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Analyzing the Distribution of Crimes in Oyo State (Nigeria) using Principal Component Analysis (PCA)

Olufolabo.O.O*, Akintande O.J*, Ekum M.I**
Department of Statistics, Yaba College of Technology
Department of Mathematics, University of Lagos
Department of Mathematics, University of Lagos

Abstract: *This paper analyses Oyo State crime data which consists of eighteen major crimes reported to the police between the periods of 1996 – 2014. The crimes consist of robbery, kidnapping, house and store breakings, theft/stealing, grievous hurt and wounding, murder, rape, assault etc.*
There is an average of 56 cases of Murder, 152 cases of Armed Robbery, 12 cases of Suicide, 541 cases of Grivious Harms/Wounding, 1196 cases of Assaults, 392 cases of Burglary/Stealing, 263 cases of Store Breaking, 544 cases of House Breaking, 1385 cases of Stealing/Theft, 99 cases of Rape/Indecent Assaults, 12 cases of Kidnapping, 442 cases of False Pretence/Cheating, 110 cases of Unlawful Possession, 16 cases of Arson, 327 cases of Breach of Peace, 23 cases of Forgery, 8 cases of Child Stealing and 29 cases of Unnatural Offences.
Correlation analysis and principal component analysis (PCA) were employed to explain the correlation between the crimes and to determine the distribution of the crimes in the state. The result shown a significant correlation between Store breaking and Stealing. Assaults have a strong positive relationship with False Pretence and Breach of Peace. Kidnapping has a strong positive relationship with False Pretence Breach of Peace. False Pretence has a strong positive relationship with Breach of Peace. There is weak positive relationship between Murder case and Armed Robbery, Suicide, Grivious harm/wounding, Assaults, Store breaking, House breaking, Stealing, False Pretence, Unlawful possession, Breach of peace, Forgery, Child stealing and Unusual crimes. Murder has a positive relationship with Rape and Arson. And a weak negative relationship with Burglary. Armed Robbery has a positive relationship with Kidnapping and weak positive relationship with other forms of crimes, a weak negative relationship with Burglary, Store breaking, Stealing and Unlawful possession. Suicide has a positive relationship with Rape. Grivious harm/Wounding has a positive relationship with Assaults.
Stealing/Theft is more prevalent in Oyo State. Besides Stealing/Theft, Assaults is prominent among other crimes. The PCA has suggested retaining six components that explain about 83.79 percent of the total variability of the data set.

I. Introduction

Crime is a known word peculiar to every nations, societies and communities around the world. An adage in Yoruba says; "Ilu ti kosofin; ese osi nibe" This means that, there is no crime; where there is no law! We can infer therefore that, where there is law, there is crime! Law and order is a defined ways by which nation's controls crimes in the society. Crime is a menace which requires close monitoring and analysis. Hence, there is need to study the rate at which crimes are committed in the society and ways to curbing it. It is impossible to eradicate crime in the society but it is important to provide measures in curbing it. Despite the fact that, crime is inevitable in a society Durkheim (1933), various controlling and preventive measures had been taken, and are still being taken to reduce the menace.

Crime does not have any boundary. It has nothing to do with a country being developed, developing or under-develop. In fact, worst crimes are reported daily in the news in most developed countries of the world. Crime therefore varies across continents and it prevalence can be nation's characterized. We mean that, some crimes are peculiar with some nations, communities and societies. For instance, Kidnapping, Homicides, armed robbery and killing involving the use of armed weaponry are peculiar in most advanced countries. Suicide bombing, Rape, Homicides, Religion crime and Massacre are peculiar in the Arab nations. Kidnapping, Ethnic fight, Tribal war, Corruption, Rioting, Religion clashes etc., are peculiar in Africa, etc.

