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MODELING OF ROAD TRAFFIC CRASH COUNTERMEASURES IN OGUN STATE

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ABSTRACT
Road traffic crash is a global concern and Nigeria is not left behind. In 2016, 387 Road Traffic Crashes were recorded in Ogun State out of which 279 persons were killed and 1366 were injured The aim of the study is to develop a model for describing road traffic crash countermeasures in Ogun State. Questionnaire on existing safety measures which involved 8 questions were administered to 240 respondents drawn from six of the twenty LGAs of Ogun State. A multivariate regression model was developed for describing road traffic crash countermeasures. The model revealed that all the countermeasures contributed positively to the overall level of road traffic crash control. Maintenance of road network with positive regression parameter of 1.0610 contributed most to the overall reduction in road traffic crash in the study area. It is therefore concluded that more attention should be channeled towards road maintenance and rehabilitation in Ogun State.

Keywords: *Countermeasures, crashes, road network, road maintenance.*

1. INTRODUCTION

Road traffic crash (RTC) is one of the causes of preventable injuries and death globally. World Bank revealed that road traffic accident cost 1-2 % of the gross national product (GNP) of developing countries, or double the aggregate sum of advancement received worldwide by developed nations [1].

This research is specially targeted to draw the attention of road traffic/safety regulatory agencies in Ogun State on the need to develop sustainable and reliable mitigating strategies to meander recurrent road crash cases across road networks in the state. Around 1.2 million people died annually worldwide as a result of road fatalities and Injuries. These unfortunate casualties possess 30-70% of orthopedic beds in developing country's hospital [2].

With continuation of present patterns, road traffic accident is anticipated to be the third driving supporter of the worldwide level of disease, simply behind clinical depression and coronary illness by 2020 [3]. In developing nations 90 percent of the Disability Adjusted Life Years' (DALYs) lost happen as a result of road traffic accident [4]. One DALY is generally proportional to one solid year of life lost. In developing nations 75% of every single poor family who lost a part to road traffic death announced a decline in their way of life and 61 percent revealed that they needed to obtain cash to cover costs following their misfortune.

To this end, strong and innovative policies need to be brought to bear, globally, as part of the objective the decade of action to reach the target of 50% reduction in road death/fatalities by year 2020. This was also emphasized in the United Nations sustainable development goals [5].

1.1 Safety Measures to Curb Road Crashes

Road safety measure or system has no particular or standard package appropriate for all countries or states. Interventions proven in one state such as Ondo state may not easily be transferable to Ogun State, and will require careful adaptation and evaluation before any intervention measures can be deployed. Where interventions are inadequate, there is need to develop new measures through scientific research. Whether in high-income, or low-income and middle-

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income states in Nigeria, there are several good practices that can be followed [6]:

I. Dealing with vulnerability to risk through effective transport system;
II. Improving the road network as safety measure in curbing road traffic crashes;
III. Improving road users visibility;
IV. Encouraging the design of protective device in vehicle;
V. Ensure compliance with road safety regulations;
VI. Promoting post-crash care.

1.1.1 Dealing with vulnerability to risk through effective transport system

Safety-conscious planning and design of the land use and road network is necessary to reduce the risk of road traffic death and injuries. Exposure to risk of road traffic injury can be decreased in Ogun State by strategies that include:

I. Reducing volume of traffic for effective and efficient road safety management;
II. Creating alternative routes to ensure free flow of traffic;
III. Switching from higher-risk to lower-risk modes of transport should be encouraged;
IV. Promoting safety-centered planning, design and operation of the road network.

1.1.2 Improving the road network as safety measure in curbing road traffic crashes

Examples of road design considerations for road traffic injury and death prevention is by classifying roads and setting speed limits by their function. Some of the roads are for certain purpose. They are used by various types of vehicles with differences in speed, degree of protection and mass of vehicle. In built-up and on urban roads this often results to conflicts between the activities of motor vehicle users and pedestrians/ cyclists safety. Classifying roads functionality in the form of a "road hierarchy", as it is known in highway engineering is important for providing safer routes and safer designs. Such a classification takes account of land use, location of crash sites, vehicle and pedestrian flows, and objectives such as speed control.

1.1.3 Improving visibility of road users

The fundamental prerequisites for the safety of all road users is to be seeing and being seen. Visibility of particular groups of road users can be improved in various ways. Adoption and enforcement of laws requiring daytime running lights and use of mounted brake lights, positioned on the rear windshield of cars, giving a high visibility from the rear.

