Assessing the Effectiveness of "Carrots and Sticks" Approach on Terrorists' Strength and Sustainability: A Mathematical Deterministic Model

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Abstract: **- In an effort to marshal resources toward building coalition against international terrorism, countries and international bodies heavily rely on strategies that such as the "sticks and carrots" approach to change the incentives of both the terrorists and their supporters. This study presents a novel mathematical deterministic model whose variables are parameters of the internal and external dynamics of the organization: analytically and numerically solve to study the dynamical evolution of the terrorists' strength under the simultaneous interdiction the leaders and foot-soldiers. The result shows that, though the "carrots and sticks" may be cost intensive and challenging, yet it has the propensity to drive the growth rates and the terrorists' strength to a vulnerable value. Significantly, the study also revealed that the "carrots" approach only has propensity of interdicting more recruiters' class than otherwise. However, taking a fifty year forecast of the terrorist evolution indicates that, the war on terror may take longer than necessary to accomplish by "carrots and sticks" approach only. Given the veracity of our model, it should be possible to evaluate the efficacy of the various policies of government and hence measure the degree of success or failure of a given counterterrorism measure.**

Key words: **"Carrots and Sticks" approach, Mathematical deterministic model, counterterrorism**

I. INTRODUCTION

Insecurity and terrorism, in particular has been a major driving force behind the deplorable socio-economic and political development and the escalation of institutions of organized crimes in most countries of the world, especially, African countries, in recent times. Methods to finding a long term solution to the hydra-headed problems of terrorism by relevant world governments in the last decades can be psychologically categorized into two major approaches: the *"Carrots"* and the *"Sticks"* or tactically, the "Water" and *"Fire"* strategies. Modern terrorism, though hidden under ethnicity and religious ideology sentiments to garner moral supports, recruit operatives and spread its erroneous propagandas, its cardinal objective is purely political. Hence, methods that are devoid of parochial, ethnic and religious sentiments would yield a more credible and result-oriented counter-terrorism (CT) measures.

Research findings over the last decades suggest that most of the approaches employed by relevant world governments to counter terrorism and terrorist activities, falls under the conventional warfare strategies (stick or fire approach), with very minimal consideration to the "Carrots" or "Water" approach, mostly at extreme cases when terrorism boil-down to "kidnapping for ransom" and hostage taking. The "carrots and sticks" approach; a social science metaphor for "reward" and "punishment" or "positive incentives" and "negative incentives" system, date back to Pavlov traditional theory of motivation[25]. According to the proponents of motivation theory of counter-terrorism[2],[45],[55], though very challenging and cost intensive to implement, "carrots" and "sticks" can elicit compliance or cooperative behaviour from adaptable adversary. Similarly, in civil conflict situations, conciliatory and coercive effort of the state can elicit cooperative behaviour from contending parties.

A theoretical study observes that, when participation in group activities is optional, punishing uncooperative behaviour is the cheaper method[3],[47].The philosopher John Locke once wrote:*"good and evil, reward and punishment, are the only motives to a rational creature"*[38]. Although Locke was referring primarily to the discipline of children, reward and punishment are motivational forces for behaviour across many domains of social life. Understanding the consequences of such 'carrots and sticks' is a core topic in the behavioural sciences, particularly in studies of cooperative behaviour that benefits others or the group at a cost to the cooperating individual [3],11]. Many problems in modern human societies, from interactions in the workplace to tackling civil conflicts, require genetically unrelated individuals to cooperate in situations in which collective welfare is jeopardized by few individuals or individual self-interest. *So how do rewards and punishments curb selfishness and help elicit compliance or cooperative behaviour among contending parties in civil conflicts like terrorism?*

Theoretical and experimental research on the evolution of cooperation has concentrated on punishment, with relatively few studies investigating reward[3],[47],[50],[53]. Furthermore, most studies have focused on 'peer punishment',

in which defectors are punished by group members [3],[11],[20],[40],[47],[50],[53]. However, the findings of peer-punishment studies may not be broadly applicable to modern human societies, which have developed formal sanctioning systems, where by rewards and punishments are carried out by rule-bound institutions rather than by individuals. Sasaki *et al*[49]address this with a theoretical assessment of how institutionalized reward and punishment systems regulate cooperative behaviour, and at what relative cost. The authors used evolutionary game model analysis to compares an institution that rewards cooperators and another that punishes defectors (non-cooperators). Their analysis used the 'public goods game', in which people can either cooperate or defect, and in which cooperation is collectively beneficial, but defection is better for self-interest. The authors studied reward and punishment under two conditions: in one, all individuals were forced to take part; in the other, participation was voluntary. The authors found that during compulsory participation the two incentives (punishment or reward) lead to the same outcomes if they are very small or very large. It seems that if either of the incentives is too small, cooperation cannot be achieved because a population of cooperators can be invaded by defectors. If they are large enough, both types of incentive can lead to a population of cooperators. However, differences arise when the incentives are of only intermediate value. Punishments of intermediate severity produce stable populations of either defectors or cooperators, whereas rewards of intermediate value lead to stable mixed populations in which only partial cooperation is achieved.

The authors then changed the rules of the game to allow individuals to opt out, which causes the outcomes to change remarkably. The game now considers three strategies: non-participation, defection and cooperation. In the game, very small incentives lead to an unstable pattern of non-participation with eruptions of cooperation. When the incentives are very large, a stable uniform population of cooperators emerges - as it did during forced participation. The most remarkable outcome of the study occurs when intermediate incentives are offered and participation is voluntary. In such a situation, slightly increasing the severity of punishment above very low level resulted in stable populations of cooperators. By contrast, rewards of at least medium size are needed to cause a shift in the population from a majority who opt out of participation to a stable mixture of cooperators and defectors. When participation is voluntary, only very large rewards could generate a stable and uniform population of cooperators. In conclusion, the author observed that *"people learn by observing others and they emulate successful individuals, so strategies that yield greater pay-offs proliferate, and vice versa*"[49].

This noteworthy theoretical finding has practical implications. Sasaki and colleagues' model can be used to determine the size of the incentive needed to achieve a stable level of cooperation. However, the authors' analysis does raise several issues that are relevant for understanding modern human societies. First, they show that voluntary participation crucially influences the relative cost of reward and punishment. But in modern societies, people can hardly opt out of the law. This might suggest that the results of games played with enforced participation are more applicable. Second, real-life institutions do not work perfectly; for example, punishment or reward may not be correctly implemented. It remains unclear how these imperfectly applied incentives might affect cooperation. Third, law enforcement in reality typically relies on punishment rather than reward. This study may have identified a reason why punishment has become the default in counter-insurgency strategy in most democratic societies - because punishment is a cheaper and more reliable way of inducing cooperation than is reward.

Other studies of human behaviour have also found that cooperation is strongly influenced by changes in the size of the incentive[40]. In experimental studies, reward and punishment induce similar levels of cooperation when the incentive is very large[47],[53]. The threat of a strong punishment can achieve cooperation at a very low cost[20]. For an intermediate level of incentive, punishment can induce greater cooperation than reward[53], but not consistently so[49]. Finally, cooperation breaks down rapidly if both forms of incentive are removed[11]. Although these studies were conducted in settings of forced participation and peer punishment (or reward), their findings are encouragingly similar to Sasaki *et al*[49]theoretical analysis. These similarities suggest that experimental analyses conducted in a manner closer to the framework of Sasaki *et al*[49], might further enhance our understanding of how reward and punishment can elicit behavioural compliance or cooperation in a democratic society. The political scientist Mancur Olson recognized the importance of reward and punishment for cooperation when he argued in his seminar 1965 study that *"the recalcitrant individual can be ostracized, and the cooperative individual can be invited into the center of the charmed circle"*[43]. But Olson, Locke and other early scholars who wrote about reward and punishment in human social affairs relied on casual observation and introspection.

Thus, in an effort to marshal resources to build coalition against international terrorism, countries and international bodies heavily rely on strategies that are intended to change the incentives of both the terrorists and their supporters. The most prominent strategy among these is the "sticks and carrots" approach which is often employed in the form of economic sanctions against alleged terrorist sponsor states; economic assistance and military aids for the terrorists' home countries. Economic sanctions remain important since the early days of the UN sanctions against Iran in 1980, sponsored by the United States. Similarly, aid has become an increasingly popular weapon in the fight against terrorism, especially in the aftermath of September 11, 2001 Al' Qaeda attacks on the World trade center in USA. The despair of people living in poverty and weak governments in developing countries are widely thought to be the underlying causes of terrorism, hence, economic assistance and military aids are

intended to uproot these problems. Notwithstanding the prominence of positive and negative incentives in actual counter-terrorism policies, little is known quantitatively about their effectiveness in inciting high internal personal drain and hence weakening the overall strength of the individual terrorist organization.

Research findings over the past decades indicates that the strength of any terrorist organization depends on its available labourpool; the success rate of previous attacks to stimulate recruitment and as well as funding and education to support and execute all the activities of the various operatives' classes over time"[8],[21]. Since manpower for carrying out attacks and sustaining operations is a critical resource for terrorist organizations, therefore, ideal CT measures must go beyond responding to terrorist attacks and threats, to taking proactive steps toward crippling both its existing labour pool and as well as its recruitment machineries (strength and sustainability). Conventionally, these aims have been majorly targeted through the "stick" (punishment) approaches; however, its combined effect with the minimally used *"carrot"* approaches has rarely been quantitatively appraised. In particular, *how does the "carrots" and "stick" approaches targeted simultaneously at terrorists' leaders and foot-soldiers affect the organization's strength and sustainability?*

A great deal of research seeks to understand the consequences of counter in surgency on insurgents' behavior and organization[8],[21],[34],[44],[54], but much of these literature looks at one specific strategy, such as leadership removal (decapitation) [21],[32],[33] or multiple targeting [8],[34],[39],[54] through the dominant military offensive strategy. Some case studies suggest that conciliatory and coercive strategy have distinct effects on insurgent strength and sustainability and thus, its violence rate [8],[13], but such research is rare. This study, a preliminary work on my PhD (Applied Mathematics) research dissertation on *"Optimal Allocation of Human Resources in Counter-terrorism Operations and the Cataclysmic Dynamic of Terrorism";* takes a quantitative look at the effects of the individual *"carrots"* or *"sticks"* or a combination of both approaches on terrorist strength and sustainability.

