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Remote Immobilizer for Single-Cylinder Engine with Tracking Mechanisms

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Abstract:- Security management is being applied to every equipment that has an economic value. Single-cylinder engine like motorcycle is not exempted among them as it become a necessity nowadays in the form of efficient transportation. This paper developed a prototype that can be integrated in a motorcycle to track and immobilize if it's stolen. Other features had been incorporated to alert the owner of its status including vibration level and current location. Maximum response time of the prototype is 57.97 seconds to acquire its GPS coordinates and acknowledge the command that had been executed. The longer delay between acquisitions of the feedback from the prototype especially when it is moving can be attributed to unnecessary retransmission of data until the mobile device had received it. The android application had effectively integrated the prototype's response to the mapping engine. The prototype had been perceived with high effectiveness based on their evaluation.

I. INTRODUCTION

The affordability of single-cylinder engines enables the common people to acquire such engines for various purposes. One of the common applications of these engines is the motorcycle. nowadays, the use of it becomes a basic mode of transportation due to smaller engines and better fuel efficiency than the cars. And, the platform size of these motorcycles enable to take advantage and maximizing the parking areas.

The Philippine motorcycle industry continued to race past other markets in Southeast Asia, posting the fastest growth last year. Data from the ASEAN Automotive Federation showed motorcycle sales in the country zoomed 34 percent to 1.14 million units in 2016, overtaking Singapore, which registered a 12 percent growth in sales. Thailand followed with a six percent increase in sales. Malaysia posted a four percent year-on-year growth in sales while sales in Indonesia fell seven percent.

Factors that would drive growth are the need for increase mobility and affordable financing. Using motorcycles as a means of transport is economic and sensible than using public transport in the long run, at least for the next four years or so. MDPPA said there remains a big room for the industry to grow as the motorcycle ratio in the Philippines is still low compared to some countries in the region. Last year, motorcycle production in the Philippines rose 31 percent to 1.04 million units, according to data from the ASEAN Automotive Federation.

However, due to higher value of the vehicles in the trading nowadays from one person to another, crime related on motor vehicles arises. Popular and expensive brand or not, despite being locked in your garage, your motorcycle can still be snatched. The study of Tremblay [1] supports that stealing vehicles becomes an aggregated crimes from 1974-1992. The complexity of behavior of the perpetrators and offending activities results to an innovative way of the said crime. Police reports iterates that the stolen vehicles had been purposively for resale or production of subset or spare parts to be available with the same model of the vehicles.

This paper intended to address the recommendation as reflected in the dissertation paper of the primary author. Such as using the other Subscriber Identity Module (SIM) to the prototype, utilizing other microcontrollers to process data from the sensors connected. Utilization of other microcontrollers aims to include the processing Global positioning coordinates between two points as it had not included in the previous development due to time constraints and testing.

II. OBJECTIVES OF THE STUDY

1. Test the functionality of the prototype based on its performance along:

a. start/reboot time
b. Current dissipations
c. GPS coordinates acquisition
d. data walk-time between mobile device and prototype.
2. Test the effectiveness of the prototype in terms of the following metrics of
a. TEEPS
b. ISO 9126

III. CONCEPTUAL /OPERATIONAL FRAMEWORK

The conceptual framework of the study shows the interconnection of operations between the prototype and the user along its operations. The figure below illustrates the prototype operations.

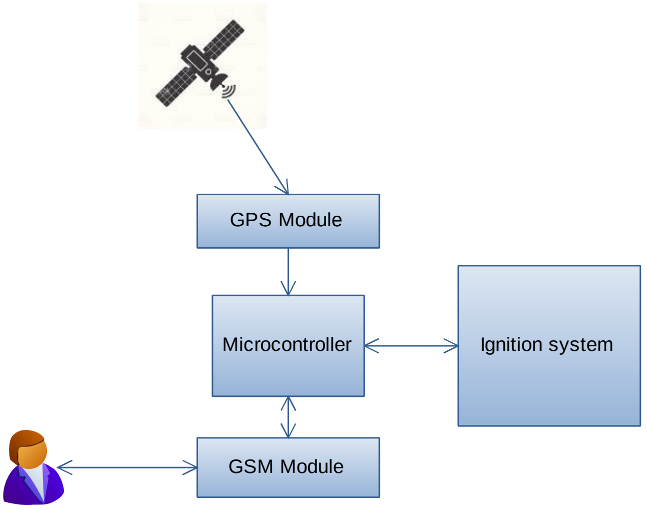

Figure 1. Operational Framework of the Study

The ignition had been partially controlled by the prototype depending on the conditions set in the microcontroller configuration. This configuration can be remotely triggered by the owner for immobilization or it can be automatically triggered if the lock mode has been invoke by owner to prevent jacking the motor vehicle. Hence, the integration of hardware and software to have an automated control over the prototype would improve then efficiency of handling the prototype such as memorizing the commands and the like(Daley and Wu[2]). Nevertheless, the prototype had been installed inside the motor vehicle in a discreet location to prevent tampering.

Proposed Circuit Implementation for the Module Development

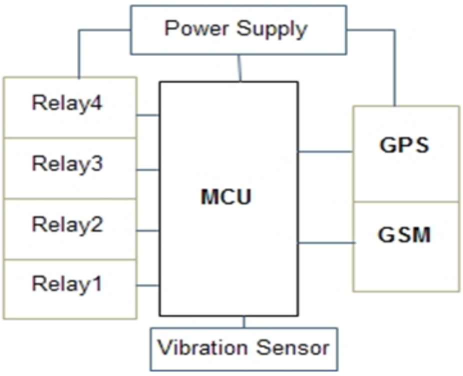

Figure 2: Prototype Block Diagram

The integration of components of the prototype were is shown in the figure #2 as block connections. The microcontroller (MCU) is an Arduino board based on Atmel 328P chip, which is intended to process all the commands to the other modules. The MCU also deliberately interact with the other modules in case the command is triggered externally such as SMS. Modules like vibration sensor and GPS sensor provides data to the MCU that should be processed to correctly interact with the relay modules and send data to GSM. Hence, GSM module serves as the communication link between the device and the end-user. SIM card that should be used by the end-user and the prototype should be of the same network, if possible, in order to minimize the delay of SMS transfer between telecommunication networks.

