BOMBINGS AND VIOLENCE ON MINDANAO: A FRACTAL ANALYSIS

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ABSTRACT

Spatio-temporal data obtained from 1980 to 2013 on the incidence of bombings in Mindanao were subjected to fractal analysis. The inter-bombing times were analyzed through a multi-fractal formalism introduced by Padua (2012) while the spatial data were plotted as points on the map of Mindanao. Results revealed that there is a substantial, albeit, geometric escalation of terrorist attacks through bombings in the last fifteen (15) years. In terms of the inter-event times, fractal analysis showed that the time intervals between bombings are getting shorter (from the previous 6 months to as short as 1 day). Geometric fractal analysis similarly revealed that bombings are targeted to sustain maximum damage in areas defined by triangles whose vertices are found in Davao City, Zamboanga City, Jolo/Sulu/Basilan, Cotabato, Lanao and General Santos City. Relative roughness analysis also demonstrated a 200% increase or double the number of bombings in the period 2000-2013 as compared to the two decades covered in the period 1980-1999. The forces that shape the fractal dimension of hostilities and bombing incidents in the last fifteen years are discussed in the paper.

Keywords: *terrorism, fractal analysis, inter-event times, multifractal formalism.*

1.0 Introduction

The spate of violence and bombing incidence on Mindanao, the southern island of the Philippines, is of serious national security concern. The spatio-temporal distribution of these incidences appear to be random and without discernible patterns but it is quite possible that there are hidden dimensions (not immediately obvious) that could aid those in the country's national intelligence and security agencies to formulate an effective strategy to minimize, if not, forestall the occurrence of similar violent incidence in the future. Over 40 major bombings against civilians and civilian property have been carried out by radical Islamist groups and separatist forces since January 2000 in the Philippines.

Numerous bombings have also been carried out in and around Metro Manila, although several hundred kilometers from the conflict in the southern regions, due to its political importance. In the period from 2000 to 2007 attacks killed nearly 400 Filipino civilians and injured well over one thousand five hundred more (Banlaoi, 2009), more casualties than these caused by bombings and other attacks in Indonesia, Morocco,

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Spain, Turkey, or Britain during the same period.

In this paper, we adopted the definition of terrorism used by the United Nations General Assembly Condemnation (1994) as *"Criminal acts intended or calculated to provoke a state of terror in the general public by group of persons or particular persons for political purposes or any unjustifiable circumstance in considerations of a political, philosophical, ideological, racial, ethnic, religious or any other nature that may be invoked to justify them"*. Most of terrorism in the Philippines are based on political conflicts conducted by rebel organizations, mainly, the Islamist separatist forces.

Just when and where the next bombing incident would take place on the island are questions of immediate concern both for disaster-preparedness and national security concerns. The usual model in stochastic processes is used to analyze the "when" question. It is the Poisson model (Ross, 1987)where the occurrence of bombings are assumed to be Poisson distributed while the inter-bombing times obey the exponential distribution. In such models, interest lie on the mean and variance of inter-event times. However, the model is based on very restrictive assumption that the arrivals obey a specific Poisson model. Along this concern, other authors have proposed entirely different approaches to the problem.

Telesca et al., (2004) hinted on the use of fractal analysis in the case of seismic data (inter-event or inter-earthquake times) gathered from three(3) locations in Italy. Investigating into the patterns of seismic sequences revealed evidence of time-scaling features.

This was shown in the fractal analysis of the 1986–2001 seismicity of three different seismic zones in Italy. Describing the sequence of earthquakes by means of the series of the inter-event times, power-law behaviour has been found applying Hurst analysis and de-trended fluctuation analysis (DFA), with consistent values for the scaling exponents. The multi-fractal analysis has clearly evidenced differences among the earthquake sequences. The Legendre multi-fractal spectrum parameters (maximum A_0, asymmetry B and width), derived from the analysis of the shape of the singularity spectrum, have been used to measure the complexity of seismicity.