In the study, we develop a mathematical deterministic model of counter-terrorism; where the state's strategies include the use of positive incentives or negative incentives or both to elicit high internal personnel drain within the organization; gather sufficient and credible intelligence for smart targeting of terrorist location; garner the desired moral supports and confidence for building a formidable *"in-policing"* mechanism with the locals, and de-legitimizing terrorism and its propagandas among the locals. Thereby weakening the overall strength and sustainability of the organization, and thus, rendered it grossly incapacitated to organize a successful terror attack in the longer term. To cripple both its existing labour pool and as well as its sustained support-base, the study hypothesize a formal identification and inclusion of the terrorist recruiters' class and their recruitment institutions as a pragmatic target for ideal CT operation. In the study we present a dynamic model of a terrorist's organizational structure consisting of three classes of operatives (leaders, foot-soldiers and recruiters). The model which uses a set of coupled differential equations to describe the structural evolution of a terrorist organization in its simplified terms, aimed at examining how the numbers of terrorist operatives in the organization changes over time under a given *CT strategy*, thus, casting our empirical-based knowledge in precise mathematical language.

Our target is to derive an analytical model of terrorism that would help to degrades or render dysfunction a given terrorist organization, while also serving as a quantitative metrics for evaluating the degree of accomplishment or otherwise of a given CT measure. Refinement of our ideas should enable security agencies to able to state emphatically, for example, that they are 85% certain that they have destroyed or captured or weaken the strength of the terrorist group under investigation; and there is still a 15% chance that terrorists might commit another deadly attack. The study has the potential to inform both scholars and CT policy makers on the optimal strategy for allocating the available CT resources towards effective CT measures. The simplicity of our model should hopefully make it an attractive target for extensions by enterprising students of military operations Research (OR) and dynamical systems analysis. The study also has the synergy to demonstrate that, terrorism though complex and divergent a socio-economics system is an area where mathematical methods can make an impact in a variety of targets and research problems.

1.1 Relevant Academic Literature

There is unfortunately scant relevant literature on the question: *how do the "carrots" or the "sticks" or a combination of both approaches impact on terrorist organizational strength and sustainability?* Bandyopadhyay and Sandler[5] consider how preemption and defense interact with each other. For example, they noted that high-cost defenders are likely to rely more heavily on preemption, while too little preemption *"may exacerbate the problem of excessive defense-by making for an even more insecure environment."* Elsewhere, however, other researcher, noted that *"offensive actions against terrorists and their supporters", while possibly effective at diminishing terrorist strength, do not seem to be cost effective* [48], given their high expense relative to the current magnitude of the terrorism problem. Bier et al [6], consider the option of making attacks more costly for terrorists, but do so in a way that treats *"carrots" and "sticks"* symmetrically - an assumption which is almost certain to be violated in practice. In another development, other researchers also pointed out some of the key differences between deterrence of terrorism through the threat of retaliation and other alternative strategies for protection, such as making oneself less vulnerable, or providing incentives for cooperation[19],[20].

1.2 The Carrot Approach to Counter-Terrorism: General Concepts and Historical Examples

Positive incentives (carrots) could for example consist of providing goods and services, or valuable opportunities to persons or groups of persons that refrain from terrorism - making non-terrorist activity more attractive [19]. Examples of positive incentives can include: direct monetary transfers; economic assistance (e.g. lucrative job placement, educational scholarship opportunities, etc.); provision of goods, services, and opportunities; lifting of sanctions; period of seize-fire, amnesty program, suspension of prison sentences, rehabilitation and reintegration programs, and removal of taxes or customs duties. Negative incentives (sticks) are also intended to increase the cost of terrorism to potential terrorists, by such means as imposing trade restrictions, freezing the terrorist's assets, arrest and assassination of operatives; restricting how the terrorist operates, and retaliating militarily. However, we consider the possibility that such negative incentives could perversely alter the terrorist's intrinsic motivation to attack (e.g., through generating greater levels of hatred in the terrorists, potentially leading them to redouble their efforts).

Positive and negative incentives may be interpreted as income effects. Enders and Sandler [15] refer to "freezing terrorist's assets," which "reduces their 'war chest' and their overall ability to conduct a campaign of terror" - for example, by freezing their bank accounts. Lakdawalla and Zanjani[35] show that "protection reduces the payoff to terrorism";they argued that "deterrence due to income reduction takes place insofar as private self-protection raises the level of non-violent activities and lowers the total amount of violent terror investments." Finally, Hausken [24] proposes a model in which defensive investment not only helps defend the government's asset, but also reduces the terrorist's resources, so that the terrorist's attack effort becomes smaller.

In this paper, we do not explicitly discuss the issue of negotiating with terrorists, since conventional wisdom abhors negotiating with terrorists or other similar adversaries (such as rogue states). However, such negotiations have of course occurred. In particular, Spector [51],[52] discusses negotiations between Israel and the Palestine Liberation Organization; between the US and Haiti; between the US and North Korea, and between Great Britain and Sinn Fein. In particular, Spector [52] argues that *"despite the risks inherent in negotiating with terrorists, the risks of following a no-negotiation policy are likely to be more deadly. States need to assess terrorist interests and intentions to find if there are reasonable entry points for negotiation and take advantage of these to transform the conflict."* Similarly, Pruitt[46] considers both the peace process in Northern Ireland and negotiations with Islamic terrorist groups. He suggests that the success of negotiations depends on flexible attitudes on the part of both parties, and that *"there are many arguments against negotiating with terrorists, but most of them do not apply to secret, backchannel talks, which are usually the method of choice in first approaching these groups."* He also observes that *"negotiation with non-ideological ethno-nationalist terrorists is more common and more successful than with other kinds of terrorists"*.

However, we do address a closely related issue - namely, the conditions under which the state would be willing to offer terrorist positive incentives to encourage internal personnel drain through defection of operatives and as well as refrain from attacking, and when potential terrorist group or operative would be willing to accept such incentives. While controversial, this is not without precedent. For example, there is a well-established tradition of computer hackers being recruited as security experts. Presumably, the financial rewards and prestige of a successful career in computer security are sufficient to deter many former hackers from returning to their old ways (especially since their careers could be expected to continue only if they refrained from hacking), but the benefits of such collaborations also accrue to their employers.

In accordance with Pruitt[46], we anticipate that our approach would apply more readily when the needs of the terrorists are ones that can feasibly be met by the state(i.e., are not too high, or too inconsistent with the values of the state). If terrorist goals are relatively achievable in that sense (such as regional independence, or better treatment of an outcast minority or unemployment or provision of socio-economic amenities etc.), then there will obviously be more opportunity to find accommodations that are mutually be acceptable to both terrorists and the state. Since the level of positive incentives required dissuading terrorists from future attacks could well be worthwhile in order to protect locals from terrorist threats.

One argument against positive incentives is that such incentives may encourage terrorists to continue fighting, or even become a snare to attract the arrival of new terrorist group. In this paper, we assume that positive incentives are conditional and hence provided only if the terrorist decides to cooperate to surrender, lay down arms, denounce terrorism, and not to launch any more attacks. Of course, there is a risk that the state may offer positive incentives and find that the terrorists still refuse to cooperate and hence further attacks still occurs. In this regard, we make an analogy with the idea of credible threats. For example, the state may threaten massive retaliation if terrorist refuses to cooperate or an attack is launched after the terrorist has accepted positive incentives. Thus, the applicability of our model is limited to a situation that the state must have a credible threat of retaliation or other enforcement mechanism (e.g., to situations in which retaliation is not too costly, etc.)

Fatigue and attrition of personnel have been empirically found to impact negatively on the dynamical evolution of terrorist organizations. In interviews with captured or retired terrorists, reveals that they often complained about the psychological stress of their past work, its moral contradictions, and the isolation from relatives and friends [28]. This is part of the reason why terrorist organizations cannot remain inactive (as

in a cease fire) for very long time without experiencing irreplaceable loss of personnel due to loss of motivation, and many organizations even resort to coercion against desertion. In an interview with Arafat loyalist (a former terrorist, a senior commander of al-Fatah, and a Palestine brigadier general), Hoffman[26]reports two examples of positive incentives. Although they were provided by the leadership of the terrorist organizations to discipline their members, rather than by the potential victims of terrorist attacks, (the state), the example could be modify so that the state can emulate same in eliciting compliance behaviour from potential terrorist operatives.

First, after Hashemite King Hussein of Jordan sought to restore his monarchy's rule by quashing the autonomy of Palestinian organizations, killing tens of thousands of people (mostly Palestinians) from September 1970 to July 1971, Yasir Arafat formed the Black September Organization (BSO), the most elite unit of the Palestine Liberation Organization (PLO), consisting of dedicated, ruthless, loyal, and highly skilled warriors. Their first two operations were the November 1971 assassination of Jordan's Prime Minister Was fial-Tal, and the September 1972 seizure of Israeli athletes at the Munich Olympic Games (exemplifying terrorism's ability to transform a cause from obscurity to renown). Two years after, Arafat was invited to address the General Assembly of the United Nations (UN), and there after the PLO was granted special UN observer status. Having obtained international recognition, Arafat wanted to "turn Black September off"[26]. The PLO leadership used positive incentives to recruit approximately 100 attractive young Palestinian women to Beirut. As Hoffman reports, "the hundred or so Black Septemberists were told that if they married these women, they would be paid $3,000; given an apartment in Beirut with a gas stove, a refrigerator, and a television; and employed by the PLO in some nonviolent capacity. Any of these couples that had a baby within a year would be rewarded with an additional$5,000." Thereafter, the PLO provided periodic tests of these individuals' willingness to return to terrorism, but none strayed, and Black September had been effectively dismantled.