All these component modules were being powered up by a Lithium-base battery pack which is consist of two output USB ports that can directly supply a current to the MCU and GPS/GSM modules up to 2A. The battery pack has a capacity of 10,050mAh or 10.05Ah. Hence, the total power that in can supply to the prototype to achieve the optimal operation is approximately at 20.1W. However, since the battery pack is a Lithium-ion based it can have a power conversion efficiency of more or less at 80%.

IV. RESEARCH METHODOLOGY

Research Design

This study utilized the descriptive-developmental design to attain its objectives. The developmental method had been utilized for the design and construction of the device/prototype. Hardware design undergo an iterative process to maximize the performance for its operational standards as may be required by the consumers. However, the driver/software accompanied by the hardware had undergo the incremental design and development as it heavily relies on the efficiency of the hardware design and operations.

Respondents

The prototype had been tested and evaluated by the following participants but not limited to students, professors, motorcycle service technicians, professional motorcycle riders. And, IT experts who directly test the application software and its communication to the prototype.

Data Collection Procedure

The prototype had been evaluated using the questionnaires along ISO 9126 and DOST Assessment Technology Protocol using TEEPS. The first one is an international standard evaluation for the quality of software that were installed in the prototype as perceived by the respondents. Hence, the latter one is an standard evaluaton for technology developments that was developed by the Department of Science and Technology (DOST) to determine the technical feasibility, economic viability, environmental soundness, political acceptability, and social acceptability of the prototype.

The installation and operation of the prototype had been demonstrated to the respondents to experience the actual process of it. Along with it, the questionnaires had been personally administered to the respondents to maximize the rate of data collections and to attend some inquiry for some clarifications about the instrument or along the prototype. The data collected had been tallied and summarized for statistical treatment using the appropriate statistical tool based on the nature of the data.

V. DATA ANALYSIS

The data collected along the different criteria such as accuracy in location tracking, response time of the prototype, and stability of the operations had been the basis of prototype operation's efficiency. The objectives along the performance analysis such as its functionality, it employed statistical test were standard deviations and coefficient of correlation to determine the closeness of the values in the data set. The incremental updates of the data collected serves as the basis for different configurations and settings of sensors to attain the optimal configurations of the prototype.

The data that had been collected from the survey questionnaire had been tallied and summarized using descriptive statistics. The perceived effectiveness of the prototype by the respondents were derived using the average weighted mean for each indicators. And, to describe the results along perceived effectiveness, the following description for the scale were utilized:

Adjectival Description to Assess the Application Software (ISO 9126)
4.20-5.00 Highly Functional / Reliable / Usable / Efficient / Maintainable / Portable
3.40-4.19 Very Functional / Reliable / Usable / Efficient / Maintainable / Portable
2.60-3.39 Functional / Reliable / Usable / Efficient / Maintainable / Portable
1.80-2.59 Moderately Functional / Reliable / Usable / Efficient / Maintainable / Portable
1.0 -1.79Poorly Functional / Reliable /Usable / Efficient / Maintainable / Portable

Adjectival Description to Assess the Prototype (TEEPS)

4.20-5.00 Highly Durable / Safe / Accurate / Precise / Economically Viable / Environmentally Sound / Politically Stable / Socially Acceptable
3.40-4.19 Very Durable / Safe / Accurate / Precise / Economically Viable / Environmentally Sound / Politically Stable / Socially Acceptable
2.60-3.39 -Durable / Safe / Accurate / Precise / Economically Viable / Environmentally Sound / Politically Stable / Socially Acceptable
1.80-2.59 Moderately Durable / Safe / Accurate / Precise / Economically Viable / Environmentally Sound / Politically Stable / Socially Acceptable
1.0 -1.79Poorly Durable / Safe / Accurate / Precise / Economically Viable / Environmentally Sound / Politically Stable / Socially Acceptable

Functionality Performance of the Prototype along:

A. Start/boot time

This section describes the start-up time of the prototype which refers to powering on the prototype until it is ready for external commands that usually triggered by the end-user through its application installed in the android phone. As the prototype starts to start up, it provide the status and the module that is being tested between each stage of boot up process until it inform the end-user through SMS that it is now ready to accept a dynamic commands. Hence, these dynamic commands be sent to the prototype either through manual transmission using SMS or using the android application. Furthermore, a series of data collection of start-up time of the prototype at different trials had been summarized in the table 1.

Table 1. Start-up time of the prototype

Trial Number	Total Start up time(s)
1	94
2	101
3	90
4	87
5	95
6	80
7	88
8	88
9	87
10	78

The prototype had been tested only on telecommunication network, hence, the data collected had been further tested to determine the closeness of the values in the data set. Statistical results on the data set had been tested with standard deviation as shown in the Table 4.

As shown in table 4, data sets shows a standard deviation of 6.81175 based on the mean value of 88.8 on its data set. However, to determine the closeness of the data sets for each values, coefficient of variation(CV) had been computed such as

$$CV = \frac{SD}{Mean} = \frac{6.81175}{88.8} = 0.077$$

As a rule of thumb, if CV is larger than 1.0 it indicates that variation between values is large, otherwise, it is small. Furthermore, based on the computed CV it proves that the start-up times of the prototype were closer to each other. Nevertheless, its variations of values in the data set are statistically negligible.

Table 2. Descriptive Statistics on Start-up Time

	N	Mean		Std. Deviation	Variance
	Statistic	Statistic	Std. Error	Statistic	Statistic
start_up_time	10	88.8000	2.15407	6.81175	46.400
Valid N (listwise)	10				

In addition, based on the statistical test the prototype start-up time is indicated as 88.800 ± 2.15407. Therefore, its minimum start-up time is 86.64593 seconds and the possible maximum value is 90.95407 seconds.

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B. Current Dissipation

The prototype is consist of four modules that interactively responses to each other depending on the commands where it was originated. However, each module requires current to process each command either it is an external trigger such as SMS command or internal trigger raised by the vibration sensor. Based on the specifications of the modules, their current dissipations were summarized in the Table 3.