Our study focus only on a State (Oyo State) in Nigeria. In categorizing crimes, crime do varies even within States of a nation. For instance, in Nigeria today (2003-till date), Bombing, Terrorism, Suicide bombing, Religion war& killings, vandalism etc., is a crime peculiar in the Northern part of Nigeria particularly in the states like Borno, Adamawa, Kano and Yobe whereas, Kidnapping, Pipeline vandalism, Armed robbery and Oil theft are order of the day in Niger-Delta part of Nigeria. In the South west and in the Eastern part of Nigeria, we have heard of cases of Ritual killing, Theft &Stealing, Kidnapping, Assaults, Wounding, Armed robbery etc.

This implies that, Crime prevalence may varies across borders but there is no society, community or nation that is void of Crime.

Therefore, in Ibadan, Oyo state, there are 18 major categories of crimes associated with the people. Police department in the identified Stealing/Theft as the most committed crime in the state.

Several crime aid factors in societies includes but not limited to illiteracy, poverty, broken home, bad company, environment, religion belief and extremism, failure of Police and authority in administering justice.Just as crimes varies across the globe; it motivating factors also varies depending on the nation. In most advanced nations where the standard of living is considerably well enough, one may overrule Illiteracy and poverty as a crime motivating factor. What motivate crime in country **A** may be less significant in country **B**. In analyzing our own situation for this study, all these factors are significant relevant to crime rates in most of our societies.

II. Methodology

In order to test for similarities between crimes and the differences in the crimes committed in Oyo state over the last 20 years and to determine which of these crimes is/are significant to another.

We performed some descriptive review of the data in order to explain the distributions in the crime rates over the last 20 years in Oyo state. In other words, to determine the crime rates on yearly bases and to understand the prevalence of a crime over the other. The Principal Component Analysis helped us to go deeper into analyzing the significant-components of crime rates in Oyo state.

III. Principal Component Analysis.

Principal components analysis (PCA, for short) is a variable reduction technique that shares many similarities to exploratory factor analysis. Its aim is to reduce a larger set of variables into a smaller set of 'artificial' variables, called 'principal components', which account for most of the variance in the original variables. If these variables are highly correlated, it implies that the components extracted have a high degree of relationship with the original variables. This helps you understand whether some of the variables you have chosen are not sufficiently representative of the construct you are interested in, and should be removed from your new measurement. PCA is conceptually different to factor analysis, in practice it is often used interchangeably with factor analysis, and is included within the 'Factor procedure' in SPSS.

Methods:

Let X be a vector of p random variables, the main idea of the PC transformation is to look for a few (< p) derived variables that preserved most of the information given by the variance of the p random variables (Jolliffe, 2002). Let the random vector $X' = [X_1, X_2, \ldots, X_p]$ have the covariance matrix $\sum$ with eigenvalues $\lambda_1 \geq \lambda_2 \geq \lambda_3, \ldots\ldots\ldots, \geq \lambda_p \geq 0$.

Consider the linear combinations,

$Y_j = \alpha'_j X = \alpha'_{j1}X_1 + \alpha'_{j2}X_2 + \ldots\ldots\ldots\ldots + \alpha'_{jp}X_p = \sum \alpha'_{jk}X_k$, j = 1, 2, 3…., p of the element of X, where α_j is a vector of p components $\alpha'_{j1}, \alpha'_{j2,\ldots\ldots,} \alpha'_{jk}$

Then

$Var(Y_j) = \alpha'_j \sum \alpha_j$ j = 1,2,….., p ……..(1.1)

$Cov(Y_j) = \alpha'_j \sum \alpha_k$ j = 1,2,….., p ……..(1.2)

The PCs are those uncorrelated linear combinations Y1,Y2,…,Yp whose variances in (1.1) are as large as possible (Richard and Dean, 2001). In finding the PCs we concentrate on the variances. The first step is to look for a linear combination $\alpha'_1 X$ with maximum variance, so that

$\alpha'_1 X = \alpha'_{11}X_1 + \alpha'_{12}X_2 + \ldots\ldots\ldots\ldots + \alpha'_{1p}X_p = \sum \alpha'_{1k}X_k$

Next, look for a linear combination $\alpha'_2 X$ uncorrelated with $\alpha'_1 X$ having maximum variance, and so on, so that at the k^{th} stage a linear combination $\alpha'_k X$ is found that has maximum variance subject to being uncorrelated with $\alpha'_1 X, \alpha'_2 X, \ldots\ldots, \alpha'_{k-1} X$. The kth derived variable $\alpha'_k X$ is the k^{th} PC. Up to p PCs could be found, but we have to stop after the q^{th} stage ($q \leq p$) when most of the variation in X have been accounted for by q PCs.