Second, the authorities in Northern Ireland pursued a similar strategy before the 2001cease-fire: *"Hard-core IRA and Loyalist terrorists (mostly in their thirties) serving long prison sentences were given brief furloughs during holiday periods"* [26].Combined with a variety of factors in prison conditions, and the possibility of early release, the objective was to allow these to develop family ties, and *"wean these men from terrorism."*According to Hoffman, *"the program was so successful that the option could be offered to only a limited number of prisoners, lest the terrorist organizations, fearing the loss of too many senior veterans and commanders, forbid their members to participate in the program"*. The lesson to be learned, the author argues, is that *"creative thinking can sometimes achieve unimaginable ends." "Rather than concentrating on eliminating organizations, as we mostly do in our approach to countering terrorism. We should perhaps focus at least some of our attention on weaning individuals from violence"*.

Another example where it is reasonable to assume that positive incentives could weaken the terrorist's strength and or prevent or reduce the frequency of terrorist attack, is the amnesty program employed by the Nigerian state to disarmed, demobilize and reintegrate the Militant groups in Nigeria Niger Delta region. While the Niger Delta conflict may not have taken analysts by surprise, the new manifestations of the violence particularly the spaces within which they were occurring, was unfathomable in the early 2000s. The struggle over the control of the Niger Delta resources (which form 90% of Nigerian foreign exchange earnings) has not always been violent initially. Niger Deltan elders/elites, from the very beginning were interested in negotiating and dialoguing the contentious politics of oil production in the area through peaceful and non-violent approach through socio-political and ethno-cultural movements.

However, elders/elites involvement took a violent turn when the Niger Deltan youths suddenly lose confidence and trust in their elders' ability to wills government attention to the plight of the region, and thus, began to challenge the Nigerian state, oil companies, and the elites in the region. The youths became increasingly suspicious of their elders/elites who they accused of being weak, fearful, greedy and generally ineffective in obtaining concessions from government and the oil companies on behalf of the people. They therefore resolved to mobilize and engaging the state and the oil companies[30], through incessant threat and violent protests, which gave rise to many militants groups such as the Niger Delta People Volunteer Force (NDPVF), Movement for the Emancipation of the Niger Delta (MEND), Coalition for Militant Action in the Niger Delta (COMA), and the Martyrs Brigade (MB), and the spread of insurgency in the region[22],[23],[41],[42]. In response to the spreading insurgency, the state first employs the negative incentive strategy, by deploying troops of military combatant and war arsenals to protect the oil and gas facilities and as well as coerce compliance of the militants groups in the area. Nonetheless, governments' effort continued fruitless, with the formation of die-hard militant groups comprising of thousands of well-armed youths trained in covert military operations and determined to engage the forces of the state in prolonged warfare.

Amongst other demands, the militant groups sought "resource control and self-determination" by every means necessary, including kidnapping of oil workers, seizure of oil facilities, looting of crude oil, and physical engagement with security forces. After years of fruitless government efforts; including arrest, assassination and imprisonment of militants and as well threats to force the militants to long-term inactivity, the federal government under the leadership of President Musa Yar' Adua finally decided to adopt the only alternative of positive incentive strategy – the Amnesty program in 25th June, 2009. The development of the amnesty program which

came forth in pursuant of section 175 of the 1999 Constitution of the Federal Republic of Nigeria originated from the mutual cognition and recognition of the input from different key stockholders and ministries. The emphasis was on designing disarmament, demobilization and reintegration (DDR) project for any repentant or groups of repentant militants. The amnesty package include among other incentives, payment of monthly allowance, vocational skill acquisition programs, entrepreneurial training programs, foreign educational scholarship and job placement for potential repented militant. Presently, the DDR projects, which saw many ex-militant being trained in vocational skills, trades, given scholarship to study in higher institution abroad, and funded for other entrepreneurial skill programs are increasingly being used to keep post-conflict Niger Deltan from slipping back into crises and to stimulate economic growth and development the Niger Delta[12]. A result of which is bringing relative peace, security and economic development to the embattled region.

1.3 The Stick Approach to Counter-Terrorism: General Concepts and Historical Examples

The "sticks" or negative incentives are intended by the state to increase the cost of terrorism and thus reduce terrorist attacks, in an attempt to force the terrorist to refrain from terrorism or from attacking. Examples of negative incentives might include: military retaliation; termination of trade relations with countries that engage in or sponsor terrorist activities (either directly or indirectly, e.g., by providing safe havens for terrorists); imposition of (selective) trade restrictions; freezing of terrorist assets; limits on the movement of personnel, goods, and services by terrorist organizations; and restrictions on the manner in which terrorist groups can operate. However, negative incentives may be experienced either negatively or positively by terrorists. In other words, the threat of negative incentives may have either a deterrent impact, or a variety of perverse effects such as the emergence of hatred or the desire for vengeance among terrorists and their supporters, the rise of hostile groups, loss of international prestige, political instability in allied nations, etc.

Perverse effects of counter terrorism may alter terrorists' intrinsic motivation, increasing their willingness to attack. Terrorists may get the feeling that they are fighting with their backs against the wall (i.e., in "death ground"). This may inspire a redoubling of the terrorists' effort. For example, the imposition of negative incentives (military offensive on suspected terrorist locality) could incite "blowback" action and thus, increase recruitment to terrorism, or increase political support for the methods and objectives of the terrorists (which in turn could generate additional sponsors and economic support for terrorism). Commenting of counter-terrorism efforts in China and Afghanistan, scholars argues that *"containing the Xinjiang Islamist threat is likely to backfire, much in the same way containment of the Soviet Union in Afghanistan produced the ongoing blowback of terrorism"*[38]. Determining when negative incentives are likely to have a deterrent impact on terrorists' strength, and when they are likely to arouse greater antagonism, will obviously be extremely difficult in practice. In fact, even terrorists may not know when negative incentives are first imposed whether they will react with submission or vengeance. However, terrorist has a capable strength which can increase or decrease through the imposition of negative incentives.

For a historic example where it is reasonable to assume that negative incentives weaken the terrorist's strength, consider US relations with Libya. This relationship began to deteriorate when Gaddafi seized power in 1969. The US withdrew its ambassador in 1972, and Libya was designated as a "state sponsor of terrorism" in 1979. The US became increasingly frustrated over the lack of success of its covert attempts to topple Libyan president Gaddafi. Two weeks after the Berlin discotheque bombings, the US sent 30 bombers to strike Tripoli and Benghazi for 11 minutes in the early morning of April 14, 1986. The objective was to kill Gaddafi - who had been dubbed a "mad dog" by then President Reagan. The immediate outcomes were: survival of Gaddafi; hospitalization of his wife and eight of his children (some with serious injuries); and the death of his adopted daughter. In retrospect, these negative incentives appear to have been successful at deterring future attacks (weakening the terrorist's strength), since after the incident, Libya disappeared from media attention as a sponsor of terrorist attacks, while the US and Britain encouraged and funded opposition groups within the country. Eventually, Gaddafi pledged his support for the "war against terrorism", and agreed to pay compensation to the victims of the 1988 Lockerbie bombing (for which a Libyan intelligence agent had been jailed). Formal US relations with Libya were reestablished in 2006, and US Secretary of State Rice visited Gaddafi on September 5, 2008 - the first such visit since 1953[9].

Conversely, for historic examples where negative incentives can possibly boost the terrorist's strength (inspiring perverse effects such as the emergency of hatred and/or redoubling of attack effort), consider the following. First, Euskadi Ta Askatasuna (a Basque separatist organization) has killed over 800 people since 1968, despite strong negative incentives from Spain, including the current incarceration of more than 700 ETA members[14]. Second, Al-Qaeda continues to experience recruitment of new members, despite substantial efforts to curtail its activities following the attacks of September 11, 2001 on the World Trade Centre, in US. Third, consider the case of China and the Tibetan-rights activists. Chinese opposition to Tibetan freedom appears to have strengthened the Tibetan Youth Congress (founded by descendants of the 14th Dalai Lama and other Tibetan aristocrats in exile). This organization, established in 1970, now has about 30,000 members, and up to 70 branches world wide[31]. Fourth, Hezbollah (founded in 1982, and considered by many to be a terrorist organization) has built itself up over time, with lavish support from Syria and Iran, despite heavy opposition and negative incentives from countries such as

Israel. More generally, the list of active terrorist organizations continues to be long, despite substantial negative incentives against terrorism over the last decades.

II. THE MATHEMATICAL MODEL

To develop our model, we consider a potential numerical terrorists' strength$S(t)$at any time *(t)* to consist of the population of three potential classes of operatives; Leaders Y(t), Foot-soldiers X(t) and recruiters Z(t); with their differential derivatives, $Y'(t)$, $X'(t)$ and $Z'(t)$, representing their respective rate of growth. Since the leaders $Y(t)$, with their valuable skills, wealth of experience and financial sovereignty contribute more to the overall strength $S(t)$ of any organization than an equivalent number of other operative; then $S(t)$ can be taken as a weighted sum of leaders,$Y(t)$ recruiters, $Z(t)$ and foot-soldiers$X(t)$; with leaders, $Y(t)$ having more weight, say $m > 1$than other variables [21]. Mathematically,

$$S(t) = mY(t) + X(t) + Z(t) \quad - \quad - \quad (1)$$

2.1. The Birth Process of the Organization

(a)The leaders: Theoretically, from the history of Al-Qaeda, Hezbollah, ISIS and other terrorist organizations, the pool of terrorist leaders and experts $Y(t)$ grows primarily when foot-soldiers acquire battlefield experience or receive training (internally, or in terrorist-supporting states[27],[31]. Consequently, the pool of terrorist leaders $Y(t)$ is provisioned with new leaders at a rate proportional to the number of foot soldiers $[i.e.\ Y' = pX(t]$, (where the proportionality constant (p)denote the *"promotion"* process).