Table 3. Current Dissipations of Components/Modules

Module Name	Average Current Dissipation*
Arduino Uno(MCU)	55mAh
GSM/GPS Module	24mAh
Relay Module	13mAh
Vibration Sensor	15mAh
Total	107mAh

*current measurement is based on module specifications during operations

As shown in the table the prototype draws a total of 107mAh in full operation. However, the full operation of the prototype occurs only when the MCU processed the commands. Nevertheless, the other modules or components were in sleep mode when there is nothing to process, thus decreasing the power consumption. Instead, the MCU is in full operations all the time to monitor changes in some components of the prototype like the vibration sensor and the GSM/GPS module. Furthermore, during sleep mode the amount of current that being draws from the power supply of the prototype is equivalent only to power dissipation of the MCU or 55mAh. Thus, the power bank as the main supply of the prototype would have an estimated running time as computed

$$\text{Running Time}=\frac{10{,}050mAh}{107mA}=93.92\text{hours}$$

However, since the battery pack is a lithium-based thus it power conversion efficiency is more or less at 80% or approximately the full charge of the battery pack would last up to 75.136 hours of full operations. On the other hand, during sleep mode it would approximately last for 182 hours. This type of batteries pack has a high stability on charging and discharging cycle(Xu[3]), thus it can supply enough power that is needed by the prototype to achieve it required functionality.

C. Acquisition of GPS Coordinates

The standard of GPS coordinates that may be acquired by any end-users were composed of the different part in every data sentence which includes latitude, longitude, time, altitude, directions, correction factors, etc. However, this study, it only parses the latitude and longitude of the data sentences that being feed from the satellites that the prototype is in contact. The collected data of acquired GPS coordinates for every position were presented in the succeeding tables to determine the precision of the prototype in acquiring GPS coordinates. The prototype is held as stationary to acquire GPS coordinates that have a high reliability. The correctness of the GPS coordinates that had been acquired by the prototype is if it report that its velocity is equivalent to zero (0). As shown in the Table 4, there were five trials reported that the velocity of the prototype to be stationary or equivalent to zero(0).

Table 4. Acquired GPS Coordinates of the Prototype

Trial	Latitude	Longitude	Velocity
1	12.976592	124.007073	0.060000
2	12.976575	124.007080	0.040000
3	12.976553	124.007075	0.060000
4	12.976552	124.007077	0.020000
5	12.976515	124.007043	0.070000
6	12.976545	124.007068	0.020000
7	12.976543	124.007068	0.020000
8	12.976540	124.007063	0.040000
9	12.976540	124.007063	0.020000
10	12.976540	124.007063	0.040000
11	12.976507	124.007075	0.060000
12	12.976507	124.007075	0.000000
13	12.976507	124.007075	0.020000
14	12.976507	124.007075	0.060000
15	12.976507	124.007068	0.020000
16	12.976508	124.007067	0.000000

Trial	Latitude	Longitude	Velocity
26	12.976510	124.007070	0.020000
27	12.976520	124.007078	0.070000
28	12.976517	124.007083	0.020000
29	12.976522	124.007080	0.040000
30	12.976522	124.007080	0.040000
31	12.976520	124.007080	0.000000
32	12.976522	124.007075	0.060000
33	12.976522	124.007075	0.020000
34	12.976520	124.007082	0.020000
35	12.976518	124.007082	0.020000
36	12.976518	124.007080	0.020000
37	12.976518	124.007080	0.020000
38	12.976510	124.007078	0.020000
39	12.976510	124.007078	0.020000
40	12.976517	124.007070	0.040000
41	12.976518	124.007063	0.000000

17	12.976510	124.007067	0.020000
18	12.976510	124.007067	0.040000
19	12.976510	124.007067	0.020000
20	12.976510	124.007068	0.040000
21	12.976510	124.007068	0.040000
22	12.976510	124.007068	0.040000
23	12.976510	124.007068	0.040000
24	12.976510	124.007068	0.040000
25	12.976515	124.007078	0.020000

42	12.976518	124.007065	0.040000
43	12.976520	124.007065	0.070000
44	12.976517	124.007062	0.040000
45	12.976515	124.007072	0.020000
46	12.976515	124.007070	0.020000
47	12.976515	124.007070	0.020000
48	12.976513	124.007070	0.020000
49	12.976513	124.007072	0.000000
50	12.976513	124.007072	0.020000

Since the prototype relies on raw GPS coordinates based on the available number of GPS in the area. Basically, these values were based on the trilateration procedure for every GPS receivers. Each GPS receivers have the capability to correlate the GPS signal based on at least three satellites reference to calculate its geographical location (Rodal,et. Al[4]).

As a result, the prototype reported a different values of GPS coordinates. However, statistically testing the GPS coordinates values such as latitude and longitude, it yield the following results as shown in the Table 5.

Table 5. Descriptive Statistics of GPS Acquisition

	N	Mean		Std. Deviation	Variance
	Statistic	**Statistic**	**Std. Error**	**Statistic**	**Statistic**
Latitude	50	12.97652112	.000002477	.000017518	.000
Longitude	50	124.00707158	.000001018	.000007200	.000
Valid N	50				

As shown in the table, latitude and longitude values have a standard deviation of 0. 000017518 and 0.000007200, respectively. These values indicates that the GPS coordinates that were acquired as held as stationary were closer to each values in the data set and the standard mean. The variation of these acquired coordinates in one place may be also attributed to changing line-of-sight with the reference satellite and some attenuated GPS signal when the communication is slightly or completely block by the surrounding building(Lachapelle[5]). Furthermore, these results suggest that these values will be mapped on the same point using the mapping engine that is accompanied in the android application.

D. Data walk-time between mobile device and prototype.

The walk-time of the data between devices refers to the total response time that were accumulated starting from the android phone request until the prototype's response to the android request. The results of this test simulate the speed of responses between mobile request and prototype's responses. The communication protocol between these devices relies on Global System for Mobile Communication(GSM) frequency, the response time of the prototype should be measured in different conditions such as speed and location to determine the base performance(Alanko[6]). Since, these devices were utilizing the nearest cellular sites for communication, bottlenecks such as network users and data traffic in every base station may cause a disruptions or delay of responses between them. The table below is the sample data collection from the prototype response.

Table 6. Sample of Data collection from the Prototype's responses

Trial#	**Response Time(s)**	**Speed(kph)**	**GPS-Lat**	**GPS-Long**	**Distance from Origin(m)**
1	15.85	0.00	12.973257	124.007950	0.00
2	18.47	24.67	12.975045	124.009700	274.18
3	16.83	25.09	12.976213	124.012082	554.91
…	…	…	..	…	…
99	38.26	21.45	12.972730	124.003760	458.32
100	15.62	21.84	12.976673	124.013130	677.25
101	13.36	26.59	12.976913	124.014448	812.79

As seen from the table, there were total of 101 trials for data collection with varying speed at different locations. The data walk time of responses between these devices is shown in the column named Response Time that is measured in seconds. Hence, the prototype starts at a specific GPS coordinates labelled at Trial #1 with a corresponding response time of 15.85 seconds. The Trial #2 indicates that the prototype already started to mobilize, where it responses its speed and GPS coordinates. The distance from the original GPS location(Trial #1) is computed using the modified haversine equation for computing distances between GPS coordinates using the data on WGS-84 standards. The mobile device serves as the terminal that request the current location of the prototype and its speed as it mobilize within the specified GPS coordinates that were specified in the table.