1.1.4 Encouraging the design of protective device in vehicles

Crash-protective vehicles design is essential to passenger survival during any crash. With laminated windscreens fastened to the car to prevent ejection, collapsible steering column, reinforced front and passenger compartment, door locks that prevent doors from opening during a crash and crash-resistant roofs, it can be guaranteed that fatality rate will drop sharply.

1.1.5 Ensuring compliance with road safety regulations

Enforcing road safety rules is one of the important aspects of road traffic injury prevention in Nigerian and the rest of the world. It is necessary to ensure compliance through enforcement, information and education. Attempts at enforcing road traffic legislation will not have any lasting effect, either on road user behavior or on road traffic crashes unless the enforcement is continued for a long time, and is perceived to be so by road users [7].

Enforcement levels need to be high and total so as to ensure that the perceived risk of being caught remains high. Imposing very strict penalties (in the form of higher fines or longer prison sentences) as being practiced in Nigeria today, does not affect road-user behavior. Because once they pay for their fine their vehicle will be released without corrective measures. But once offenders are caught, their penalties should be dealt with swiftly using selective enforcement strategies. Automated means such as high-speed cameras are cost effective and should also be deployed on Nigerian roads. This should be encouraged to assist in monitoring and tracking purposes.

Enforcement of the following road traffic laws; speed limits, use of seat-belts, alcohol impairment, use of crash-helmet and child restraints are all geared towards ensuring safer motoring environment.

The human factors constitute about 80% of the cause of road traffic accidents recorded in Nigeria today [8]. Human factors involve the drivers, law enforcement agents, pedestrians and the engineers as used in road

crashes investigations globally. Most drivers on Nigeria roads are very rude, recklessly, discourteous and have scant regard for human life. This has led to daily avoidable carnage on Nigeria roads especially within the study area. Virtually of all the significant factors contributing to the high proportion of crashes in Ogun State, the human factors top the list. [9].

Road traffic death and injuries have significant effect on socio-economic aspirations and development in Nigeria, due to the premature loss of qualified professionals and able youths who are the future leader of this nation [10].

Ogun State, a heavily motorized state in Nigeria has been labeled with poor road condition and high rate of road traffic crashes. On a daily basis crash is being recorded in the state most of which are fatal. Lagos-Ibadan corridor ranked third in RTC in 2016 with 397 crashes involving 3526 persons resulting in 228 deaths and 1244 others injured [11,12]. In 2018 December, Ogun state was one of the three states which recorded the highest number of road crashes and fatalities in Nigeria.[13].

Hence, need to evaluate the existing road crash countermeasures deployed to curb road traffic crash in Ogun state, Nigeria.

2. METHODOLOGY

The population of this study consists of all traffic officials and commercial drivers in six local government areas in Ogun State with major carriages. These are Ado- Odo Ota, Abeokuta north and south, Ijebu-Ode, Sagamu, and Obafemi Owode numbering about 360 registered commercial Drivers and 240 traffic officials.

The total number of registered commercial drivers and traffic officials investigated were two hundred and forty (240). The sample size was determined based on the following calculations carried out using the formula developed by Toro Yamane $(n) = \dfrac{N}{1+N(e)^2}$

Where N=600

95% confidence level and p =0.05

Sample size derived was 240

A purposive sampling technique was adopted for the selection of the two corridors namely Lagos- Ibadan and Lagos – Abeokuta.

Multivariate regression analysis was carried out on the obtained data to establish the effect of each road safety measure variables on the overall crash countermeasures carried out in the study area. MATLAB software was used for the computation.

$$y = \beta_0 + \beta_1 X_2 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon \quad (1)$$