(b) The Foot-soldiers: Unlike the dynamic of leaders, research also shows that the growth in the number of terrorist foot-soldiers (rank-and-file) $X(t)$ through recruitment process (r) is driven primarily by two factors, (i) the intensity and success rate of terrorist propaganda, and (ii) effect of blowback action occasioned by the collateral damages and mass killing of innocent civilian population during military offensive against terrorists' cells within a locality. This often incites the spirit of disaffection and animosity among the local population and, hence causing a "blowback action". The blowback action provoke "*Herostratos syndrome*" in the disaffected youth population (the source of new insurgents).This help to pump-up new recruits and even increasing the number of new insurgents groups[4],[7].Thus, the growth in the number of foot-soldiers $X(t)$ varies with the strength $S(t)$ of the organization and with the number of commissioned recruiters $Z(t)$ as well as the recruitment and training facilities$[i.e. X' = rSt+cZ(t)$, (where the proportionality constant c denote the *"commission"* process).This assumption capture the often seen cycle where every military attacks leads to greater recruitment (increase (r)) which leads to greater strength *(increase S(t))* and more attacks from the terrorist[1],[10],[17],[18],[54].

(c) The Recruiters: Research also shows that the growth in the number of potential terrorist recruiters$Z(t)$ increases primarily when *"non-suicide"* ex-jihadists acquire training by radical religious clerics, or socio-cultural or clandestine organization; usually funded by external states or financially sovereign individuals[8]. Hence, the increase in number of terrorist recruiter varies with the strength,$S(t)$ of the organization and with the number leaders,$Y(t)$ in the organization$[i.e.\ Z' = cSt+pY(t$. This process is termed *"commission"*, $(c>0$.

2.2 The Death Process of the Organization

The growth rates of terrorist operatives are often opposed by two processes: (i) internal personnel loss due to demotivation, fatigue, desertion as well as in-fighting and splintering[28]. This phenomenon is modeled as a loss of a fraction, $(d > 0)$ of the number of operatives per unit time. (ii) Counter-terrorism measures targeted specifically at arresting, assassinations, kidnapping and as well as efforts to disrupt communications, financial asset and threat to force the operatives into long-term inactivity. We modeled this as a deduction of a fixed fraction, say, $(\alpha > 0)$from leaders, $(\omega > 0)$from the foot-soldiers and $(\sigma > 0)$ from the recruiters' classes, per unit time. Mathematically:

$$\left.\begin{aligned} Y' &= pX(t) - dY(t) - \alpha Y(t) \\ X' &= rS(t) + cZ(t) - (d+\omega)X(t) \\ Z' &= cS(t) + pY(t) - (d+\sigma)Z(t) \end{aligned}\right\} \quad (2)$$

However, in this paper we are considering the impact of boosting the internal personnel drain factor $(i.e. d \gg 0$through the "Carrots" approach (positive incentive measures) and using the conventional CT measures the "Stick" approach (negative incentive measures), on the terrorist strength and sustainability.

2.2.1`Assumptions of the Model

The model is predicated on the following assumptions:

(i.) On the average, the numerical strength of a terrorist organization at any interval of time is nourished by the combined processes of promotion $(p > 0)$, recruitment, $(r > 0)$ and commission $(c > 0)$ and drained through desertion $(d > 0)$and CT measures $(\alpha,\ \omega,\ \sigma > 0)$ targeted on the respective classes of operatives.

(ii.) Once a foot-soldier $X(t)$ is promoted to leadership $Y(t)$ cadre, a new foot-soldier is recruited as a replacement. If in some organizations such recruitment isn't automatic, then the current model is still valid for these organizations as long as $(r > p)$

(iii.) Similarly, once a leader $Y(t)$is assigned a recruiters' $Z(t)$responsibility, a new foot–soldier $X(t)$ is promoted to a leadership position as a replacement. Also if in some organizations such promotion isn't automatic, then the current model is still valid for these organizations as long as$(p > c)$. In any case the drain due to promotion is marginal because

foot-soldiers are far more numerous than leaders even in relatively "top heavy" organizations.

(iv.) The ingenuity of recruiters $Z(t)$, like a catalytic enzyme, to speed up the recruitment and transformation process of the recruits into radical foot-soldiers without being directly targeted by a viable CT measures, allows terrorist organizations to grow through a sustained support-base that is constantly supplying new personnel for the possible conversion into radical foot-soldiers[8].

(v.) As implicit assumptions, the model also assumes:

(a) A state of stable gradual change, such that the effect of one terrorist or interdiction process is smoothed. This should be acceptable in all cases where the terrorist organization is not very small and thus changes are not very stochastic.

(b) That an organization's growth is constrained only by the available manpower and factors such as money or weapons do not impose an independent constraint.

(c) That the growth in foot-soldiers is not constrained by the availability of potential recruits since in most ideologically driven terrorism, willing recruits are always plentiful.

Combining equation (1), equation (2) and the above array of assumptions, we arrived at our mathematical model represented by the system of three ODEs:

$$\left.\begin{array}{c} S(t) = mY(t) + X(t) + Z(t) \\ Y^{'} = pX(t) - (d+\alpha)Y(t) \\ X^{'} = rmY(t) + (r-d-\omega)X(t) + (r+c)Z(t) \\ Z^{'} = (mc+p)Y(t) + cX(t) + (c-d-\sigma)Z(t) \\ (m>1; 0<p,r,c,d,\alpha<1) \end{array}\right\} \quad (3a)$$

The system of ODEs (3) will be subjected to the initial conditions

$$Y(t_0) = Y_0;\ X(t_0) = X_0; and\ Z(t_0) = Z_0 \quad (3b)$$

Table 1: Model Variables, Parameters and their Description

Variable/ Parameters	Description	Values
$Y(0)$	Number of terrorist leaders at time (t).	5.0
$X(0)$	Number of terrorist foot-soldiers at time (t).	120
$Z(0)$	Number of terrorist recruiter at time (t).	2.0
m >1	Weight of the leadership (over other operatives),	10.0
$0<p<1$	Proportion of foot-soldier promoted to a leader, 3%	0.03
$0<r<1$	Proportion of foot-soldiers recruited, 12%	0.12
$0<c<1$	Proportion of commissioned recruiters 1%	0.01
$0<d_0<1$	Proportion of internal personnel drain, 3%	0.03
$0<d_1<1$	Proportion of operative interdicted by "carrots", 20%	0.2
$0<\alpha<1$	Proportion of leaders interdictedby"sticks" 20%	0.2
$0<\omega<1$	Proportion of foot-soldiers interdicted by "sticks" 20%	0.2
$0<\sigma<1$	Proportion of Recruiters interdicted by "sticks" 20%	0.2

III. ANALYSIS OF THE MODEL

Before studying the solution paths of equation (3a), in this section, we first analyze equation (3a) to find the terrorist's equilibrium points and their local stability. To determine the equilibrium points, let the dynamic of each population in equation (3a) equals zero, $(i.e. Y^{'} = X^{'} = Z^{'} = 0)$:

$$\left.\begin{array}{c} 0 = pX(t) - (d+\alpha)Y(t) \\ 0 = rmY(t) + (r-d-\omega)X(t) + (r+c)Z(t) \\ 0 = (mc+p)Y(t) + cX(t) + (c-d-\sigma)Z(t) \end{array}\right\} \quad (4a)$$

At this state, we assume that there is no terrorist activity, and thus, no interdiction process except the internal personnel drain. This proves that $E_0 = (Y(t),\ X(t),\ Z(t)) = (0,\ 0,\ 0)$is the terrorist-free equilibrium state (TFES) of the model. To determine the stability of the equilibrium state by the linearization stability method, we have that

$$\left.\begin{array}{c} f_1 = pX(t) - (d+\alpha)Y(t) \\ f_2 = rmY(t) + (r-d-\omega)X(t) + (r+c)Z(t) \\ f_3 = (mc+p)Y(t) + cX(t) + (c-d-\sigma)Z(t) \end{array}\right\} \quad (4b)$$

$$\left.\begin{array}{l} \frac{\partial f_1}{\partial Y} = -(d+\alpha);\ \frac{\partial f_1}{\partial X} = p;\ \frac{\partial f_1}{\partial Z} = 0; \\ \frac{\partial f_2}{\partial Y} = rm;\ \frac{\partial f_2}{\partial X} = (r-d-\omega);\ \frac{\partial f_2}{\partial Z} = (r+c); \\ \frac{\partial f_3}{\partial Y} = (mc+p);\ \frac{\partial f_2}{\partial X} = c;\ \frac{\partial f_2}{\partial Z} = (c-d-\sigma); \end{array}\right\}$$

Therefore the Jacobian matrix is

$$J = \begin{bmatrix} -(d+\alpha) & p & 0 \\ rm & (r-d-\omega) & (r+c) \\ (mc+p) & c & (c-d-\sigma) \end{bmatrix} \quad (4b)$$

Therefore,

$$|J-\lambda I| = \begin{vmatrix} -(d+\alpha)-\lambda & p & 0 \\ rm & (r-d-\omega)-\lambda & (r+c) \\ (mc+p) & c & (c-d-\sigma)-\lambda \end{vmatrix} = 0 \quad (4c)$$

Solving the expression (4c) for λ, using MATLAB, we also have

$$\left.\begin{array}{l} \lambda_1 = \frac{1}{6}\begin{pmatrix} 48\alpha r\sigma + 48\alpha\omega c - 48\alpha\omega\sigma \\ + 108mpc^2 + 84\alpha c^2 \\ + 108rp^2 + 108cp^2 + \cdots \end{pmatrix} \\ \lambda_2 = \frac{-1}{12}\begin{pmatrix} 48\alpha r\sigma + 48\alpha\omega c - 48\alpha\omega\sigma \\ + 108mpc^2 + 84\alpha c^2 + \\ 108rp^2 + 108cp^2 + \cdots \end{pmatrix} \\ \lambda_3 = \frac{-1}{12}\begin{pmatrix} 48\alpha r\sigma + 48\alpha\omega c - 48\alpha\omega\sigma \\ + 108mpc^2 + 84\alpha c^2 + \\ 108rp^2 + 108cp^2 + \cdots \end{pmatrix} \end{array}\right\} \quad (4d)$$

By Routh-Hurwitz criteria, $\lambda_1 > 0, \lambda_2 < 0,$ and $\lambda_3 < 0,$ the terrorist free equilibrium state $E_0 = (0, 0, 0)$ is marginally stable; a common characteristics of most terrorist organizations.