The value of computed distances is shown in the column name Distance from origin measured in meter. The visual comparison between speed and response time of the prototype is shown in the figure 3. Data points between the two variable does not shows any coherency or pattern that would conclude their relationship. Hence, the figures entails that the two variables were not directly related. Hence, the total response time cannot be directly attributed to the distance of the prototype from its original location. The delay of responses of the any mobile terminal cannot be directly transferred mobile terminal, however, cellular network sites should handover the data to the nearest cellular tower(Hornfeldt, J., & Rinnback, L.[7]). In addition, the determination of the current location of the prototype as it mobilize cellular towers need to completes its signal ranging by fusing the measured data in terms of decibels(dBm) (Camp[8]). As a results, the hand-over of data always connect to the cellular tower sites with lowest dBm. Thus, sending back and forth the response data between these devices might cause the delay despite of its current location and respective distances from its original location.

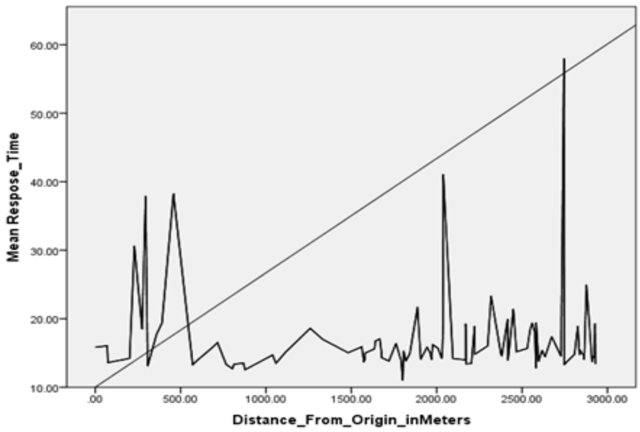

Figure 3: Response Time vs. Distance from the Origin

Along with the included variables in the data collection is the speed of the prototype during the mobilization. The data along the speed of the prototype and the response time of the prototype had been plotted as shown in Figure 5. The response time of the prototype held as dependent to the speed of the prototype, the latter considered as the independent variable.

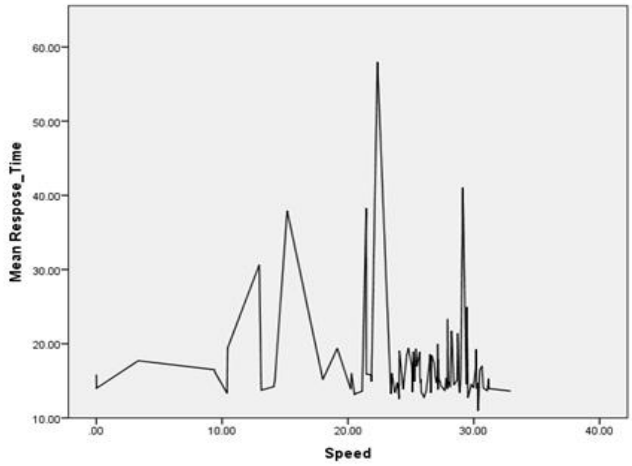

Figure 4: Response Time vs. Prototype's Speed

As shown in the figure 4, the variation of speed incurred by the prototype does is not consistent with the data points along the response time between the start of the mobile device request and prototype's response. Furthermore, the independent variable is not enough to conclude that it is the cause of the dependent variable such as the response time. The results of the plotted data indicates that as the prototype continuously mobilize, its GSM module signal strength continuously changing also and its distances between transceiver cellular tower sites changes as well. As a result, the response time of the prototype varies for each request on its specific location and speed (Innes[9]). In addition, the changes in location due to varying speed, both cellular tower sites and mobile terminal creates unnecessary retransmission causing the performance to slow down and increases time for the rate of data transfer (Korhonen, et. Al[10]).

Table 7 presents the statistical treatment to determine the association between response time along its controlling variables such as speed of the prototype and its distance from the origin of the prototype. it uses the bivariate correlation to determine the extent of association between these variables.

Table 7: Statistical Treatment for Data Collected on Response Time

Correlations			
Statistical Bases			Respose_Time
Kendall-Tau	Speed	Correlation Coefficient	-.106
		Sig. (2-tailed)	.118
		N	100
	Distance_From_Origin_inMeters	Correlation Coefficient	.037
		Sig. (2-tailed)	.581
		N	101
Spearman's rho	Speed	Correlation Coefficient	-.138
		Sig. (2-tailed)	.171
		N	100
	Distance_From_Origin_inMeters	Correlation Coefficient	.052
		Sig. (2-tailed)	.606
		N	101
Correlation is significant at the 0.05 level (2-tailed).			

As shown in the table, the results of statistical treatment verifies the association of prototype's response time and speed of it during mobilization test. The statistical test suggests that the response time and speed of the prototype were not directly associated. Hence, significant value (sig) for each statistical tool were greater than the significant level of 0.05, which suggests that there is no direct association between these variables. Nevertheless, it is considered that there is/are other factors/s that may attribute to the response time values of the prototype such as positional and elevation accuracy can contribute to these variation of values.

Table 7 also proves that the prototype's response time and its distance from the origin yield a numerical value of significant value which is greater than the significant level of 0.05, which is 0.581 and 0.606 for Kendal-tau and spearman's rho, respectively. This results suggests that there is no direct association between these variables. Furthermore, it should consider other variables to support the values in the response time of the prototype.

Table 8 shows the perceived technical performance of the prototype in terms of the following indicators such as safety of operation, precision of design, durability of the parts, and speed and accuracy .As shown, safety of operation yield a weighted mean of 4.66 which is interpreted as highly safe.