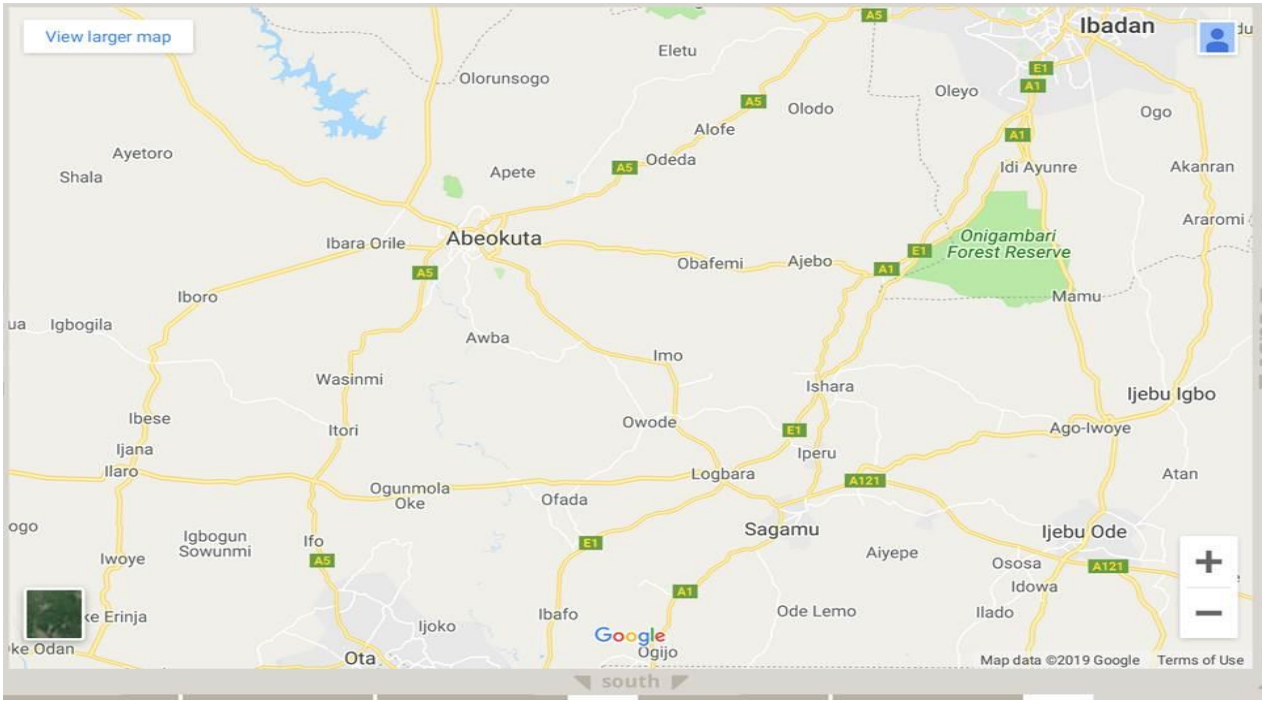

Figure 1: A map of Ogun State showing major road networks in Ogun State. (www.google.com/ogunroadnetwork)

Using the method of least squares, we can develop a set of normal equations

$$\Sigma y = n\beta_0 + \beta_1\Sigma X_1 + \beta_2\Sigma X_2 + \beta_3\Sigma X_3 + \beta_4\Sigma X_4 + \beta_5\Sigma X_5 + \beta_6\Sigma X_6 + \beta_7\Sigma X_7 + \beta_8\Sigma X_8 + \varepsilon \quad 1.2$$

$$\Sigma X_1 y = \beta_0\Sigma X_1 + \beta_1\Sigma X_1^2 + \beta_2\Sigma X_1X_2 + \beta_3\Sigma X_1X_3 + \beta_4\Sigma X_1X_4 + \beta_5\Sigma X_1X_5 + \beta_6\Sigma X_1X_6 + \beta_7\Sigma X_1X_7 + \beta_8\Sigma X_1X_8 \quad 1.3$$

$$\Sigma X_2 y = \beta_0\Sigma X_2 + \beta_1\Sigma X_1X_2 + \beta_2\Sigma X_2^2 + \beta_3\Sigma X_2X_3 + \beta_4\Sigma X_2X_4 + \beta_6\Sigma X_2X_6 + \beta_6\Sigma X_2X_6 + \beta_7\Sigma X_2X_7 + \beta_8\Sigma X_2X_8 \quad 1.4$$

$$\Sigma X_3 y = \beta_0\Sigma X_3 + \beta_1\Sigma X_1X_3 + \beta_2\Sigma X_2X_3 + \beta_3\Sigma X_3^2 + \beta_4\Sigma X_3X_4 + \beta_5\Sigma X_3X_5 + \beta_6\Sigma X_3X_6 + \beta_7\Sigma X_3X_7 + \beta_8\Sigma X_3X_8 \quad 1.5$$

$$\Sigma X_4 y = \beta_0\Sigma X_4 + \beta_1\Sigma X_1X_4 + \beta_2\Sigma X_2X_4 + \beta_3\Sigma X_3X_4 + \beta_4\Sigma X_4^2 + \beta_5\Sigma X_4X_5 + \beta_6\Sigma X_4X_6 + \beta_7\Sigma X_4X_7 + \beta_8\Sigma X_4X_8 \quad 1.6$$