In this paper, we propose to use a simpler version of the Legendre multifractal spectrum as proposed by Padua (2012). This same version was used by Padua et al., (2013) in the analysis of earthquake data for the Philippines. Meanwhile, the "where" question is approached through Geometric fractals. Fractal geometry, the original impetus for fractal analysis, was introduced by Benoit Mandelbrot (1967) in his book : Fractals and the Geometry of Nature. Mandelbrot posited that while classical geometry or Euclidean geometry focused on smooth, continuous and regular objects, nature is a strong motivation for developing models that would describe its inherent ruggedness and irregularity. Crucial to this modelling is the notion of a dimension viz., that it is possible to construct real geometric objects whose dimensions are fractional rather than integral. Fractal dimensions (λ) represent the ruggedness of an object: the higher they are, the rougher are the objects.

2.0 Fractal Spectrum

In this section, we provide a brief

overview of fractal spectrum as modified by Padua (2012). This fractal spectrum will be the main analytic tool for analyzing the occurrence of inter-bombing times in the island of Mindanao.

The utility of multifractal analysis in the analysis of seismic data in Italy was demonstrated by Lapenna et al., (2003), in the Philippines by Panduyos and Padua (2013), and in other countries by various authors. Of these multifractal models of seismic data, the main tool used was Legendre's multifractal spectrum which essentially involves finding a sequence of multifractal manifolds which can be expressed in terms of power laws. In Padua and Barabat (2013) a simple multifractal spectrum $\lambda(s)$ was found useful in fractal data analysis.

A useful device for examining multifractal observations is the multifractal spectrum. The current multifractal spectrum in use is Legendre's spectrum but its application is largely confined to scientists in specialized fields because of its complexity. Padua (2013) suggested a simpler version of a multifractal spectrum, namely:

$$\lambda(s) = 1 - s\log\left(1 - F(x)\right), \qquad s = \frac{1}{\log\left(\frac{x}{\theta}\right)}$$

$$\lambda(s) = 1 - \frac{\log(1-\alpha)}{\log\left(\frac{x}{\theta}\right)} \quad , \theta \geq x, \quad \alpha = F(x)$$

that behaves in exactly the same way as Legendre's spectrum. Thus, monofractal $\lambda(s)$ - spectrum is a cluster of points or a single point while multifractal spectra are single–humped, continuous functions of scales. The fractal spectrum was shown to be a one–to–one function, monotonically increasing with x on a logarithmic scale for non – fractal distributions. Instead of examining the observations on the data space, we propose to examine them in the spectral space. The value of θ used in (8) serves as a powerful "microscope" that enhances the detailed picture of the spectrum $\lambda(s)$ in terms of its finer structures. A typical multifractal $\lambda(s)$ spectrum is shown below:

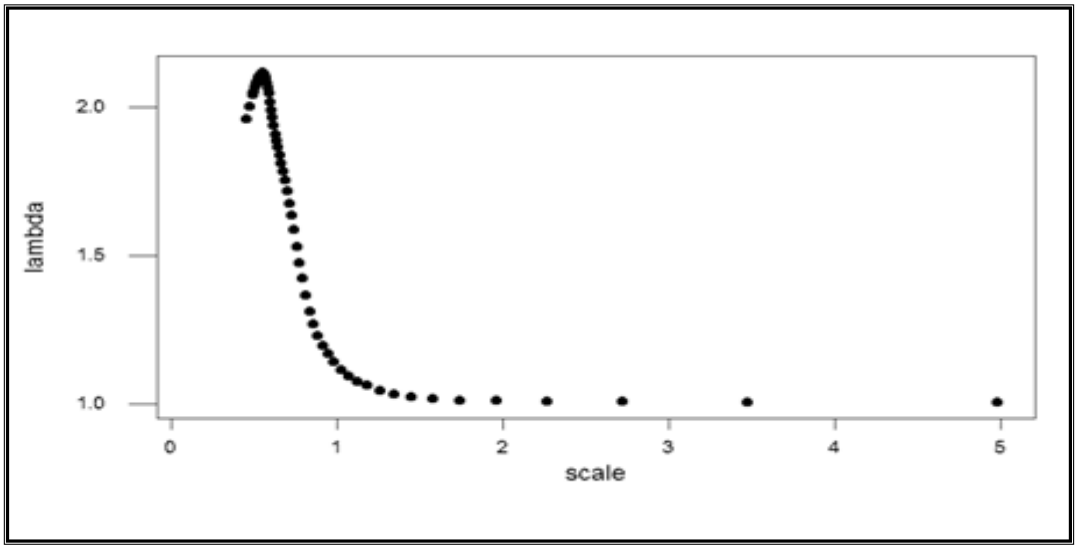

Figure 1. Plot of fractal dimension versus scale for earthquake magnitudes

Note that the multifractal spectrum is a single-humped continuous function of scales. This was also mentioned in the work of Lapenna et al., (2003) using the Legendre spectrum method.