Table 8. Level of Technical Performance

TECHNICAL PERFORMANCE	Weighted Mean	Interpretation
Safety of Operation	4.66	Highly Safe
Precision of Design	4.65	Highly Precise
Durability of the Parts	4.64	Highly Durable
Speed and Accuracy	4.57	Highly Accurate

This result may be attributed to the situation that the respondents were initially oriented in terms of precautionary measures along its integrations such as basic connections of the prototype in the existing electrical system of the motorcycle to prevent short circuit, damage to the prototype, and the vehicle accessories. This also implies that the evaluators did not find any risk when the product was installed, demonstrated and tested in the motorcycle unit and there was no observed failure during this phase of the study. The safety instructions were presented during the actual demonstration and it is also indicated in the installation and operational manual to prevent related electrical-related accident and damage to the prototype as well (Lewis[11])

The precision of the design got the weighted mean of 4.65 which describes as highly precise according to its design. The prototype attained the precise electrical voltage and current values that utilized by the motorcycle by tapping only one line within its electrical nodes. The electrical wire that had been utilized could either be the negative or positive line depending on the choice of the technician as it may depends on the brand or model of the motorcycle in connecting the terminal wires from the relay modules of the prototype. On the other hand, the GPS coordinates that being supplied from the satellite feed that being interpreted by the mapping engine in the android application is within the acceptable tolerance error by the respondents during the actual testing of the prototype. The study of Wang[12] suggests that experimentation of design may lead the prototype within the acceptable range of tolerance of the end-users. That implies that the GPS values that being presented to the end-users is within the acceptable marginal error. As such, effective design in the case of prototyping may only achieved if it is subjected to a series of experimentation or trials, thus marginal errors may reduce including its correction factors that may be embedded in each design or model (Saqib[12])

As perceived by the respondents, the durability of the prototype yields a weighted mean of 4.64, which is interpreted as highly durable. This results may be attributed to actual demonstration that respondents were allowed to inspect the module installed in the prototype. As seen, most of its components or parts were properly screwed in plastic fibers which is made of acrylic sheet with non-conductor spacers to avoid short circuits that may damage the modules and electronic parts. Component modules were firmly attached and tightly enclose in a transparent box for the purpose of demonstration. The squared grooves and angle of the casing was made using the CNC machine to achieve precise dimensions and prevent from breakage during assembly and actual testing of the prototype due to excessive vibration that it may experience as it is installed. Hence, optimal settings of the component modules and dimensional accuracy of the casing could ensure the durability of the whole prototype, in general.

In terms of speed and accuracy, the prototype yield an average weighted mean of 4.57 based on respondents' perception, which is interpreted as highly accurate. This results may be attributed to the condition that the user commands is being acknowledged and executed by the prototype as it should. Hence, the prototype's acknowledgment is a form of feedback mechanism by the prototype to confirm that is already ready to execute the commands that had been received from the user's android phone. In addition, satellite data along GPS coordinates may pose a marginal error of about 0.5 meter to 1.0 meter, but still the motorcycle is within the visual contact of the respondents. Thus, this error may be considered within the tolerance of the respondents (Taft[14]). On the other hand, the speed of data transmission from the user's android phone may vary from one location to another since its commands is being transferred from one cellular sites to another until it received by the prototype. The prototype had been tested with different conditions such as time of testing, hot and cold restarting of the prototype to determine its speed of data transmission until the commands had been received by the prototype. As a results, algorithms in the prototype had been optimized to properly acknowledge and executed the commands.

Table 9 shows the perception of the expert evaluators and potential owners regarding the maintenance costs and its affordability in purchasing, licensing and maintenance or replacements of parts.

Table 9. Level of Economic and Financial Viability of the Device.

ECONOMIC VIABILITY	Weighted Mean	Interpretation
The cost of licensing for each prototype unit is appropriate as to the safety of the motorcycle	4.64	Highly Economically Viable
The cost of the prototype is appropriate to the listed features of it.	4.59	Highly Economically Viable
The cost of the maintenance /replacement is affordable	4.50	Highly Economically Viable

As perceived, indicator such as the cost of licensing for each prototype unit is appropriate as to the safety of the motorcycle yield an average weighted mean of 4.64 that is interpreted as highly economically viable. The estimated cost of licensing of the prototype along its monthly communication cost that being consumed by the SIM card during its transmission of data as per request by the end-user. However, their monthly cost is highly economically viable since telecommunication networks offers lower data rates as compared when it comes to safety and cost of the motorcycle (Pollock, et. al,[15]) which this reason could be attributed to this result. On the other hand, since the purpose of the prototype is along security management, the operational licensing should be monopolize by the author to prevent unauthorized commands to the prototype from the other network subscriber (Saracho[16])

The cost of the prototype is highly economically viable based on its average weighted mean of 4.59 as perceived by the respondents. The availability of the components module in the market makes the cost of the prototype and cheaper cost of fabrication makes the total cost of it to be much cheaper (Malhi[17]). However, the cost of the prototype as compared to the security that it may be offered with the unit cost of a motorcycle is very much cheaper if it had been stolen. Hence, the cost of the prototype is only fraction of the total cost of the each motorcycle unit (Kelnar[18]).

Respondents' perceived rating of the prototype along its cost of maintenance and replacement of the parts yield an average weighted mean of 4.50, which is interpreted as highly economically viable. Since this prototype is along security management, to prevent the disclosure of the wiring system from the prototype and the motorcycle itself, the researchers may solely perform the maintenance and replacement of the defective part. Henceforth, the high availability and stability of these low-cost component modules in the market makes the replacement and maintenance cost along its defective parts to be much cheaper causing a rapid testing and implementations of newly installed components (Rector[19]).

Table 10 presents the respondents' perception along the level of environmental soundness of the device. As perceived by the respondents, indicator such as the prototype does not emit adequate heat that can be considered as thermal pollution yield an average weighted mean of 4.86, which is interpreted as highly environmentally sound. This implies that the prototype does not create any thermal variation in the surroundings that may increase the temperature within the motorcycle unit.

Table 10. Level of Environmental Soundness of the Device.

ENVIRONMENTAL SOUNDNESS	Weighted Mean	Interpretation
The prototype does not emit adequate heat that will be considered as thermal pollution.	4.86	Highly Environmentally Sound
The prototype will not cause any form of disruption to rate of combustion of the engine.	4.82	Highly Environmentally Sound
The prototype does not emit electromagnetic waves that will pose a threat to the owner of the motorcycle	4.73	Highly Environmentally Sound
The frequency that is being used to send data between the motorcycle and the mobile device does not pose a threat to human health.	4.73	Highly Environmentally Sound

Indicator such as the prototype will not cause any form of disruption to rate the combustion of the engine yield an average weighted mean of 4.82, which is interpreted as highly environmentally sound based on the respondents' perception. This result implies that the prototype operation does not disrupt the rate of combustion of the engine, since, it only target the electrical system of the motorcycle. Henceforth, it could only trigger the stoppage of the engine during immobilization process but it will not interfere with the rate of combustion of the engine or its rate of fuel efficiency.