$$\Sigma X_5 y = \beta_0\Sigma X_5 + \beta_1\Sigma X_1X_5 + \beta_2\Sigma X_2X_5 + \beta_3\Sigma X_3X_5 + \beta_4\Sigma X_4X_5 + \beta_5\Sigma X_5^2 + \beta_6\Sigma X_5X_6 + \beta_7\Sigma X_5X_7 + \beta_8\Sigma X_5X_8 \quad 1.7$$

$$\Sigma X_6 y = \beta_0\Sigma X_6 + \beta_1\Sigma X_1X_6 + \beta_2\Sigma X_2X_6 + \beta_3\Sigma X_3X_6 + \beta_4\Sigma X_4X_6 + \beta_5\Sigma X_5X_6 + \beta_6\Sigma X_6^2 + \beta_7\Sigma X_6X_7 + \beta_8\Sigma X_6X_8 \quad 1.8$$

$$\Sigma X_7 y = \beta_0\Sigma X_7 + \beta_1\Sigma X_1X_7 + \beta_2\Sigma X_2X_7 + \beta_3\Sigma X_3X_7 + \beta_4\Sigma X_4X_7 + \beta_5\Sigma X_5X_7 + \beta_6\Sigma X_6X_7 + \beta_7\Sigma X_7^2 + \beta_8\Sigma X_7X_8 \quad 1.9$$

$$\Sigma X_8 y = \beta_0\Sigma X_8 + \beta_1\Sigma X_1X_8 + \beta_2\Sigma X_2X_8 + \beta_3\Sigma X_3X_8 + \beta_4\Sigma X_4X_8 + \beta_5\Sigma X_5X_8 + \beta_6\Sigma X_6X_8 + \beta_7\Sigma X_7X_8 + \beta_8\Sigma X_8^2$$

The validity test was carried out to guide the utilization of the model developed. The existing road safety measures examined were eight and these form the independent variables for the multivariate analysis carried out. Table 1 shows a description of these variables.

Table1: Exiting road safety measures

Variable code	Existing road safety measures
X1	The use of seatbelt
X2	Installation of traffic light in selected intersection
X3	Enforcement of traffic rules and regulation
X4	Maintenance of road network
X5	Public enlightenment on road safety rules
X6	Vehicle road worthiness testing and certification
X7	The regulation and issuance of driving licence
X8	Installation of speed limiter on commercial vehicles.

3. RESULTS AND DISCUSSION

The developed multivariate linear regression model is shown in equation (10)

$$\hat{y} = -0.0671 + 0.9974x_1 + 0.9801x_2 + 0.9939x_3 + 1.0610x_4 + 1.0056x_5 + 0.9899x_6 + 0.9996x_7 + 0.9991x_8 + \delta \quad (10)$$

The details of the computation using the summing variables are shown in appendix 1

X_1 = The use of seatbelt

X_2 =Installation of traffic light in selected intersection

X_3 = Enforcement of traffic rules and regulation

X_4 = Maintenance of road network

X_5 = Public enlightenment on road safety rules

X_6 = Vehicle road worthiness testing and certification

X_7 = The regulation and issuance of driving licence

X_8 = Installation of speed limiter into commercial vehicles.

The variables X_1 to X_8 are the various existing road safety measures while the crash countermeasures (y)are the output from the model. Table 2 gives a description of the values of the various regression parameters that constituted the model based on their partial derivative with respect to overall countermeasures.

Table 2: Model description.

Crash countermeasure with respect to various variables	Description
b_0 = -0.0671	
$\frac{\partial y}{\partial x_1}$ = 0.9974	Road crash countermeasure with respect to The use of seatbelt
$\frac{\partial y}{\partial x_2}$ =0.9801	Road crash countermeasure with respect to Installation of traffic light in selected intersection
$\frac{\partial y}{\partial x_3}$ =0.9939	Road crash countermeasure with respect to Enforcement of traffic rules and regulation
$\frac{\partial y}{\partial x_4}$ =1.0610	Road crash countermeasure with respect to Maintenance of road network
$\frac{\partial y}{\partial x_5}$ = 1.0056	Road crash countermeasure with respect to Public enlightenment on road safety rules
$\frac{\partial y}{\partial x_6}$ = 0.9899	Road crash countermeasure with respect to Vehicle road worthiness testing and certification
$\frac{\partial y}{\partial x_7}$ =0.9996	Road crash countermeasure with respect to The regulation and issuance of driving licence
$\frac{\partial y}{\partial x_8}$ = 0.9991	Road crash countermeasure with respect to installation of speed limiter

The standard error of the model is 0.2122. However, the combination of the independent variables yielded a coefficient of determination (R^2) of 1 which indicates that the model explained all the variability of the response data around its means. In addition, the coefficient of determination obtained indicates that the regression predictions perfectly fit the data [14].