- The variance of a PC is equal to the eigenvalue corresponding to that PC,
  $Var(Y_j) = \alpha'_j \sum \alpha_j$ j = 1,2,….., p

- The total variance in a data set is equal to the total variance of PCs

  $\sigma_{11} + \sigma_{22} + \ldots\ldots \sigma_{pp} = \sum Var(X_j) = \lambda_1 + \lambda_2 +, \ldots\ldots\ldots, + \lambda_p = \sum Var(Y_j)$

The data was standardized for the variables to be of similar scale using a common standardization method of transforming all the data to have zero mean and unit standard deviation. For a random vector$X' = [X_1, X_2, \ldots, X_p]$ the corresponding standardized variables are

$$Z = \left[z = \frac{(Xj - \mu j)}{\sqrt{\sigma_{11}}}\right] \qquad j = 1,2,\ldots, p$$

In matrix notation

$$Z = V^{1/2}(X - \mu).$$

Where $V^{1/2}$ is the diagonal standard deviation matrix. Thus E (Z) = 0 and Cov(Z) = P.

The PCs of Z can be obtained from eigenvectors of the correlation matrix ρ of X. All our previous properties for X are applied for the Z, so that the notation Yj refers to the j^{th} PC and (λ_j, α_j) refers to the eigenvalue – eigenvector pair. However, the quantities derived from ∑ are not the same from those derived from ρ (Richard and Dean, 2001).

The j^{th} PC of the standardized variables $Z = [z_1, z_2, \ldots, z_p]$ with Cov (Z) , is given by

$$Yj = \alpha'_j Z = \alpha'_j(V^{1/2})^{-1}(X - \mu)$$

So that,

$$\sum Var(Y_j) = \sum Var(Z_j) = P \qquad j = 1,2,\ldots, p$$

In this case, (λ_1, α_1) , (λ_2, α_2),……, (λ_p, α_p) are the eigenvalue- eigenvector pairs for ρ with $\lambda_1 \geq \lambda_2 \geq \lambda_3, \ldots\ldots, \geq \lambda_p \geq 0$.

Interpretation of the Principal Components:

The loading or the eigenvector $\alpha_j = \alpha_1, \alpha_2, \alpha_3, \ldots, \alpha_j$, is the measure of the importance of a measured variable for a given PC. When all elements of are positive, the first component is a weighted average of the variables and is sometimes referred to as measure of overall crime rate. Likewise, the positive and negative coefficients in subsequent components may be regarded as type of crime components (Rencher, 2002 and Printcom, 2003). The plot of the first two or three loadings against each other enhances visual interpretation (Soren, 2006).

The score is a measure of the importance of a PC for an observation. The new PC observations Yij are obtained simply by substituting the original variables Xij into the set of the first q PCs. This gives

$Y_{ij} = \alpha'_{j1}X_{i1} + \alpha'_{j2}X_{i2} + \alpha'_{j3}X_{i3} + \ldots\ldots\ldots\ldots + \alpha'_{jp}X_{ip}$ j = 1, 2, 3…., p; i= 1,2..,n

The plot of the first two or three PCs against each other enhances visual interpretation (Soren, 2006).