Indicators such as it does not emit an electromagnetic waves that will pose a threat to the power of the motorcycle, and frequency that being used to send data between motorcycle and mobile device does not pose a threat to human health had been perceived with an average weighted mean of 4.73 and interpreted as highly environmentally sound. The mobile device and the prototype were operating at the same frequency. The frequency that being utilized by the cellular sites is within safe limits in terms of data transmission that will be utilized for public communications. Thus, its frequency and its related electromagnetic waves will not pose a threat to human health nor the operation of the motorcycle. In addition, the heat generated from the electromagnetic waves isn't enough to produce energy that can start a fire to the gasoline tank of the motorcycle.

Table 11 presents the respondents' perception of the prototype along the political stability. One of its indicators is that the prototype does not violate any laws along operational standards. This indicator yield an average weighted mean of 4.50, which is interpreted as highly politically stable. This result may be attributed to the condition that as of this time, there were no existing laws that will control the operational standards of these modules in terms of industrial integration or any kind. However, it is ideal enough for rapid prototyping and proof of concepts for industrial applications.

Table 11. Respondents' perceptions on the prototype along the political stability

POLITICAL STABILITY	**Weighted Mean**	**Interpretation**
The prototype does not violate any laws along operation standards	4.50	Highly Politically Stable
The frequency that being utilized by the prototype does not violate any government standards regarding wireless communications.	4.50	Highly Politically Stable
The component installed or utilized does not violate any standards set by the Federal Communications Commission.	4.45	Highly Politically Stable

In addition, respondents' rating in the indicator such as the frequency that being utilized by the prototype does not violate any government standards regarding wireless communications yield an average weighted mean of 4.5, which is interpreted as highly politically stable. The result implies that the prototype is operating within the government permitted frequency that is suitable for public utilization. Since, the prototype is only utilizing the frequency provided by the telecommunication cellular sites available in the area it does not violate laws regarding the frequency of data transmission.

Indicator along the component installed utilized does not violate any standards set by the Federal Communications Commission(FCC) yield an average weighted mean of 4.45 and interpreted as highly politically stable. The components modules that were utilized in the prototype were follow the standards of the electronics design as categorized as low-powered materials to minimize the amount of heat that is being generated during its full operations. Thus, as perceived it follows the common standards by the FCC in terms of electronic designs and wireless communications.

Table 12 revealed the social acceptability of the device with the rating indicated as the product is highly socially acceptable. As to the purpose of the device, the pool of evaluators rated it highly socially acceptable with a numerical value of 4.91. The prototype had serves its purpose to secure the motorcycle unit by disabling its electrical system and real time tracking it, in case it will be stolen. As tested during the actual demonstration, auto-alarm and mapping system had catch the attention of the respondents or evaluators in terms of security that being offered by the prototype. Nevertheless, security features of the prototype is a user-driven due to the results of rigid field experiments (Alam[20])

Table 12. Level of Social acceptability of the Device

SOCIAL ACCEPTABILITY	Weighted Mean	Interpretation
The purpose of the prototype serves the security of the motorcycle and the owner	4.91	Highly Socially Acceptable
The presence of tracking mechanism of the prototype to motorcycle does not affect the normal operation of the whole unit.	4.77	Highly Socially Acceptable
It may be operated of any person across gender type.	4.73	Highly Socially Acceptable
The unit cost is reasonable for its purposes that it may serve.	4.68	Highly Socially Acceptable
The deployability or installability of the prototype may be done by most of the technicians of motorcycles.	4.55	Highly Socially Acceptable
The prototype does not have the ability to disclose the location of the motorcycle to any device.	4.50	Highly Socially Acceptable

The presence of the tracking system does not affect normal operation of the motorcycle was assessed by the evaluators as highly socially acceptable with a rating of 4.77. The tracking mechanism of the prototype operates at 1,575MHz on its frequency, thus it will not directly affects the GSM module either through jamming or massive interference. Hence, the frequency of both modules would not directly affect the operations of the motorcycle itself. Nevertheless, these component modules were compliance with FCC regulations or with their operational frequency were allowed by the government.

Indicator such as it may be operated of any person across gender type yield an average weighted mean of 4.73, which interpreted as highly socially accepted. This result implies that its features and functionality of the applications were directly presented to the screen of the android phone. Hence, the wide coverage of familiarity of every age in the operation of android-based and iOS-based smart phones, the user interface and terms becomes a self-explanation for the respondents along its purpose of each features presented.

The unit cost is reasonable for its purpose that it may serve as it yield an average weighted mean of 4.68 based on respondents rating. The rating of this indicator is interpreted as highly socially acceptable. The ability of the device to interact with the existing electrical system of the motorcycle and its integrations of GPS coordinates on end-users phone may be attributed to this result. In addition, the security features that being offered by the prototype is reasonable enough for its cost as compared to the cost of a motorcycle unit if it will be stolen.

As observed by the technicians as evaluators, the deployability or installability of the prototype can done by most of the technicians of motorcycles yield an average of 4.55. The numerical rating for this indicator is interpreted as highly socially acceptable. As observed by the technicians as evaluator of the prototype during the actual demonstration on installation, the prototype may be installed by any technicians in any model or brand as long as there is a space provision to the size of the prototype. However, to increase the security management of the prototype, the technicians that will install the prototype will depends on their skills to conceal the connection of wires between the prototype and the electrical systems of the motorcycle. Therefore, the installation of the prototype required an utmost familiarity of the technician in the existing electrical wiring of the motorcycle.

The least numerical rating among these indicators is the prototype does not have the ability to disclose the location of the motorcycle to any device yield an average weighted mean of 4.50, which is interpreted as highly socially acceptable. this result may attributed to the condition that since the prototype is working with GSM module that requires SIM card, the SIM card number cannot be disclose to other persons. Hence, the prototype will respond only to the designated number that is pre-encoded to the algorithms of the microcontroller. Therefore, the location of the motorcycle unit will be disclose only to the authorized mobile number of the person who owns it.