4. CONCLUSION

The interactions of the itemized road traffic crash countermeasures were established using multivariate technique and the model reveled that all the countermeasures contributed positively to the overall level of road traffic crash control. Maintenance of road network with positive regression parameter of 1.0610 contributed most to the overall reduction in road traffic crash in the study area. Installation of traffic light in selected intersection contributed least (0.9801) to the overall reduction in the road traffic crash and fatality. This could be due to the fact that corridors investigated are trunk. A roads which barely require the intervention of traffic lights.

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APPENDIX 1: COMPUTATION OF THE NORMAL EQUATION PARAMETERS

Y	X1y	x2y	x3y	x4y	x5y	x6y	x7y	x8y
19	57	19	57	38	57	38	38	57
20	60	60	40	40	60	60	20	60
18	36	54	18	54	36	54	54	18
22	66	66	66	66	66	66	66	22
21	63	42	63	63	63	63	63	21
19	19	19	38	57	57	57	57	57
23	69	69	46	69	69	69	69	69

Y	X1y	x2y	x3y	x4y	x5y	x6y	x7y	x8y
17	51	34	51	34	51	17	34	17
16	48	16	48	32	48	16	32	16
14	42	28	14	14	28	14	42	14
13	39	26	13	13	39	13	13	13
15	45	30	15	15	45	15	45	15
13	26	26	13	13	26	13	39	13
12	12	24	12	12	36	12	24	12

Y	X1y	x2y	x3y	x4y	x5y	x6y	x7y	x8y
14	14	14	42	14	42	14	28	28
11	11	11	33	11	11	11	11	22
16	16	16	48	32	32	16	48	48
15	45	15	30	30	15	45	30	15
24	72	72	72	72	72	72	72	72
19	19	19	38	57	57	57	57	57
14	42	14	28	28	28	14	28	14
21	63	63	63	63	63	21	42	63
15	30	30	45	15	30	15	45	15
16	48	16	32	48	32	32	32	16
16	48	32	32	48	32	16	32	16
15	45	30	30	45	30	15	15	15
16	32	48	32	48	32	32	16	16
14	14	42	28	42	14	14	28	14
20	20	60	60	40	60	60	40	60
18	36	54	54	36	36	54	36	18
19	38	57	57	38	19	57	38	57
16	16	48	48	32	16	32	48	16
17	51	17	51	34	17	51	51	17
11	11	11	11	11	22	11	33	11
15	15	15	30	45	45	30	30	15
23	69	69	46	69	69	69	69	69
22	66	44	66	66	66	66	66	44
23	46	69	69	69	69	69	69	69
19	19	38	57	57	57	57	57	19
23	46	69	69	69	69	69	69	69
19	57	19	38	57	57	57	57	19
20	40	60	40	60	60	60	60	20
18	36	54	18	54	36	54	54	18
21	63	42	63	63	63	63	63	21
23	69	69	46	69	69	69	69	69
15	30	15	45	30	30	15	45	15
23	69	69	46	69	69	69	69	69
24	72	72	72	72	72	72	72	72
23	69	69	69	69	46	69	69	69
24	72	72	72	72	72	72	72	72
22	66	44	66	66	66	66	66	44
16	16	32	32	48	16	48	48	16
24	72	72	72	72	72	72	72	72
20	40	60	40	60	60	60	60	20
18	36	54	18	54	36	54	54	18
20	60	60	20	60	60	60	60	20
21	63	42	63	63	63	63	63	21