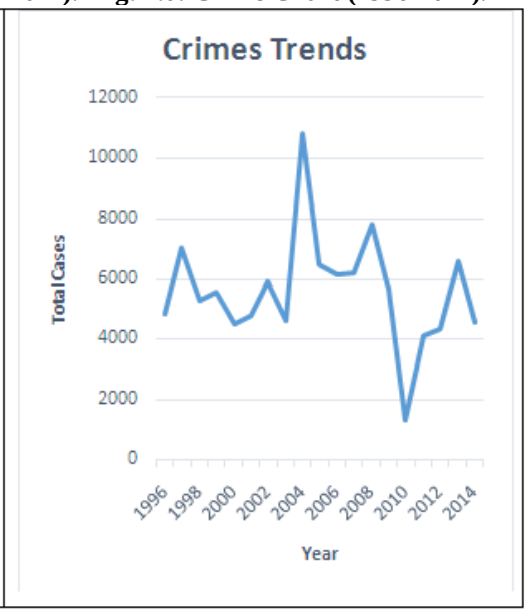
The proportion of Variance:

The proportion of variance tells us the PC that best explained the original variables. A cumulative proportion of explained variance is a useful criterion for determining the number of components to be retained in the analysis. A Scree plot provides a good graphical representation of the ability of the PCs to explain the variation in the data (Cattell, 1966).

IV. Analysis And Result

Table 1: Crime rates across the year (1996-2014). Fig: 2.0: Crime Chart (1996-2014).

Year	Total crime(s) recorded
1996	4810
1997	7061
1998	5256
1999	5548
2000	4476
2001	4789
2002	5920
2003	4629
2004	10803
2005	6508
2006	6180
2007	6203
2008	7809
2009	5648
2010	1296
2011	4112
2012	4334
2013	6617
2014	4540



Source: Federal Department of State Police, Oyo State

We take 1996 as the base year for this analysis. In 1996; 4810 crimes were recorded. In 1997; 7061 were recorded. This amount to 2251increase in the number of offenders. It amount to 46.8% increase in crime rate within a year.

Increase/Decrease rate (I/DR) = $\frac{|\text{Number of Current Crime} - \text{Number of Previous Crime}|}{\text{Number of Crime in the Previous Year}}$ X 100

Between 1997 and 1998; the rate decreased to 5256 crimes. This amounts to 1805 decrease in the number of offenders. 25.6% decrease in crime rate. In 1999, the crime rates increased to 5548. This amount to 292 increase in crime rate.

In 2000; a total of 4476 crimes were recorded. This amount to 1072 decrease in crimes from the previous year (1999). It amount to 19.3% decrease in crime rates. In 2001; a total of 4789 crimes were recorded. This amount to 313 increase in crimes. This gives 6.99% increase in crime rates.

In 2002; a total of 5920 crimes were recorded. This amount to 1131 additional increase in the number of crimes. It resulted to 23.6% increase in crime rate. In 2003; a total of 4620 crimes were recorded. It amount to 1291 decrease in the number of offences. It amounts to 21.8% decrease in crime rate.

Year 2004 recorded the highest number of crime committers. 10803 offenders were booked. This amount to a sparring increase of 6174 additional offenders from the previous year (2003) and amount to 133.4% increase in crime rate. We cannot say precisely what caused this unusual increase in crime rate in Oyo state in 2004 but we sensed that some factors could be responsible.

The lowest crime rates is recorded in 2010. Only 1296 offenders were booked. This amount to 77.05% decrease in crime rates compare to the previous year (2009). In 2011; an unusual increase of 217.3% increase in crime rates was recorded compared to 2010.

2012, 2013 and 2014 have a total 4334, 6617 and 4540 crimes recorded respectively. And it amounted to 5.4% and 52.7% increase in crime rates in 2012 and 2013 respectively and 31.4% decrease in 2014.