Table 13 presents the evaluation results of the application software by the respondents along its functionality, reliability, usability, efficiency, maintainability, and portability. As perceived by the respondents, the functionality of the prototype yield an average weighted mean of 4.38, which is interpreted as highly functional. The functionality of the prototype had been rated based with the following metrics such as sustainability, accurateness, interoperability, compliance, and security.

Table 13. Application Software Evaluation

Indicators	**Weighted Mean**	**Interpretation**
Functionality	4.38	Highly Functional
Reliability	3.88	Very Reliable
Usability	4.50	Highly Usable
Efficiency	3.88	Very Efficient
Maintainability	4.13	Very Maintainable
Portability	4.31	Highly Portable

The perception of the respondents that the device is highly functional may be attributed to their observation that the application software in both front-end and back-end were carrying out the required operations according to its purpose during the actual demonstration of the prototype. Hence, the demonstration serves as the theoretical simulation to the prototype to fully understand its functionality where it is being observed or tested by the respondents along its included features (Esbjörnsson[21]). It also indicates that the users experience a minimal design in the application software along its features in controlling the device that were readily available through its front-end application. In addition, the data output of the back-end may be integrated to the front-end application for better presentation such as GPS Coordinates and response of the prototype along its operational status. Furthermore, an observed security of the application software between front-end and back-end were observable and manifested in the two-factor authentication to login in the front-end application to initiate communication to the back-end application installed in the prototype.

The reliability of the prototype yield an average weighted mean of 3.88, which is interpreted as very reliable. The reliability of the prototype were tested along the following metrics such as maturity, fault tolerance, and recoverability. The maturity of the parts that were used in the prototype were not yet known to be massively used in the industrial applications, however, in this prototype it had been achieved the reliability that is being required in its features. As observed during actual demonstration of the prototype, both front-end and back-end application does not manifest any hang-app or it crashes during its testing. In addition, the full restart of the application software in both front-end and back-end can easily be recovered by restarting either of the two. Hang-app in android application seldom happens since its procedures were systematic as to prevent overlapping commands. In the case of prototype, recovery of normal operations may be triggered by hot restart in case it does not response to commands from the front-end. However, this may happens only if the SIM card had achieved it maximum capacity where it cannot hold new messages as commands from the front-end application. This hardware and software co-simulation is being tested in rigid conditions to determine the synchronicity of the configurations or settings between hardware and software application (Rowson[22]).

The usability of the software in both front-end and back-end application yield an average weighted mean 4.50, which perceived as highly usable. The usability of the application software was evaluated with the following metrics such as understandability, learnability, and operability. As observed, the ability of the front-end application software to be readily usable by the user during actual demonstration could be attributed to this results. It also indicates that end-users do not require further instructions on how to operate the prototype through its front-end application software. Furthermore, end-users could easily understand the functionality of every features presented in the front-end application due to simple terms that had been utilized in the user design for better experience. Furthermore, this results can also attributed to its simple designs that end-users would not require sufficient time to learn all the functionality for each features.

The average weighted mean of efficiency of the prototype yield a value of 3.88 which is interpreted as very efficient. Since the prototype is operating at a frequency of cellular site, its results may be attributed to the respondents' perception that there is an slight delay causing between transmission of commands from the front-end application until it had been acknowledged by the prototype that it had been executed based on its respective algorithms. As manifested in the actual demonstration, the value from satellite feed is being integrated with the map installed in the android phone causing it a slight delay of 15 seconds or less before the gps coordinates may be plotted. Hence, this amount of time delay could trigger a tolerance of any end-user to wait for its display. However, the time delay may be attributed to the low cpu frequency of the android phone and its processor is based on ARM architecture. The slight delay serves as a timing delegations to better achieved the delegation of task between application software such as data processing from its source until it had been acquired by the front-end application software (Gupta[23]). Furthermore, the time delay cannot considered as time constraint for the prototype but it only serves as the gap to efficiently manage the data transfer between the source and the target application software.

The maintainability of the prototype had been perceived as very maintainable which yield an average of 4.13. it had been evaluated with the following metrics such as changeability, stability, and testability. Overall, it have perceived as very maintainable based on respondents' evaluations. This results may be attributed to the evaluators' ability to necessary change the algorithms in both front-end and back-end application software if they have skills required. However, end-users were not allowed to change the main algorithms to prevent installation of unnecessary commands to the prototype that would lead to disclosure of its real time location or unwanted immobilization from any unauthorized users. Since, both front-end and back-end application were tested with different conditions with several trials, the evaluators simply evaluated it with utmost stability based on the actual demonstrations of the prototype. Furthermore, evaluators were given a chance to test the prototype's response based on SMS command which may be attributed also to this results along the maintainability of the prototype.

The portability of the prototype application software had been interpreted as highly portable, which yield an average weighted mean of 4.31, based on the respondents' perceptions. Its portability had been tested with the following metrics such as installabilty and replaceability. This result may be attributed to condition that android application software may be installed in different ways, thus making its front-end application software to be highly portable. In addition, even the algorithms of the prototype may be easily distributed and installed to the prototype. However, the replaceability of the algorithms in both front-end and back-end application software still requires from the original authors to prevent the security leaks of the algorithms, which prohibits the end-users from altering the original functions of the prototype.

The developed prototype achieved it objectives to remotely immobilized the motorcycle. Hence, the recovery of its location after it was immobilized it creates a feedback of regarding its current location for the user to inform its current location through an open source mapping engine that is available to android phones. Other features had been integrated to fully utilize the capability of the modules installed such as vibration sensor, which immobilization can be triggered after it attain a certain intensity of vibration of the motorcycle. Hence, an android application has been develop to address the learnability of every end-user to control the prototype even without the assistance.

The values of GPS coordinates that being feedback from the prototype varies from each request even though the prototype is held stationary. However, each value can be considered as statistically equal since its standard deviation is so small even its coefficient of variation as well. Thus, GPS coordinates would still be mapped in the same place in which the mapping engine cannot identify the deviation of values from the previous values.

On the other hand, the response time of the prototype varies from one location to another. The distance between the prototype and the mobile device that request the status of the device cannot directly attribute to the response time of the prototype. hence, the mobility of the prototype makes some unnecessary retransmission between cellular tower sites to successfully send the message to the mobile device that request its location.