3.0 Research Design and Methods

Data for the bombing incidents in Mindanao were obtained from various sources but mainly through a trace of the newspaper headlines dating as far back as the 1980's. We noted the places and dates of occurrences of bombings (but not the number of fatalities).

Spatial Analysis

Spatial analysis of the data proceeded in the following manner: We divided the observations by periods: 1980-1999 and 2000-2013. We then plotted the bombing locations on a map (of Mindanao) downloaded from the NET for each of the time periods. The two (2) dimensional graphs were then subjected to a fractal analysis using the FRAKOUT.com software available free from the NET. In order to do this, the images were converted into files whose extensions were either PNG or BMP prior to inputting them into the software. The resulting fractal dimensions were then compared for complexity analysis.

Temporal Analysis

Temporal analysis of the data set was performed using the multi-fractal formalism introduced by Padua (2012). The inter-bombing times were computed and subjected to a fractal analysis. The fractal spectrum was determined using Equation (8) and the spectral parameters: maximum A, asymmetry B and width W derived from the analysis of the shape of the singularity spectrum. These have been used to measure the complexity of the inter-event times.

4.0 Results and Discussions

The time series plot of inter-bombing times is shown below:

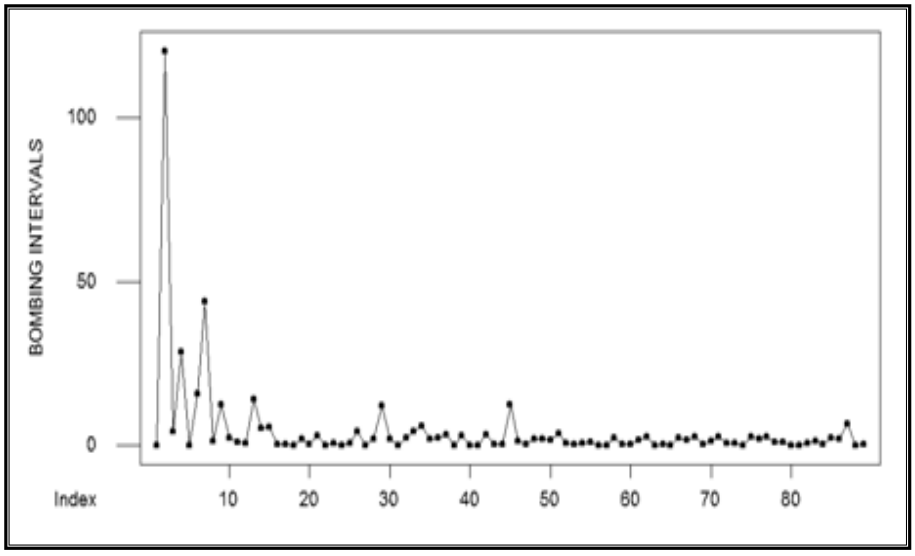

Figure 2. Time Series Plot of Inter-Bombing Times

The time series plot shows evidence of multifractality. In the period from 1980 to 1997, the intervals between bombings were longer, thereafter, getting shorter and shorter, and thus, becoming more frequent. These indicate escalation of terrorists attacks on Mindanao by the Islamic extremist groups. Peace agreements between these groups and the Philippine Government appeared to have had no appreciable impact on the cessation of terrorism on the island. In fact, data appeared to support the opposite conclusion: that once a Peace Agreement with one group is signed, a break-away group or another group would begin to escalate terrorism mainly on the disputed areas of the region.