Table 2.0: Correlation Matrix

	M	A	S	G	A	B	S	H	ST	R	K	P	UN	AR	BR	F	C	U
M	1.00																	
A	0.47	1.00																
S	0.36	0.29	1.00															
G	0.40	0.28	0.24	1.00														
A	0.47	0.24	0.06	0.60	1.00													
B	-0.07	-0.41	-0.01	0.11	0.19	1.00												
S	0.46	-0.03	0.44	0.44	0.43	0.23	1.00											
H	0.42	0.12	-0.15	0.16	0.23	-0.04	0.09	1.00										
ST	0.48	-0.08	0.33	0.46	0.39	0.34	0.80	0.14	1.00									
R	0.61	0.25	0.58	0.55	0.47	0.26	0.68	0.50	0.71	1.00								
K	0.52	0.50	0.09	0.40	0.55	-0.29	0.11	0.38	0.27	0.44	1.00							
P	0.35	0.32	0.06	0.41	0.70	0.03	0.20	0.40	0.23	0.51	0.78	1.00						
UN	0.27	-0.11	-0.04	0.27	0.19	0.38	0.55	0.35	0.38	0.46	-0.20	0.11	1.00					
AR	0.56	0.11	0.13	0.06	0.32	-0.22	0.37	0.41	0.40	0.35	0.47	0.34	-0.05	1.00				
BR	0.37	0.37	-0.10	0.42	0.79	-0.06	-0.02	0.23	0.13	0.22	0.76	0.73	-0.16	0.23	1.00			
F	0.38	0.33	-0.24	0.24	0.37	0.33	-0.24	0.19	0.07	0.15	0.47	0.35	-0.06	0.08	0.60	1.00		
C	0.05	0.15	-0.24	-0.05	0.17	0.17	0.00	-0.07	0.05	-0.02	0.27	0.12	-0.30	0.21	0.21	0.51	1.00	
U	0.50	0.30	0.10	0.42	0.55	0.23	0.02	0.24	0.37	0.41	0.64	0.63	-0.03	0.35	0.71	0.71	0.07	1.00

In summary, Store breaking and Stealing has a very strong positive relationship. Assaults have a strong positive relationship with False Pretence and Breach of Peace.

Kidnapping has a strong positive relationship with False Pretence Breach of Peace. False Pretence has a strong positive relationship with Breach of Peace.

The strong or positive relationship implies that as one increases the other also increases. Murder has a positive relationship with Rape for instance, implies that, as murder cases increases, Rape cases increases. This means that, some Murder cases could be as a result of Rape, Arson, Armed Robbery, Suicide, Grivious harms/Wounding, Assaults, Store breaking, House breaking, Stealing, False pretence, Unlawful possession, Breach of peace, Forgery, Child stealing and Unusual crimes. That is all these crimes are correlated, hence, one may leads to another.

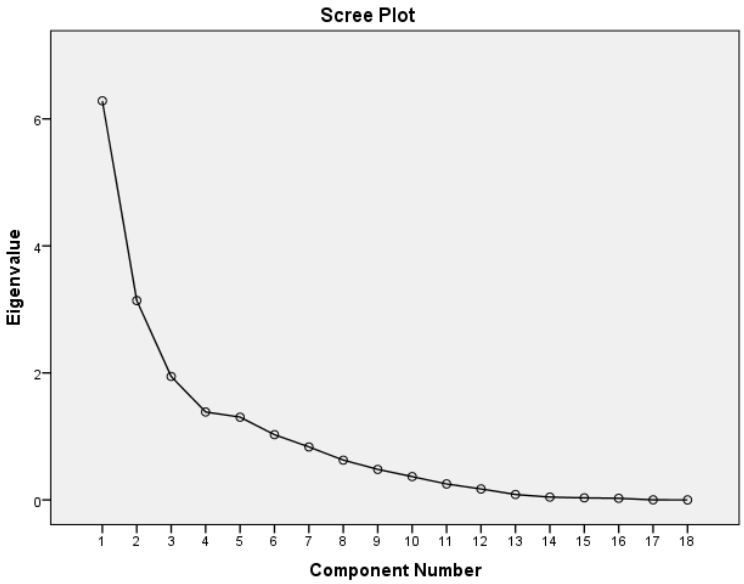
Principal Component Analysis (PCA).

Table 3.0: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.206
Bartlett's Test of Sphericity	Approx. Chi-Square	327.500
	df	153
	Sig.	.000

Although the KMO value is small (< 0.5) but the Bartlett's test of Sphericity indicates we can proceed. That is the test is highly significant.