As evaluated by the respondents along TEEPS standard, the respondents find the device to have a highly technical performance, socially acceptable, politically stable, and environmentally sound. Indeed, the prototype's operation only adopts the standards set by the government along digital electronics and global system for communications. Nevertheless, it does not emit any harmful electromagnetic waves that could affect the operation of the motorcycle and the health of the operator. And, the cost of the prototype is within the tolerance of the end-user in terms of motorcycle's security. However, the perception of the evaluators along the software application is not comparable the TEEPS evaluation. As perceived by the evaluators using the ISO 9126, the prototype and the android application still requires improvement.

VI. CONCLUSIONS AND RECOMMENDATIONS

The startup or reboot time of the prototype is within the specifications of the microcontrollers, hence the connected sensors and other passive components only relies to the readiness of the microcontroller to accept and process inputs from these sensors. The current dissipations of all components were configured to its normal operations thus the consumption of energy from the battery pack was estimated to last up to 75.136 hours only. Hence, the acquisition of GPS coordinates still depends on the number of visible GPS satellites before the GPS module can lock its location thru GPS coordinates.

As evaluated by the respondents along TEEPS standard, the respondents find the device to have a highly technical performance, socially acceptable, politically stable, and environmentally sound. Indeed, the prototype's operation only adopts the standards set by the government along digital electronics and global system for communications. Nevertheless, it does not emit any harmful electromagnetic waves that could affect the operation of the motorcycle and the health of the operator. And, the cost of the prototype is within the tolerance of the end-user in terms of motorcycle's security. However, the perception of the evaluators along the software application is not comparable the TEEPS evaluation. As perceived by the evaluators using the ISO 9126, the prototype and the android application still requires improvement. The prototype should be still tested in different single-cylinder engines in which the diagram of installation should be properly documented to prevent damage to the prototype.

REFERENCES

[1]. Tremblay, P., B. Talon, &D. Hurley, (2001). Body switching and related adaptations in the resale of stolen vehicles. Script elaborations and aggregate crime learning curves. *British Journal of Criminology*, *41*(4), 561-579

[2]. Daley, H. and Wu, T. (1980). 'The diffusion of personal computers'. StanfordUniversity, Institute for Communication Research, Stanford CA.

[3]. Xu, J., Chen, Y., & Dai, L. (2015). Efficiently photo-charging lithium-ion battery by perovskite solar cell. *Nature communications*, *6*, 8103.

[4]. Rodal, E. B., Farmer, D. G., & Lau, C. Y. (1997). *U.S. Patent No. 5,594,453*. Washington, DC: U.S. Patent and Trademark Office.

[5]. Lachapelle, G. (2007). Pedestrian navigation with high sensitivity GPS receivers and MEMS. *Personal and Ubiquitous Computing*, *11*(6), 481-488.

[6]. Alanko, T., Kojo, M., Laamanen, H., Liljeberg, M., Moilanen, M., & Raatikainen, K. (1994). Measured performance of data transmission over cellular telephone networks. *ACM SIGCOMM Computer Communication Review*, *24*(5), 24-44.

[7]. Hornfeldt, J., & Rinnback, L. (1999). *U.S. Patent No. 6,006,097*. Washington, DC: U.S. Patent and Trademark Office.

[8]. Camp, W. O. (2001). *U.S. Patent No. 6,252,543*. Washington, DC: U.S. Patent and Trademark Office.

[9]. Innes, G. D., & Bonner, D. (2000). *U.S. Patent No. 6,061,565*. Washington, DC: U.S. Patent and Trademark Office.

[10]. Korhonen, J., Aalto, O., Gurtov, A., & Lamanen, H. (2001). Measured performance of GSM, HSCSD and GPRS. In *ICC 2001. IEEE International Conference on Communications. Conference Record (Cat. No. 01CH37240)* (Vol. 5, pp. 1330-1334). IEEE.

[11]. Lewis, M., &Seeman, S. E. (1973). Performance Experience with Prototype Betacel Nuclear Batteries. *Nuclear Technology*, *17*(2), 160-167.

[12]. Saqib, S., &Urbanic, J. (2012). An experimental study to determine geometric and dimensional accuracy impact factors for fused deposition modelled parts. In *Enabling Manufacturing Competitiveness and*

Economic Sustainability(pp. 293-298). Springer, Berlin, Heidelberg.
[13]. Wang, L., Wang, C., & Liu, J. (2014). Error analysis and prototype testing of deepwater pipe flange connection tool. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, *228*(11), 1978-1993.
[14]. Taft, R. M., Kondor, S., & Grant, G. T. (2011). Accuracy of rapid prototype models for head and neck reconstruction. *The Journal of prosthetic dentistry*, *106*(6), 399-408.
[15]. Pollock, N. R., Rolland, J. P., Kumar, S., Beattie, P. D., Jain, S., Noubary, F., ... & Whitesides, G. M. (2012). A paper-based multiplexed transaminase test for low-cost, point-of-care liver function testing. *Science translational medicine*, *4*(152), 152ra129-152ra129.
[16]. Saracho, A. I. (1997). *The implications of intertemporal consistency for patent licensing*. Universidad del País Vasco.
[17]. Malhi, K., Mukhopadhyay, S. C., Schnepper, J., ke, M., & Ewald, H. (2012). A zigbee-based wearable physiological parameters monitoring system. *IEEE sensors journal*, *12*(3), 423-430.
[18]. Kelnar, M., Martinek, R., Machacek, Z., Vanus, J., Bilik, P., & Zidek, J. (2016). Realization of prototype of a low-cost bidirectional communication system through fibreless optics. *Wireless Personal Communications*, *91*(1), 137-150.
[19]. Rector, J. (1998, May). Economic and technical viability of integral passives. In *1998 Proceedings. 48th Electronic Components and Technology Conference (Cat. No. 98CH36206)* (pp. 218-224). IEEE.
[20]. Alam, M., Yang, D., Rodriguez, J., &Abd-Alhameed, R. A. (2014). Secure device-to-device communication in LTE-A. *IEEE Communications Magazine*, *52*(4), 66-73.
[21]. Esbjörnsson, M., Juhlin, O., & Östergren, M. (2002, December). The hocman prototype-fast motor bikers and ad-hoc networking. In *Proc. of MUM*.
[22]. Rowson, J. A. (1994, June). Hardware/software co-simulation. In *31st Design Automation Conference* (pp. 439-440). IEEE.
[23]. Gupta, R. K., & De Micheli, G. (1993). Hardware-software cosynthesis for digital systems. *IEEE Design & test of computers*, *10*(3), 29-41.