There also appears to be some pattern evolving in terms of the "month" in which the bombings occurred. Table 1 shows the summary of the frequency of occurrence per month over the period of study:

Table 1. Frequency of bombings on Mindanao per month

Month	Freq.	%	Month	Freq.	%
Jan.	7	6.54	July	9	8.41
Feb.	10	9.35	Aug.	6	5.61
March	8	7.48	Sept.	5*	4.67
April	**18**	**16.82**	**Oct.**	**14**	**13.08**
May	11	10.28	Nov.	4	3.74
June	5	4.67	Dec.	10	9.35
Total	59			50	

If the choice of the month for terrorism were truly random, then each month would have 8.33% probability of being the target month. Tabular values, however, show that the month of April is almost twice as likely as the other months to be the favoured "bombing month" followed by October. We are unable to explain why these months are the favoured months for terrorism but they happen to be months when students are on school holidays in the Philippines and the target places for bombings are often busy markets, bus stations, bars and the like.

The geometric fractal dimension using the FRAKOUT software is $\lambda = 1.1382$ while its statistical fractal dimension using the maximum likelihood estimation procedure is $\lambda = 1.1329$. The latter estimate of the fractal dimension is more accurate than the geometric fractal since the former is affected by pixel sizes and computer limitations.

Variable	N	N*	Mean	StDev
lambda	81	8	1.1329	0.0895
THETA = 0.001				

Figure 3 shows the fractal spectrum of the computed fractal dimensions:

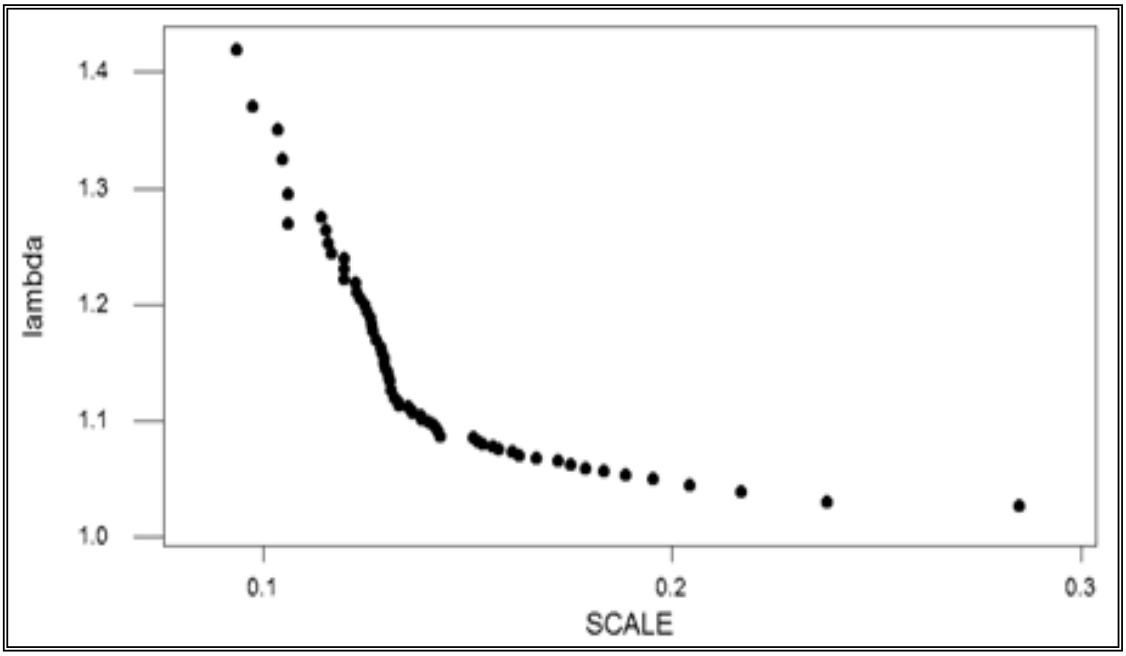

Figure 3. Fractal Spectrum for Inter-Bombing Times

The fractal spectrum shows evidence of multi-fractal distribution (instead of a mono-fractal distribution). The histogram of the fractal dimensions (Figure 4) computed also confirms this hypothesis. The multi-fractal distribution of the fractal dimensions implies at least two (2) operant fractal dimensions: one operating at the lower scales (from 0 to 0.10) and another at higher scales (higher than scale = 0.10).