Fig 1: Screen Plot of the Principal Components.



The eigenvalues and the cumulative proportions of the explained variance are displayed in Table 4. Considering the eigenvalue-one criterion and the Scree plot in figure 1, it would be reasonable to retain the first six PCs. A commonly accepted rule says that it suffices to keep only PCs with eigenvalues larger than 1. However, the seventh and the eighth eigenvalues and are approximately close to 1, so that the first 6 PCs can be retain to explain 83.79 percent of the total variability or the first 8 PCs to explain up to 91.90 percent of the total variability.

Table 4.0: Eigenvalues

CRIMES	Eigenvalues	Proportion	Cumulative
MURDER	6.284	34.910	34.910
ARMED ROBBERY	3.139	17.439	52.349
SUICIDE	1.944	10.798	63.148
GRIVIOUS HARM/WOUNDING	1.384	7.691	70.838
ASSAULTS	1.304	7.242	78.081
BURGLARY/STEALING	1.027	5.708	83.788
STORE BREAKING	.834	4.634	88.423
HOUSE BREAKING	.626	3.479	91.902
STEALING/THEFT	.481	2.670	94.571
RAPE/INCEDENT ASSAULT	.367	2.039	96.610
KIDNAPPING	.252	1.397	98.007
FALSE PRETENCE/CHEATING	.172	.956	98.964
UNLAWFUL POSSESSION	.085	.471	99.435
ARSON	.044	.244	99.679
BREACH OF PEACE	.032	.177	99.856
FORGERY	.024	.136	99.992
CHILD STEALING	.001	.007	99.999
UNNATURAL OFFENCE	.000	.001	100.000

This table 5 below; concentrated on the six PCs that explains 83.788 per cent of the total variability of the data set are retained.

Component 1 has a positive relationship (weak and strong) with all the crimes recorded but majorly it identify (strong relationship with) Murder, Grivious harm/wounding, Assaults, Stealing/Theft, Rape/Indecent Assault, Kidnapping, False Pretence/Cheating, Arson, Forgery, Breach of Peace and Unnatural offences as the major crimes committed or concentrated offences.

Component 2 identify Forgery, Unlawful possession, Store Breaking and Stealing/Theft as the major crimes committed. It has a negative relationship (decrease) with Forgery and Unlawful possession and a positive relationship (increase) with Store breaking and Stealing/Theft.

Component 3 identify Burglary/Stealing only as the concentrated offence. This implies that, Burglary/Stealing is the daily offence in this location.

Component 4 increases with Suicide and decreases with House breaking. We can viewed this location as measure of new common offence while the other offence is becoming history or reducing.

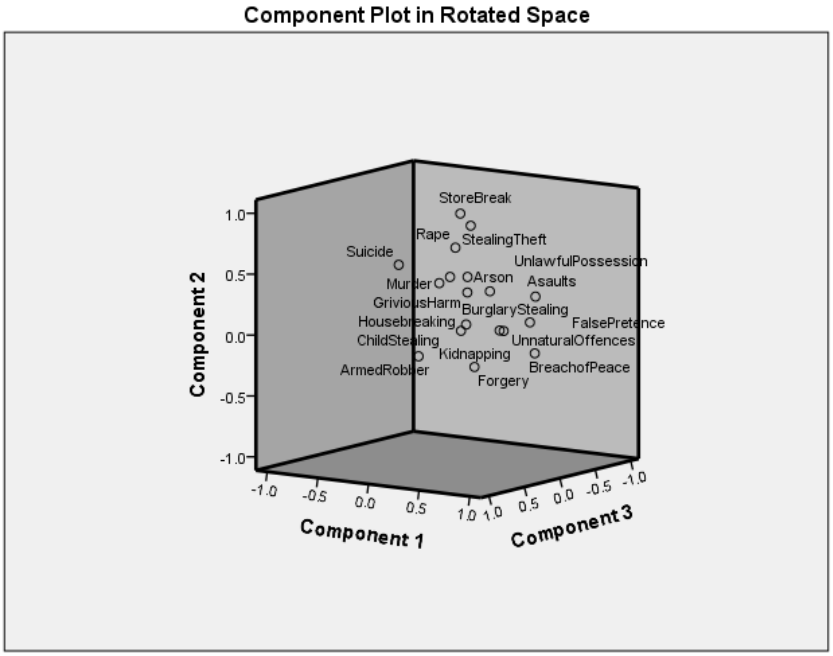
Component 5 identify Arson and Child Stealing and Component 6 identify no specific crime as prevalence.