3.1. Numerical Simulation

Given the experimental data set on table-1, we analyze our model (3),to study the evolutional dynamics of the terrorist strength when the state offer positive incentive to enhance internal personnel drain in the organization, while at the same time offering negative incentive to the leaders and foot-soldiers classes simultaneously. To achieve this aim, we first analyze the impact of "carrot" approach on the terrorist strength, and then by comparison, analyze the combine effects of the two approaches. Mathematically, the solution path of each sub-model corresponds to the question of whether at some future time the value of the variables $Y(t)$, $X(t)$and $Z(t)$would reach zero, i.e.

$$\left.\begin{aligned} \lim_{t_0 \to t} Y(t) = \lim_{t_0 \to t} X(t) = \lim_{t_0 \to t} Z(t) = 0 \\ \Rightarrow \lim_{t_0 \to t} S(t) = 0 \end{aligned}\right\} \quad (5)$$

For experimental analysis, we consider a notional terrorist group with initial strength of 5 leaders, 120 foot-soldiers and 2 recruiters. Research findings and journalistic accounts of how Al-Qaida and its affiliates developed and grows over the last decades indicate that; constraint by the heterogeneity of the terrain, the asymmetric nature of the warfare, the insufficient credible intelligence and as well as limited human/material resources at the disposal of CT operatives and decision makers; a notional terrorist organization under the influence of an orchestrated CT measure can at-most be nourished at an average rate of 3% per leaders, 12% per foot-soldiers and 1% per recruiters annually. This dynamics is hampered by internal personnel drained factor of 3% and CT measure of 20% per class of operatives[8],[10],[21],[34],[54]. Thus, in this analysis, we are hypothesizing a positive incentive measures (Carrots) that would boost the internal personnel drain factor (d) to at-least 20%.

3.1.1Terrorist Evolution under "Carrots" Approach

The first condition analyzes the strength at default internal drain$(d_0 = 0.03, \alpha = \omega = \sigma = 0)$, represented by the blue curve and denoting when there is noviable "Carrots" (positive incentives) from government, while the second condition $(d_1 = 0.2, \alpha = \omega = \sigma = 0)$ represented by the red curve, denote when there is viable "Carrots" from government to incite high internal personnel drain. In figure 1 below, the terrorists' evolution under "no Carrots" regime all depicts a positive exponential growth curves (blue curves), and the evolution under "carrot" regime, all depicts slow linear growth curves (red curves).

The figure 1(a), (b) and 1(c) below shows that, without a viable "Carrots" approach, the population of the leaders, foot-soldiers and recruiters, grows exponentially from its initial 5 leaders, 120 foot-soldiers and 2 recruiters to a corresponding 110 leaders, 1000 foot-soldiers and 87 recruiters within a period of ten years. This gives an increase of 10.5 leaders, 88 foot-soldiers and 8.5 recruiters annually. While with viable "Carrots" measures, the population of the operatives declined linearly to 20 leaders, 180 foot-soldiers, and 16 recruiters, giving an increase of only 1.5 leaders, 6.0 foot-soldiers and 1.4 recruiters annually. Thus, the "carrot" approach alone has the propensity of interdicting an average of 9.0 leaders, 82 foot-soldiers and 7.1 recruiters annually.

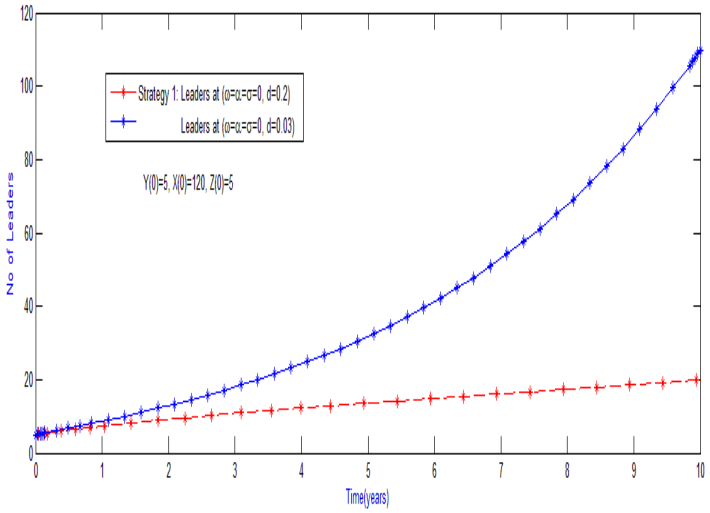

Figure 1(a): Leaders Evolutionunder "Carrot" approach

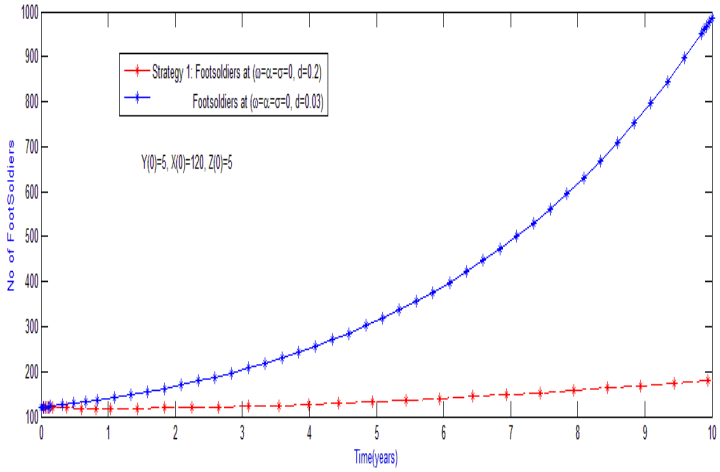

Figure 1(b): Foot-soldiers Evolution under "Carrot" approach

Similarly, figure 1(d) below, summarized strength evolution of the organization: without positive incentive measures, the overall terrorist strength grow exponentially from initial 172 operatives to 2171 operatives (an increase of 199.9 operatives annually). While with viable "Carrots" measures, the overall strength of the terrorist declined to 395 operatives (an average interdiction of 177.6 operatives annually).

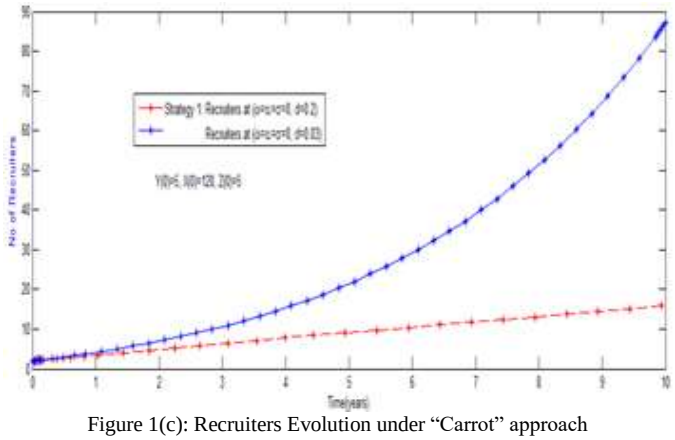

Figure 1(c): Recruiters Evolution under "Carrot" approach

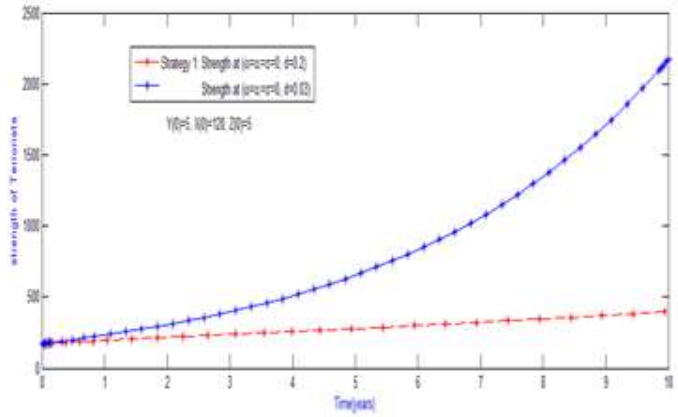

Figure 1(d):Strength Evolution under "Carrot" approach

3.1.2 Terrorist Evolution under "Carrot and Stick" Approach

The first condition analyzes the evolution at inherent internal drain and CT measures targeted at the leaders and foot-soldiers simultaneously($d_0 = 0.03, \alpha = \omega = 0.2, \sigma = 0$); represented by the blue curve. This denotes when there are only negative incentive (stick) measure targeted at the leaders and foot-soldiers simultaneously. The second condition analyzes the terrorist evolution at the combination of high internal personnel drain and negative incentive (stick) targeted at the leaders and foot-soldiers simultaneously,($d_1 = 0.2, \alpha = \omega$=*0.2,*$\sigma$=*0,* represented by the red curve. This denotes when there is a combination of viable positive(carrots), and negative incentives (sticks).The figure 2 below compare the dynamical evolution of the terrorist at the inherent and enhanced internal personnel drain factors in combination with the conventional negative incentives (stick) measures.

The figure 2(a), (b) and (c) below, shows that, with only the conventional CT measure, but without a viable "carrot" approach, the population of the organization grows from the initial 5 leaders, 120 foot-soldiers and 2 recruiters to a corresponding 15.2 leaders, 140 foot-soldiers and 26 recruiters within a period of ten years. This gives an increase of 1.02 leaders, 2.0 foot-soldiers and 2.4 recruiters annually. While a combination of a viable "carrot" approach and the conventional military offensive, the population of the operatives declined to 2.8 leaders, 25.6 foot-soldiers, and 5 recruiters. This gives an average interdiction of 1.24 leaders, 11.44 foot-soldiers and 2.1 recruiters annually.