Y	X1y	x2y	x3y	x4y	x5y	x6y	x7y	x8y
18	54	18	54	36	54	54	36	18
21	63	63	42	63	63	63	42	42
15	30	15	45	30	30	15	45	15
20	20	60	60	40	60	60	40	60
17	34	51	51	17	34	51	34	17
21	42	63	63	63	42	63	42	63
17	17	51	51	51	34	17	51	17
18	18	54	54	54	18	36	54	36
11	11	11	22	22	22	11	11	11
12	12	12	24	36	12	24	12	12
15	45	15	15	45	15	15	30	45
17	51	34	34	51	17	51	34	17
13	26	13	26	39	13	13	26	13
17	17	51	51	51	17	51	34	17
14	28	14	42	42	14	14	28	14
13	13	26	13	39	26	13	13	26
14	14	28	42	14	28	28	14	28
12	12	12	36	12	24	24	12	12
15	45	45	45	15	15	15	15	30
14	14	14	28	14	42	14	28	42
15	15	15	45	15	45	45	30	15
16	16	32	48	16	48	16	32	48
20	40	60	40	60	60	60	60	20
16	32	16	32	48	32	48	32	16
17	51	51	34	17	51	17	51	17
19	38	57	57	57	57	19	19	57
16	16	32	32	16	48	48	48	16
18	36	54	18	54	36	54	54	18
16	32	16	32	48	32	48	16	32
22	66	66	44	66	66	66	44	66
23	69	69	46	69	69	69	69	69
21	63	63	42	42	63	63	63	42
19	19	57	38	57	57	19	57	57
22	44	66	66	66	66	66	44	66
20	60	60	20	40	40	60	60	60
18	54	18	54	54	18	18	54	54
17	34	51	51	17	51	51	17	17
20	60	60	20	60	60	60	20	60
22	66	66	66	22	66	66	66	66
20	20	60	60	20	60	60	60	60
19	19	57	57	57	19	38	57	57
21	63	63	42	42	63	63	63	42
19	57	38	57	57	19	57	38	38

Y	X1y	x2y	x3y	x4y	x5y	x6y	x7y	x8y
21	42	63	63	63	42	63	63	42
20	60	60	20	40	60	60	60	40
21	63	42	63	63	63	63	63	21
19	57	38	57	19	57	38	57	38
20	60	40	60	60	60	20	60	40
21	63	63	63	42	63	63	63	21
19	57	38	57	57	19	57	57	19
17	17	34	51	51	51	17	51	17
18	54	54	18	54	18	54	54	18
20	60	40	60	60	20	60	60	40
18	54	18	54	54	54	18	54	18
19	57	38	38	38	38	57	38	57
18	36	36	54	36	54	54	36	18
19	57	38	57	38	57	57	38	19
17	34	51	17	51	17	51	51	17
19	38	57	19	57	57	57	57	19
17	34	51	17	51	51	17	51	17
20	60	60	20	60	60	60	60	20
21	63	63	63	63	42	63	63	21
13	13	26	13	13	39	13	39	13
16	48	32	16	32	48	16	48	16
19	57	57	19	38	57	57	57	19
17	51	51	17	34	51	17	51	17
16	48	32	48	16	32	16	48	16
15	45	30	15	15	45	15	45	15
14	42	28	14	14	28	28	28	14
11	11	22	11	11	22	11	22	11
14	14	28	14	28	42	14	42	14
15	15	45	30	45	15	15	30	30
14	14	42	42	28	14	28	14	14
15	15	45	15	30	45	30	30	15
16	48	32	16	32	48	32	16	32
13	13	26	13	13	39	13	26	26
14	14	42	14	14	42	28	28	14
13	13	26	13	13	13	26	26	39
12	12	12	12	12	36	12	36	12
15	15	15	45	30	30	15	30	45
12	24	12	12	36	24	12	12	12
15	15	30	15	45	30	30	30	30
14	14	14	28	42	14	28	42	14
16	48	16	32	32	32	32	48	16
15	45	15	30	15	45	30	30	15
17	17	34	51	51	34	51	34	17

Y	X1y	x2y	x3y	x4y	x5y	x6y	x7y	x8y
18	54	18	36	54	36	36	36	54
15	30	45	30	45	15	30	15	15
14	14	42	28	42	14	28	14	14
18	36	54	36	54	18	54	18	54
16	48	48	32	32	16	32	32	16
14	42	14	28	42	14	28	14	14
17	34	51	51	34	34	51	17	17
16	32	48	32	48	16	32	16	32
14	28	42	28	42	14	14	14	14
13	13	26	26	39	13	26	13	13
14	14	42	14	28	14	28	14	42
15	15	45	30	45	15	30	30	15
14	14	42	28	42	14	14	28	14
11	11	11	11	11	22	11	33	11
12	24	12	12	12	24	12	36	12
11	11	11	11	11	22	11	33	11
21	42	21	63	63	63	63	63	63
12	24	12	24	24	24	12	12	12
14	28	42	14	28	14	14	42	14
13	13	13	26	39	13	39	13	13
11	11	11	11	33	22	11	11	11
16	48	16	32	48	32	16	48	16
13	13	13	26	13	26	39	26	13
14	28	14	28	42	28	14	28	14
13	13	13	13	39	39	13	26	13
15	15	45	15	45	45	15	30	15
14	14	14	14	42	42	14	42	14
13	26	13	26	13	39	26	13	13
14	14	28	14	28	28	28	42	14
11	33	11	11	11	11	11	22	11
15	45	15	15	15	45	30	45	15
14	14	14	14	42	28	28	42	14
16	16	32	48	48	32	48	16	16
13	13	26	13	13	39	26	26	13
15	30	15	15	45	45	30	30	15
21	42	63	63	63	42	63	42	63
20	40	60	60	60	20	60	40	60
21	21	63	63	63	63	63	42	63
22	44	66	66	66	66	66	44	66
20	40	60	60	60	60	60	40	20
19	38	57	57	57	57	19	57	19
17	17	51	51	51	34	17	51	17
18	18	54	54	54	36	18	54	36

