the risk of the road traffic accidents when this implemented in Metro Manila and later on the urban centers because of its advantage and technology in order to minimize road accidents.

3.) The proposed implementation strategy has challenges on IoT adoption since many stakeholders are from government agencies, riding public, vehicle owners, infrastructure developers and internet (ICT) service providers.

4.4 Future Research and Challenges

1.) Include the study of the road traffic accidents by enumerating the cost damage from its nature of accidents.
2.) Expand the study with the other urban areas that considering volume on high road traffic accidents and target the areas for improvement.
3.) Thorough advanced research on IoT that will address other risk factors to reduce road traffic accidents.
4.) Further study on the effects and impact of IoT in relation to the implementation of the road and traffic rules by the government and the support needed from the private ICT providers.

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Biographies

Ryan M. Paradina is a project engineer of camera manufacturing site 3, under the automotive camera department of Integrated Micro-Electronic Inc. (IMI), a wholly-owned subsidiary of Ayala Corporation currently ranking as the 5th largest EMS provider in the world per New Venture Research. As a project engineer, he handles requests for quotation (RFQ), development and implementation of qualification plans to increase yield, meet reliability and manufacturing requirements, BOM creation/updating, execution and set up of ECO, management of technical and schedule risks to minimize potential problems, planning, execution and analysis of productivity and quality improvements to exceed customer satisfaction indicator, resolution for non-conforming products, interaction with customers and identification of business development opportunities. He has more than 10 years of experience as an engineer, easily spread out from being a test product engineer to component engineer and, finally, as a project/program engineer of Amkor Technology Philippines, Emerson Electric Asia, and IMI, respectively. Mr. Paradina earned his BS Electronics and

Communications Engineering degree from Mapua Institute of Technology (now Mapua University) in 2010, and, eventually, obtained his ECE license in April 2011. As an undergrad, he was elected as the Executive Board Chairman of Institute of Electronics and Communications Engineers of the Philippines - Mapua Institute of Technology Chapter (IECEP). Engr. Ryan Paradina is currently finishing his Master of Science in Engineering Management (MSEM) at Mapua University.

Marvin I. Noroña is currently a faculty member at the Mapua University School of Industrial Engineering & Engineering Management and School of Graduate Studies. He earned his BSIE and MBA degrees from University of the Philippines and is completing a Doctor in Business Administration degree at the De La Salle University. Apart from research and teaching, he is into management consulting and training in the areas of sustainability, supply & operations management, production & service systems improvement, strategic planning and management, lean six sigma, and design thinking.