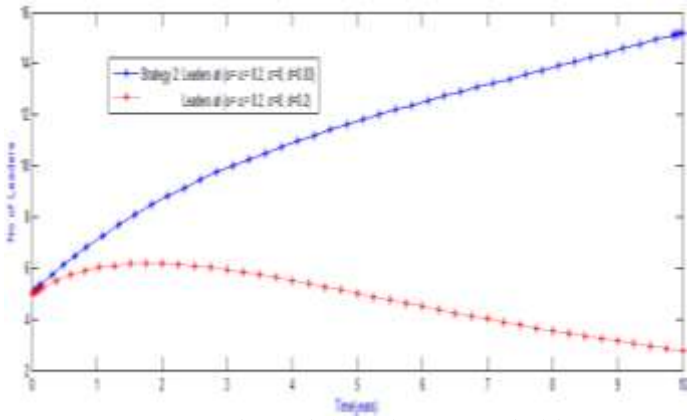

Figure 2(a): Leaders Evolution under "Carrot and Stick"

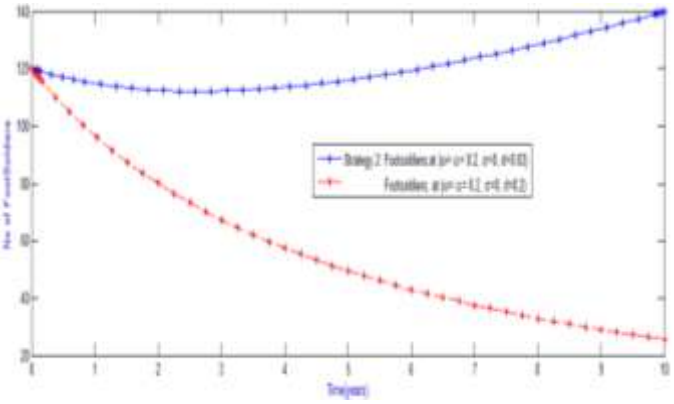

Figure 2(b): Foot-soldiers Evolution under "Carrot and Stick"

Similarly, figure 2(d) below, compares the evolution of the organization's strength under *"carrots and sticks"* approach. With the conventional CT measures (sticks) without a viable *"carrots",* the overall terrorist strength appreciates from initial 172 operatives to 318 operatives (an increase of 14.6 operatives annually). While a combination conventional military offensive and the introduction of a viable *"carrots",* yield overall decline in strength of 58 operatives (an interdiction of 26 operatives annually).

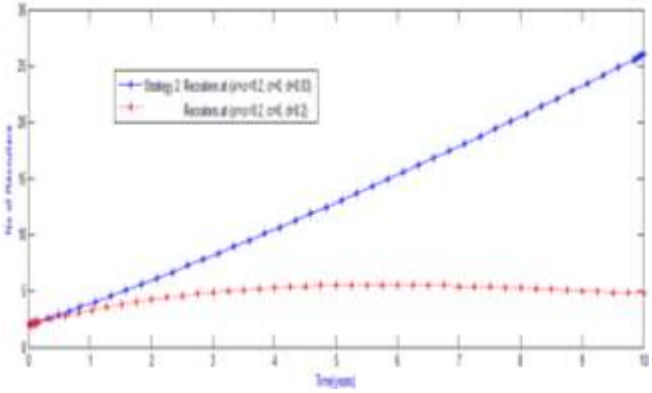

Figure 2(c): Recruiters Evolution under "Carrot and Stick"

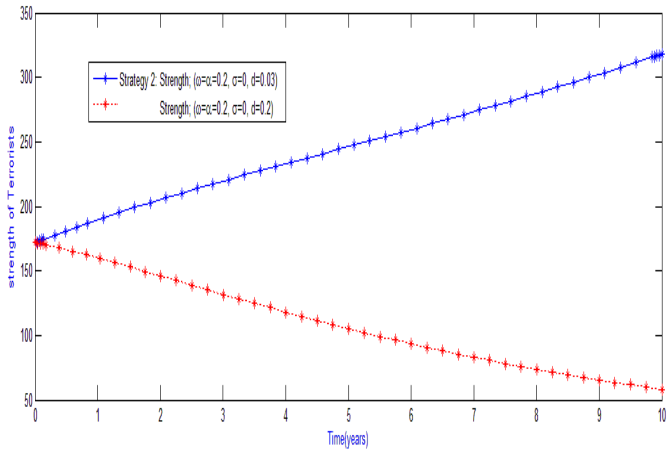

Figure 2(d): Strength Evolution under "Carrot and Stick"

3.1.3 Long Term Forecast of Terrorists' Evolution under Carrots and Stick Approach

To determine whether the understudies strategy would be sufficient to guarantee the total demise of the organization under consideration, we take a fifty years forecast of the terrorists' evolution. The figure 3 (a,b,c,d) below, shows that, in summary, given the simultaneous targeting of terrorists' leaders and foot-soldiers through the instrument of *"carrots and sticks*", the terror war of attrition would take approximately fifty (50) years to accomplish a total demise of a notional terrorist group with initial numerical strength of 5 leaders, 120 foot-soldiers and 2 recruiters. The figure 3(a) shows that from 17.85 years the leaders' population will maintain a continuous decline from 1.061 to 0.02561 operative in 50 years' time. The figure 3(b) shows that from 35 years the foot-soldiers' population will maintain a continuous decline from 1.302 to 0.2441 operative in 50 years' time. The figure 3(c) shows that from 26.32 years the recruiters' population will maintain a continuous decline from 1.053 to 0.07525 operative in 50 years' time. Similarly, the figure 3(d) shows that from 45 years the overall terrorists' strength will maintain a continuous decline from 1.026 to 0.5754 operative in 50 years' time.

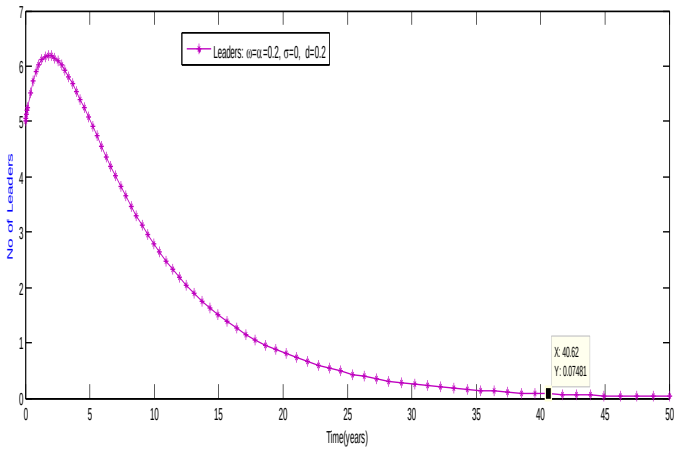

Figure 3(a): A Fifty years forecast of Leaders evolution

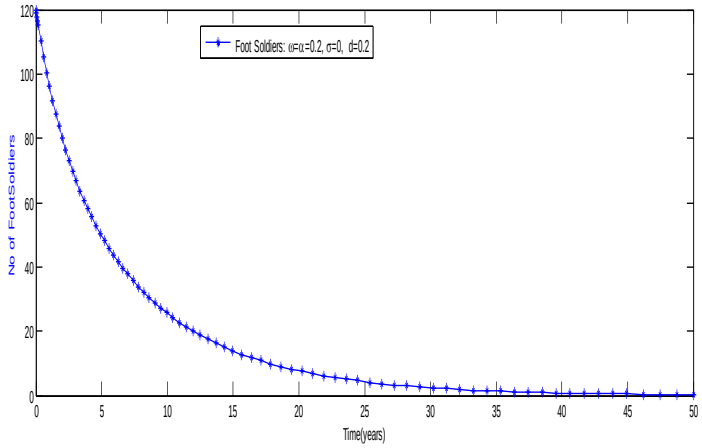

Figure 3(b): A Fifty years forecast of Foot-soldiers' evolution

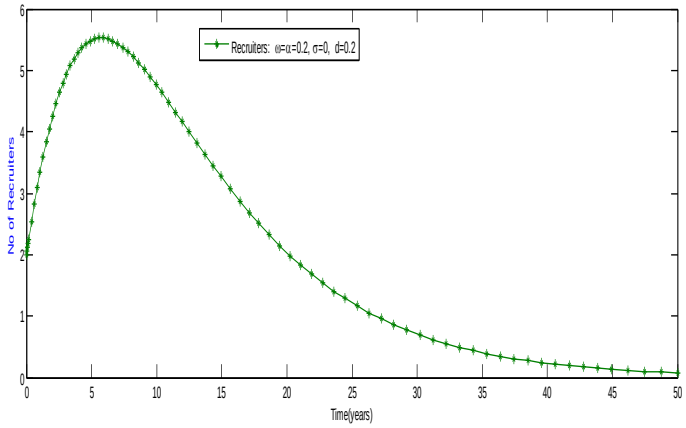

Figure 3(c): A Fifty years forecast of Recruiters' evolution

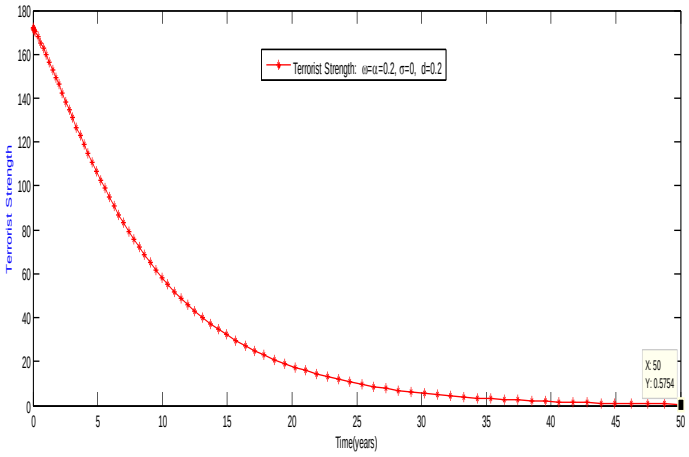

Figure 3(d): A Fifty years forecast of terrorists' strength

3.1.4 The Variability of Terrorists' Evolution with CT Strategy

Table 2 below, shows a summary of the variability of the organization's growth and interdiction rates with respect to *"carrots" and "sticks"* approaches.