Y	X1y	x2y	x3y	x4y	x5y	x6y	x7y	x8y
17	17	51	51	51	34	17	51	17
19	19	57	57	57	38	38	57	38
17	17	51	51	51	17	34	51	17
16	16	48	48	32	16	32	48	16
17	17	51	51	34	17	17	51	51
15	15	45	15	30	45	15	45	15
19	19	57	57	38	57	19	57	57
17	17	51	51	34	51	17	51	17
15	15	15	45	30	15	45	45	15
17	34	17	51	34	17	51	51	34
14	14	14	42	28	14	42	28	14
15	15	15	45	30	15	45	45	15
17	51	51	17	34	17	51	51	17
12	12	24	12	24	12	36	12	12
13	13	13	13	13	13	39	39	26
12	12	24	12	12	12	36	24	12
13	26	26	26	13	26	13	26	13
12	24	12	12	12	12	36	24	12
17	17	34	17	34	51	51	34	51
10	10	10	10	10	10	10	30	10
13	13	13	13	13	13	39	39	26
16	48	16	32	32	48	32	32	16
14	14	14	28	28	42	28	28	14
13	13	13	26	26	26	26	26	13
15	15	45	30	45	30	30	15	15
23	46	69	69	69	69	69	69	69
20	40	40	60	60	60	60	60	20
21	21	42	63	63	63	63	63	63

Y	X1y	x2y	x3y	x4y	x5y	x6y	x7y	x8y
16	16	32	32	48	16	48	48	16
24	72	72	72	72	72	72	72	72
22	22	66	66	66	66	66	66	66
24	72	72	72	72	72	72	72	72
19	19	57	38	57	57	57	57	19
21	63	63	42	63	63	63	63	21
18	36	54	18	54	36	54	54	18
16	16	16	48	32	48	48	32	16
18	54	18	54	36	54	54	36	18
19	57	19	38	57	57	57	38	38
17	17	51	34	51	34	51	34	17
18	54	54	36	54	18	54	36	18
17	51	17	51	34	34	17	34	51
16	32	16	48	32	16	16	48	48
15	15	30	45	30	30	15	45	15
16	32	32	48	16	32	32	16	48
15	30	30	45	15	30	15	45	15
14	28	28	42	14	28	14	14	28
16	32	32	48	16	32	32	48	16
17	34	34	51	51	34	34	34	17
15	30	30	45	15	45	15	30	15
17	34	17	51	17	34	51	51	34
16	32	32	48	16	48	16	48	16
14	14	28	14	28	42	14	14	42
17	51	51	17	17	34	51	51	17
14	42	28	14	14	28	14	28	28
4057	**8313**	**9054**	**9120**	**9607**	**9271**	**9073**	**9818**	**6907**

APPENDIX 2: A SET OF NORMAL EQUATIONS

The obtained values of the summing variables (Appendix 1) were substituted into equation (1) which was represented as a set of linear equations as shown in 2.1 to 2.9

$$4057 = 240\beta_o + 473\beta_1 + 514\beta_2 + 522\beta_3 + 549\beta_4 + 532\beta_5 + 512\beta_6 + 567\beta_7 + 588\beta_8 \quad (2.1)$$

$$8313 = 473\beta_o + 1109\beta_1 + 1027\beta_2 + 1036\beta_3 + 1098\beta_4 + 1082\beta_5 + 1045\beta_6 + 1137\beta_7 + 779\beta_8 \quad (2.2)$$

$$9054 = 514\beta_o + 1027\beta_1 + 1272\beta_2 + 1131\beta_3 + 1224\beta_4 + 1157\beta_5 + 1144\beta_6 + 1233\beta_7 + 867\beta_8 \quad (2.3)$$