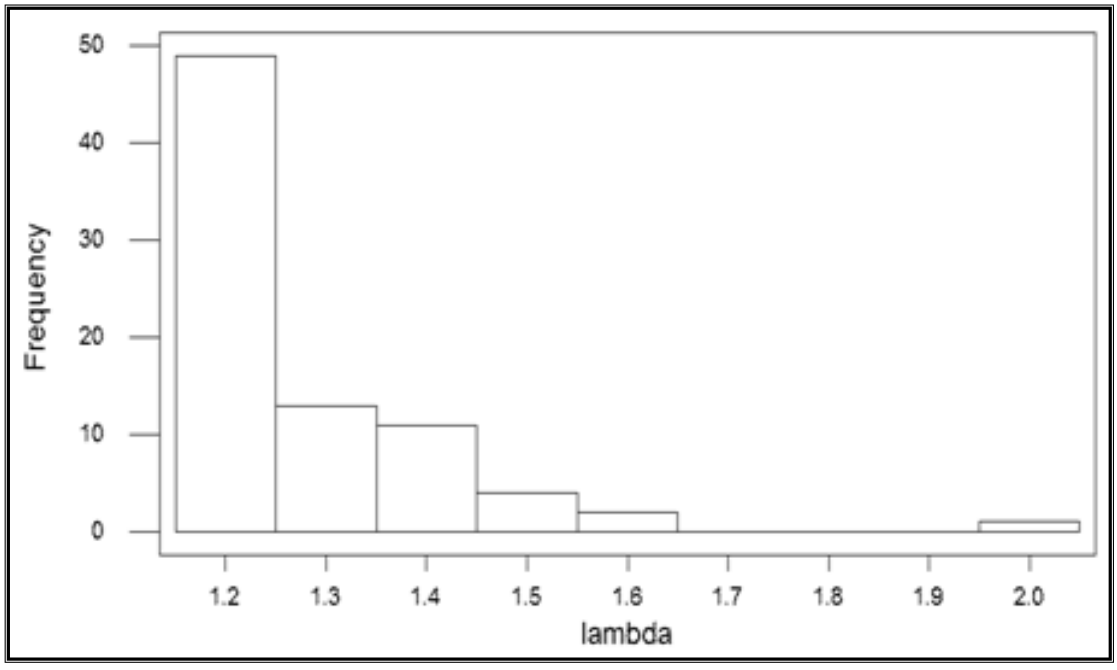

Figure 4. Fractal histogram for inter-bombing times

Spatial Analysis

The graph shown below represent the bombings that occurred on the island from 1980 to 1999 The fractal dimension calculated is λ = 1.3680.

Since there were less than 20 bombing incidents in these two decades, the lines connecting areas where consecutive bombings occur appeared smoother and less disarrayed.

The graph representing the bombing incidents from 2000 to the first half of 2013 (a period of 14 years) is shown. Note how much more chaotic the lines appear. The computed fractal dimension is λ = 1.8752