Table 2: Characteristics of "Carrot and Stick" Approach

Variable	Leaders	Foot-soldiers	Recruiters	STRENGTH
Initial Population	5.0	120	2.0	172
Annual growth at d_0 (No Carrot)	110	1000	87	2171
Annual growth at d_1, (Carrot)	20	180	16	395
Annual growth at $d_0 + CT$, (Stick)	15.2	140	26	318
Annual growth at $d_1 + CT$, (Carrot & Stick)	3.8	25.6	5.0	58
% Growth at No Carrot Regime	210%	73.3%	425%	166.2%
% Growth at Carrot Regime	30%	5%	70%	13%
% Growth at Stick Regime	20.4%	1.67%	120%	8.49%
% Growth at Carrot & Stick Regime	-2.4%	-7.87%	15%	-6.63%
%Interdiction at Carrot Regime	81.8%	82%	81.6%1	81.8%
%Interdiction at Stick Regime	86.2%	86%	70.1%	85.4%
%Interdiction at Carrot & Stick	96.6%	97.4%	94.3%	97.3%
% Interdiction of Stick over Carrot	24%	22.2%	-62.5%	19.5%

The table 2above shows that the overall terrorists' strength is lowest under the combine *"carrots and sticks"* regime, with 58 operatives, representing an annual growth rate of only -6.63% operatives. This is followed by the individual *"sticks"* and *"carrots"* regimes with a total population of 318 and 395operatives respectively, representing an annual growth rate of 8.49% and 13% operatives respectively. Correspondingly, the growth rates of the operatives are also lowest under the combine *"carrots and sticks"* regime, with a total of 3.8 leaders, 25.6 foot-soldiers and 5.0 recruiters, representing an annual growth rate of -2.4% leaders, -7.87% foot-soldiers and 15% recruiters. While the individual *"sticks"* regime yielded the total operatives' population of 15.2 leaders, 140foot-soldiers and 26 recruiters. This represents annual growth rates of20.4% leaders, 1.67% foot-soldiers and 120% recruiters. The individual *"carrots"* approach hyield a total operatives' population of 20 leaders, 180 foot-soldiers and 16 recruiters; representing annual growth rates of30% leaders, 5% foot-soldiers and 70% recruiters. However, the *"sticks"* approach has the propensity to interdict 24% more leaders, 22.2% more foot-soldiers and 19.5% more strength annually than the *"carrots"* approach.

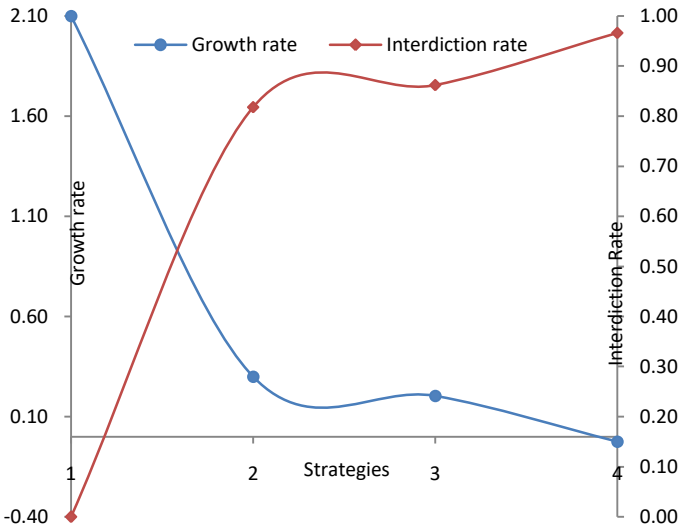

Figure 4(a): Variability of Leaders' Growth with Strategies

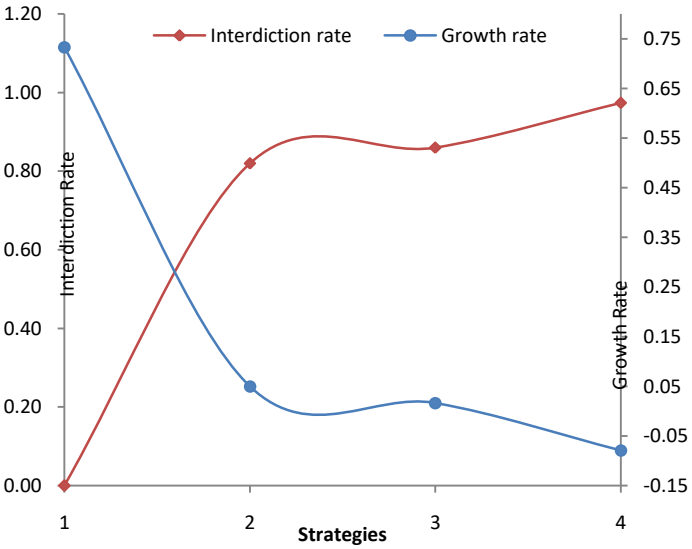

Figure 4(b): Variability of Foot-soldiers' Growth with Strategies

The figure 4 above shows the variability of the terrorist annual growth rate under the combine *"carrots" and "sticks"* approaches. The figure 4(a) shows that the annual growth rate of the leaders are lowest under the combine *"carrots and sticks"* regime, with -2% leaders; representing the highest interdiction rate of 97%, annually. This is followed by the *"sticks" and "carrots"* regime with annual growth rate of 20% and 30% leaders respectively; representing an interdiction rate of 86% and 82% annually, respectively. The figure 4(b) shows that the annual growth rate of the foot-soldiers is also lowest under combined *"carrots and sticks"* regime, with -8% foot-soldiers; representing an interdiction rate of 97%, annually. This is also followed by the *"sticks" and "carrots"* regime with annual growth rate of 2% and 5% foot-soldiers respectively; representing an interdiction rate of 86% and 82% annually, respectively.

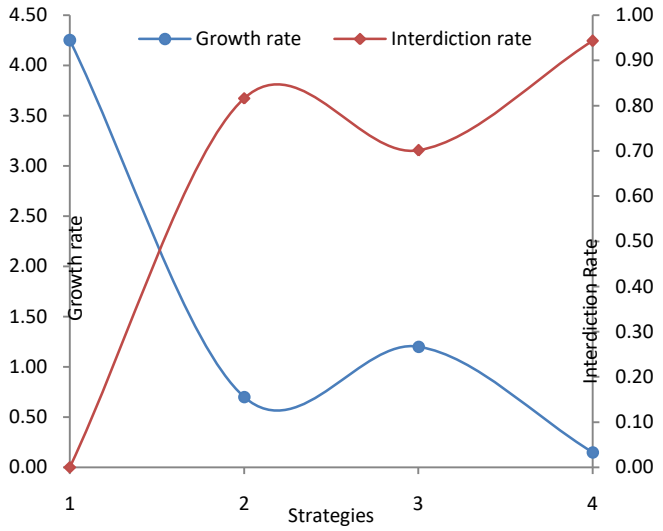

Figure 4(c): Variability of Recruiters' Growth with Strategies

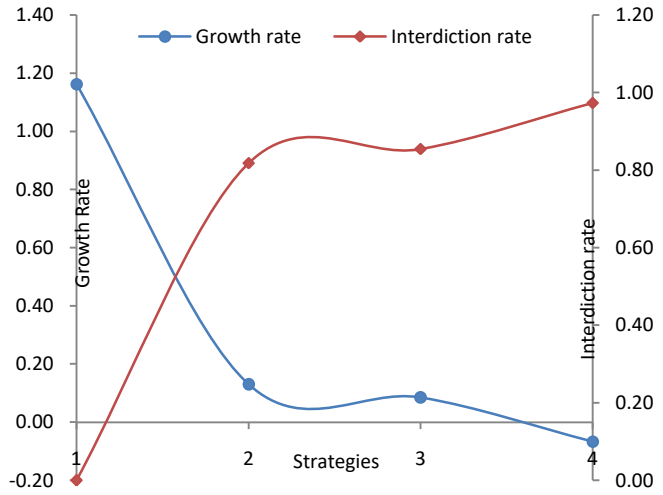

Figure 4(d): Variability of Terrorists' Strength with Strategies

Similarly, figure 4(c) above shows that the growth rate of the recruiters is lowest under the combined *"carrots and sticks"* regime, with 15% recruiters; representing the highest interdiction rate of 94% recruiters annually. In figure 4(d), the combined *"carrots and sticks"* regime also yielded the lowest system growth rate of -7% operatives; representing the highest system interdiction rate of 97% operatives annually. This is follows by the *"sticks"* and "carrots" regime with a system growth rate of 8% and 13% operatives respectively; representing annual system interdiction rates of 85% and 82% operatives respectively. Comparatively, the *"sticks"* approach alone has the propensity of interdicting 24% more leaders, and 22% more foot-soldiers annually than the *"carrots"* approach. While the *"carrots"* approach alone has the propensity of interdicting 38.5% more recruiters annually than the *"sticks"* approach.