$$9120 = 522\beta_o + 1036\beta_1 + 1131\beta_2 + 1300\beta_3 + 1220\beta_4 + 1163\beta_5 + 1142\beta_6 + 1241\beta_7 + 887\beta_8 \quad (2.4)$$

$$9607 = 549\beta_o + 1094\beta_1 + 1224\beta_2 + 1220\beta_3 + 1415\beta_4 + 1213\beta_5 + 1222\beta_6 + 1306\beta_7 + 901\beta_8 \quad (2.5)$$

$$9271 = 532\beta_o + 1082\beta_1 + 1157\beta_2 + 1163\beta_3 + 1213\beta_4 + 1336\beta_5 + 1148\beta_6 + 1286\beta_7 + 886\beta_8 \quad (2.6)$$

$$9073 = 512\beta_o + 1045\beta_1 + 1144\beta_2 + 1142\beta_3 + 1222\beta_4 + 1148\beta_5 + 1282\beta_6 + 1229\beta_7 + 861\beta_8 \quad (2.7)$$

$$9818 = 567\beta_o + 1137\beta_1 + 1233\beta_2 + 1241\beta_3 + 1306\beta_4 + 1286\beta_5 + 1229\beta_6 + 1469\beta_7 + 917\beta_8 \quad (2.8)$$

$$6907 = 388\beta_o + 779\beta_1 + 867\beta_2 + 887\beta_3 + 910\beta_4 + 886\beta_5 + 861\beta_6 + 917\beta_7 + 800\beta_8$$

The values of the variables of equations 2.1 to 2.8 were obtained by converting the equations into their matrix forms.

APPENDIX 3: MATLAB COMPUTATION OF THE REGRESSION PARAMETERS

```
A= [240 473 514 522 549 532 512 567 388; 473 1109 1027 1036 1098 1082 1045 1137 779; 514 1027 1272
1131 1224 1157 1144 1233 867; 522 1036 1131 1300 1220 1163 1142 1241 887; 549 1098 1224 1220 1415
1213 1222 1306 901; 532 1082 1157 1163 1213 1336 1148 1286 886; 512 1045 1144 1142 1222 1148 1282
1229 861; 567 1137 1233 1241 1306 1286 1229 1469 917; 388 779 867 887 910 886 861 917 800]
A =
  Columns 1 through 8

    240    473    514    522    549    532    512    567    388
    473   1109   1027   1036   1098   1082   1045   1137    779
    514   1027   1272   1131   1224   1157   1144   1233    867
    522   1036   1131   1300   1220   1163   1142   1241    887
    549   1098   1224   1220   1415   1213   1222   1306    901
    532   1082   1157   1163   1213   1336   1148   1286    886
    512   1045   1144   1142   1222   1148   1282   1229    861
    567   1137   1233   1241   1306   1286   1229   1469    917
    388    779    867    887    910    886    861    917    800

>> B= inv (A)

B =
   0.1278   -0.0056   -0.0051   -0.0090   -0.0090   -0.0091   -0.0027   -0.0130   -0.0030
  -0.0056    0.0062    0.0000    0.0000   -0.0003   -0.0011   -0.0009   -0.0005   -0.0002
  -0.0051    0.0000    0.0069    0.0002   -0.0016   -0.0004   -0.0010   -0.0006   -0.0011
  -0.0091    0.0000    0.0002    0.0067   -0.0007    0.0001   -0.0006   -0.0003   -0.0016
  -0.0092   -0.0003   -0.0017   -0.0008    0.0074    0.0006   -0.0014   -0.0001    0.0002
  -0.0092   -0.0011   -0.0005    0.0000    0.0006    0.0071   -0.0000   -0.0014   -0.0009
  -0.0027   -0.0009   -0.0010   -0.0005   -0.0014   -0.0000    0.0063   -0.0005   -0.0007
  -0.0130   -0.0005   -0.0006   -0.0003   -0.0001   -0.0014   -0.0005    0.0083    0.0006
  -0.0024   -0.0001   -0.0010   -0.0015   -0.0002   -0.0010   -0.0006    0.0006    0.0067

>> C= [4057;8313;9054;9120;9607;9271;9073;9818;6907]
C =                                                    D =

    4057                                                  -0.0671
    8313                                                   0.9974
    9054                                                   0.9801
    9120                                                   0.9939
    9607                                                   1.0610
    9271                                                   1.0056
    9073                                                   0.9899
    9818                                                   0.9996
    6907                                                   0.9991
                                                          >>
>> D= B*C
```