Table 5: Eigen Vectors: Components Factor Estimates.

Component Matrix[a]						
	Principal Component					
	1	2	3	4	5	6
MURDER	**0.760**	0.137	-0.257	-0.066	0.137	0.348
ARMED ROBBERY	0.438	-0.340	-0.481	0.209	-0.189	0.427
SUICIDE	0.267	0.455	-0.496	**0.532**	-0.061	0.154
GRIVIOUS HARM/WOUNDING	**0.652**	0.184	0.068	0.231	-0.376	-0.082
ASSAULTS	**0.796**	-0.060	0.199	0.061	-0.138	-0.352
BURGLARY/STEALING	0.111	0.333	**0.842**	0.178	0.053	0.154
STORE BREAKING	0.492	**0.763**	-0.043	0.106	0.195	-0.203
HOUSE BREAKING	0.469	0.035	-0.050	**-0.775**	-0.018	0.216
STEALING/THEFT	**0.603**	**0.583**	0.132	0.149	0.273	-0.113
RAPE/INCEDENT ASSAULT	**0.770**	0.497	-0.071	0.008	-0.013	0.165
KIDNAPPING	**0.790**	-0.422	-0.240	-0.038	0.039	-0.135
FALSE PRETENCE/CHEATING	**0.778**	-0.236	0.035	-0.140	-0.191	-0.276
UNLAWFUL POSSESSION	0.230	**0.656**	0.313	-0.386	-0.266	0.198
ARSON	**0.531**	0.024	-0.332	-0.298	**0.598**	-0.152
BREACH OF PEACE	**0.719**	**-0.536**	0.114	0.040	-0.193	-0.255
FORGERY	**0.515**	**-0.532**	0.469	0.097	0.090	0.427
CHILD STEALING	0.181	-0.392	0.281	0.224	**0.671**	0.071
UNNATURAL OFFENCE	**0.759**	-0.300	0.203	0.104	-0.087	0.094
Extraction Method: Principal Component Analysis.						
a. 6 components extracted.						

The Plot below shows the distribution of the Crimes based on the Components extracted. It take the structure of the cube due to the fact six components were extracted and all the components were represented in the plots. As displayed in the plot above, all the crimes were represented in the Component 1. It implies that, component 1 has a positive relationship with all the crimes associated with the state. We expect increase crime rate in the location represented by component 1. Therefore, Oyo state government and the Police officers need to work hard in order to curtail these menace as urgent as possible since the tendency of increase in Crimes or offences is highly significant.

Fig 2: Rotated Plot



V. Conclusion

The findings in this work revealed that, crime rates in Oyo state will drastically increase if care is not taken.

Component1 can be viewed as a measure of how unsafe the location (Oyo state) is in terms of Crime rates because most of the major crimes increases with the component 1.Component 2 can be viewed as a measure of common and uncommon crimes in this location (Oyo state). Forgery and Unlawful possession decreases and Store breaking and Stealing/Theft is increasing.Component 3 suggested Burglary/Stealing as the daily offence in Oyo state. Component 4can be viewed as measure of new common offence while the other offence is becoming history or reducing. Component 5 identify Arson and Child Stealing. Component 6 does not specify any peculiar crime. This components helped us in identifying the distribution of crimes committed in Oyo state.

Thus, identifying the distribution of these crimes in Oyo State will allows the investors, tourist and travelers to measure the level of risk and to plan preventive measures for safeguarding their investments, property and lives.

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