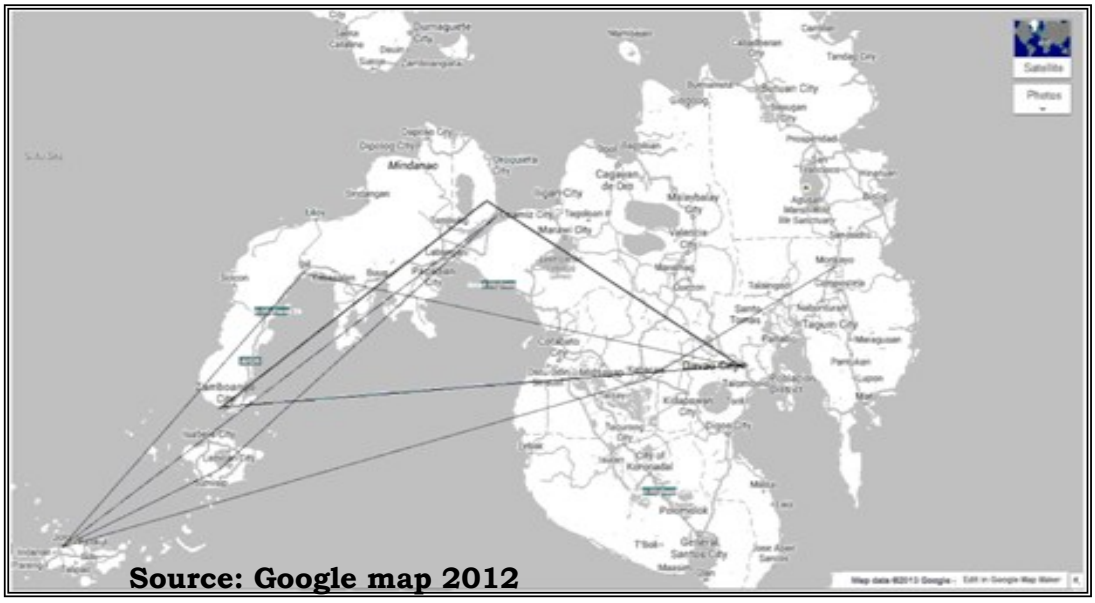

Figure 5. Incidence Map for Mindanao Bombings 1980 to 1999: λ = 1.3680

Figure 6. Incidence Map for Mindanao Bombings 1999-2013: λ = 1.8752

To compare the roughness of the graphical representations of the bombing incidence we define the relative roughness index:

Relative Roughness = $(\lambda_2-1)/(\lambda_1-1)$ x 100%

In this case, RR=237.826%, that is, the second graph is about 238% rougher than the first graph despite the shorter period of observations for the second graph. Expressed in another way, the relative roughness index indicates over 200% intensification of the terrorists attacks on Mindanao. Terrorism has indeed tremendously escalated in the last fifteen years.

Spatial comparison of the two incidence maps likewise revealed interesting patterns. In the first and smoother graph, we find two (2) triangular configurations. The smaller triangle has vertices in Davao City-Zamboanga City—Zamboanga del Sur while the bigger triangle has vertices in Davao City-Zamboanga del Sur and the islands of Basilan, Sulu. In the second more chaotic graph, we find the same two triangles in Graph 1 but with more crisscrossing lines in them and the emergence of a third triangle with vertices in Davao City-General Santos City and the provinces of Basilan-Sulu. These spatial features of the two graphs appear to demonstrate that: (1) terrorist attacks have specific targets represented by the vertices of the triangles; (2) locations inside Fractal analysis of the bombing incidences on the island of Mindanao revealed that there is tremendous terrorist attacks on the island within the last decade in the three (3) specific target areas covered by Davao City, Zamboanga City, Zamboanga del Sur, Cotabato-General Santos, and Basilan-Sulu. The temporal fractal distribution of the bombings is a manifestation of terrorists' urgent desire to obtain what they want despite of the various Peace Agreements signed by the Philippine Government and the various Islamic groups.

Discussions and Peace Agreements 1980-1999

The war for peace in Mindanao predates the data sets that we have gathered. In fact, more violence and terrorist attacks can be noted prior to 1980 under the Marcos regime kicking off with the infamous Jabidah massacre in the early 1970's. The deposed Libyan leader Muammar Gaddafi brokered an agreement that culminated in the signing of the Tripoli Agreement which introduced the concept of an Autonomous Region of Muslim Mindanao (ARMM) in 1976. The agreement became enshrined in the 1987 Philippine Constitution and enacted by Republic Act 6734. The smoother features of the graph representing the occurrence of bombing in the period 1980 to 1999 may therefore, be attributed to the "honeymoon" period after the signing of the Tripoli Agreement between the MNLF and GRP.

Indeed, with Gaddafi's assistance, the Philippine government was able to sign the Final Peace Agreement with the MNLF in 1996 in what was supposed to be the end of the Moro armed struggle in Mindanao. Misuari was elected governor of the ARMM and was made responsible in the implementation of the peacepact. Unfortunately, other factions within the MNLF were not satisfied with this peace pact and saw this as a deviation from the Framework of the Tripoli Agreement.

A group of officers led by Hashim Salamat broke away and formed the Moro Islamic Liberation Front (MILF) in their desire for complete secession from Philippine sovereignty to continue their armed struggle for an independent Bangsamoro (Moro nation) in Mindanao.

1999-2013

The exploratory talks between the government and the MILF began in August 1996, followed by low-level negotiations starting January the following year. Ramos' term as president ended in June 1998, but the low-level negotiations pushed through under the new administration of President Joseph Ejercito-Estrada. By October 1999, the formal peace talks would begin, only to be suspended by Estrada's sudden policy -shift by waging an "all-out war" against the MILF. Terrorist attacks commenced with a vengeance as evidenced by the graph of the bombing incidents in the period 1999 to 2001.

When Gloria Macapagal-Arroyo became President in 2001, a unilateral declaration of ceasefire on the part of the Government became the basis for a revival of the peace process. On March 31, 2001, Republic Act 9054 lapsed into law without the signature of the president. This law amended the Organic Act of the ARMM to provide for the region's expansion from the original four provinces. However, only Marawi City and Basilan (excluding Isabela City) voted to be included in the ARMM. Later that year, violence ensued when the military attacked the MILF after reports that the MILF has been aiding the Abu Sayyaf terrorist group which held American and Filipino hostages. Again, the bombing incidents in the period 2001-2003 have intensified for the above cited reasons. A final draft of the peace agreement was presented to the leaders of Congress on February 10, 2003, but on the next day, a set back would ensue as the military launched an offensive in Buliok Complex against the MILF which would last for more than a week. Ceasefire was enforced three weeks later. It appeared that the peace process had to begin again at square one. By March, the parties re-initiated exploratory talks in Malaysia with a commitment from both sides for a "mutual secession of hostilities." The aspect of a Muslim ancestral domain was laid down as the next agenda for the peace talks. Until the end of 2008, the peace process remained in a deadlock due to constitutional and legal issues surrounding the ancestral domain aspect.

On July 27, 2009, the parties drafted a Memorandum of Agreement on the Muslim Ancestral Domain (MOA-AD) in Malaysia. Under this agreement, some 700 villages in Mindanao would vote within a year to determine if they wish to join the "Bangsamoro Juridical Entity". Three days before the scheduled signing of the MOA-AD, local officials of North Cotabato filed a case asking the Supreme Court to block the signing of this agreement. The Court voted to strike down the MOA-AD as unconstitutional. The junking of the MOA-AD sparked another round of bombings with the armed conflicts for the year 2008 reaching a *record-high of 30 incidents in Mindanao*.

Back to the drawing board, the parties set out for yet another round of exploratory talks to draft a document entitled: "Decision Points on Principles". As spelled out, a "new autonomous political entity" governed by a "ministerial

form of government" will replace the current ARMM through a mechanism dubbed "institution of transitional mechanisms" under the new entity. On October 15, 2012, the Philippine government signed a much-hyped document touted as the *Framework Agreement on the Bangsamoro*, which culminates the Aquino Administration's effort to end the deadlock in the peace process. The absence of the de factor MNLF leader Nur Misuari in the signing ceremony was conspicuous and telling. Failing to intuit on the psychological impact of the formulation of a document without Misuari's presence, the Government practically paved the way for rebellion by the MNLF. This new document announces that the status quo is unacceptable and that the Bangsamoro shall be established to replace the Autonomous Region in Muslim Mindanao (ARMM). According to President Aquino, this is the agreement that "can finally seal genuine, lasting peace in Mindanao. Almost a year later, Zamboanga City was attacked by the MNLF (September 9, 2013) and hostage areas of the city for more than two weeks: an event which could have been prevented prior to the signing of the Framework Agreement on the Bangsamoro. Thus, from an inter-bombing time lasting for more than a year, the inter-bombing incidents deteriorated to less than a day.

It can be deduced from all these review of the various peace efforts in Mindanao that the causative factor explaining the higher fractal dimension of the second map of bombing incidence is the heightened desire by MNLF/MILF to claim parts of Mindanao as their territory. It is fuelled by the following: (a.) sudden policy shifts on the part of the GRP, (b.) formation of break-away groups among the MNLF/MILF main group whenever peace agreements are inked; (c.) internal leadership disputes from the main groups of MNLF and MILF; (d.) palliative policies rather than clear-cut policies on the Mindanao conflict.

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