3.1.4 Organizational Resilience

To predict whether the understudied counterterrorism strategies or approaches would be sufficient to degrade or drive the organization to a long term in activity, suffice us to analyze the organization's resilience index of each of the strategy. The "organizational resilience" or the capability of a terrorist group to rebound back and still engage in viable terrorist activity notwithstanding the high degree of decapitation of its operatives is a striking characteristic of most terrorist organization. It is the organization's recovery potential after destruction, which emphasizes the ability of recover and develops in a state of uncertainty, discontinuity, and emergency rather than a resistance to unexpected event. Lengnick-Hall et al[36] defined organizational resilience as a firm's ability to effectively absorb, develop situation-specific responses to, and ultimately engage in transformative activities to capitalize on disruptive surprises that potentially threaten organization survival. The terrorist organizational resilience index is scaled using a minimum-maximum rescaling method:

$$nomalized\ (X_i) = \left|\frac{x_i - X_{min}}{X_{max} - X_{min}}\right| \quad (6)$$

Where $X_i, (i = 1,2,3)$ denote the individual values of strength at each strategy, X_{min} and X_{max} denote the minimum and maximum values of X in each strategy, respectively. The min-max rescaling method adapted from the University of Notre Dame Global Adaptation Index, compare values for resilience and vulnerability, and then place the terrorist in one of four quadrants, illustrated in figure 5, below. Using the data on table 2 on equation 6 above, the organization's resilience indices are, *"Carrots"* $X_C = 0.111$ (high vulnerability); *"stick"*, $X_S = 0.073$ (high vulnerability)and *"Carrots & Stick"*, $X_{C+S} = 0.057$ (high vulnerability). This implies that, the organization under *"carrot"* approach has only 11.1% probability to rebound back to active terrorist activities after major drain in its strength, while under the *"sticks"* approach the organization is 7.3% probability of rebounding back to active terrorist activities. And under the combined *"Carrots & Stick"*, approach, the organization has only 5.7% probability of rebounding back to active terrorism after major threat on its strength and sustainability.

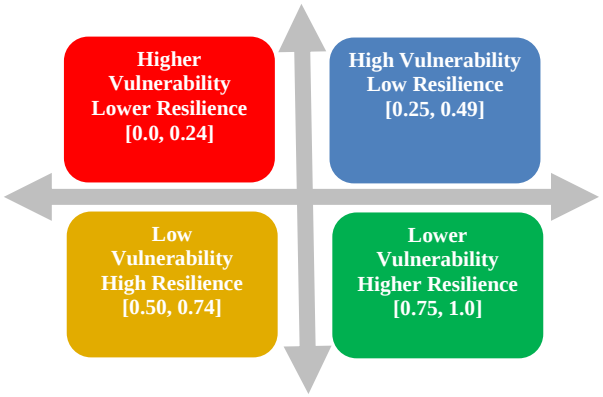

Figure 6: Resilience and Vulnerability Quadrants

IV. RESULT OF THE ANALYSIS

Characteristically, the study shows that a cautious and judicious implementation, the combination of *"carrots" and "sticks"* approaches can yield a comparatively higher terrorists' interdiction rate than the individually. Significantly, the analysis shows that, the CT strategy of targeting terrorists' leaders and foot-soldiers simultaneously, through the instruments of *"carrots and sticks"* would yield a more effective CT measure, as it has the propensity to drive the growth rates of both the operatives and the overall terrorists' strength to significant negative growth or vulnerable level. The analysis also shows that, the *"carrots"* complement alone has the propensity of interdicting more recruiters (38.5%) than the *"sticks"* approach; while the "sticks" approach has the dominant power of interdicting more terrorists' leaders (24%) and foot-soldiers (22%) than the *"carrots".* This implies that, the clandestine nature of most terrorist recruitment activities and the inherent hindrances or difficulties in identifying and accessing potential terrorist recruiters' and their recruitment institutions for proper targeting in the dominant military offensive CT strategy can be overcome by the use of viable "carrots" approach.

Therefore, though the implementation of the *"carrots and sticks"* approach may be cost intensive and challenging, its dual interdiction characteristics (reward and punishment),has the propensity to drive both the operatives' growth and the overall terrorist strength to a negative growth rates (see figure 4).This gives the approach an edge over other approaches, beside its attendance tendency to rejuvenate both the economy and moral supports of the local population. Therefore, given that the numerical strength of most terrorist organizations tends to be driven by the dynamics of the foot-soldiers; the study suggest that a selective offering of the *"carrots"* to only the foot-soldiers, while wielding the *"sticks"* on other recalcitrant operatives can reduce the cost of implementing the combine *"carrots and sticks"* approach considerably.

However, the simultaneous targeting of terrorist leadership and the numerous rank-and-files, popularly known as *"fire strategy";* though may have greater utility in an effort to fight a given terrorist group under the *"carrots and sticks"* approach by impacting significantly on the operatives' growth and the overall terrorists' strength, the strategy may not be insufficient to guarantee the total demise of the organization in view of its high vulnerability to blowback syndrome[4],[7].Similarly, considering the inherent psychological inclination of abuse and misconstrued of the objectives of the *"carrots",* the *"carrots and sticks"* approach though evolve a highly vulnerable organization, may have greater utility in an effort to fight a given terrorist group only in the short term. In the longer term, such an approach can be counter productive if the recipients perceived it to be unfairly applied for an unjust or ulterior motive. Also, notwithstanding its propensity to drive the organization's strength to a vulnerable status, a forecast of the long term evolution of the organization shows that, given the simultaneous targeting of terrorists' leaders and foot-soldiers through the instrument of *"carrots and sticks*", the terror war of attrition would take approximately fifty (50) years to accomplish a total demise of a notional terrorist group with initial numerical strength of 5 leaders, 120 foot-soldiers and 2 recruiters (see figure 3).

So, ultimately, any quest for the implementation of the *"carrots and sticks* "approach must be as part of a more comprehensive effort to give the locals more legitimacy and concession in order to gain their cooperation and supports for (i) the initiation of an all-inclusive, proactive and efficient *"in-group policing"* mechanism between the security agencies and the local population; (ii) denying a given terrorist group the popular support it requires to survive (i.e. de-legitimization of terrorism and its propagandas among the local population), and (iii) encourage and facilitate sufficient and credible intelligence gathering for smart targeting of recalcitrant terrorists' location[28],[40],[43].Such effort must demonstrate with all sincerity that the state's motive for offering the *"carrots"* is unprejudiced and must create the conditions that convince the terrorists to believe that such motive is for their own advantage.

V. CONCLUSION

We develop a mathematical deterministic model for countering terrorism; where the state's CT approaches include the use of positive (carrot) incentives and negative incentives (sticks) to elicit high internal personnel drain within the organization; while the strategy of implementation is to target the leaders and foot-soldiers simultaneously. The tripartite aims of these approaches are geared toward marshaling resources building coalition and a formidable "in-policing" mechanism with the locals; gather sufficient and credible intelligence for smart targeting of terrorist location, and de-legitimize terrorism and its propagandas among the locals. The consequence of which, would lead to the overall weakening of the organizations' strength and sustainability and thus, rendered it grossly incapacitated to organize a successful terror attack in the longer term. The model distinguishes between the effects of applying negative incentives (sticks) or positive incentives (carrots) or a combination of both approaches for influencing the behavior of intelligence and adaptable adversaries.

In an effort to marshal resources against a given local militia or terrorist groups, the state can also employ the *"carrots and sticks"* approach to help incite or encourage high internal personnel defection within the organization; gather sufficient and credible intelligence for smart targeting of terrorist location; take the local populations' supports away from the terrorists and as well as build a credible coalition against the organization. Taking the local populations support away from the terrorist's organization promise to be a panacea to local terrorism; as such effort will creates serious havoc for the terrorists and its cause receives less attention and therefore becomes delegitimized. For an ideal de-legitimization process, government must give the local population more legitimacy,

concession and motivation in order to gain their cooperation and supports, and this should be one of the primary focuses of the *"carrots"* approach.

The *"carrots"* should be provided to motivate voluntary compliance in either the terrorist operatives or the susceptible youth population with implied preferences or explicit direction, while the *"sticks"* should be wields to coerce compliance from recalcitrant recipients. Generally, democratic states prefer the *"carrots"* option, believing that reward would have a more positive or long-lasting effect, and would be viewed either as a due compensation for desired performance or as unprejudiced payment for services rendered. Unfortunately, the reverse may be the case; with the inherent psychological inclination of abused and misconstrued of the objective of the *"carrot"* the perception from its recipients may be of a bribe tainting both the donor and recipient or of equally distasteful payment from a master to a servant.

If *"carrots and sticks"* is applied conceitedly by a strong State without due diligence and cognizance of the recipients who may see the *"carrots"* as bribes or arm-twisting, the results may be short termed and counter-productive in the longer term. Improperly implemented *"carrots and sticks"* can make the state appears an oppressor, cost it resources to no advantage, or lead to imposition of punitive action with negative consequences. To fully harvest the desired utility of *"carrots and sticks"*, the state must be unprejudiced and proportional in its application of rewards and punishments, which in turn should be aligned with an unprejudiced motive. Such motive must be just in the eyes of the locals, the terrorists and other stakeholders, not simply in the eyes of the donor state. In such a situation, the reward for compliance would not be seen as a bribe or a payment for ransom, but simply as an expected consequence of working for a just cause. If the *"sticks"* is wields to coerce compliance or cooperative behaviour, then it must be seen as a proportional requirement of justice, not as an act of bullying which cannot buy what it desires.

The study also reiterates the morale vulnerability of the *"sticks"* approach to inciting a "Herostratos" syndrome and hence a blowback effect in the susceptible youth population, especially when targeted at the leaders and foot-soldiers. Therefore, to make the states unprejudiced motive for offering the "carrots|" or "sticks" more compelling and attractive to the terrorists and the locals, their different values and perceptions must be taken into cognizance. The most obvious positive incentives (*carrots)* employed in recent times includes economic assistance; lifting of sanctions; award of educational scholarships; direct monetary payments; and supply of food and services, and other refugee assistance. All of these privileges can be rewarding, but they may also be more limited and temporary in value than anticipated. For instance, if the terrorists or people felt the sanctions were improperly imposed, then lifting them will be perceived as a correction of a wrong, rather than a gracious act, and thus, may not motivate the desired actions.

The use of food or financial rewards to directly influence or elicit compliance or cooperative behaviour from the terrorist or the locals may allow the state to be by-passed to some degree. The altruistic motives of the state may be genuine, but if the hungry recipients perceive that the food aid or financial assistance is given simply to bring a coalition together, or elicit behaviour compliance for selfish intension, then the *"carrots"* would appear simply as a bribe rather than a just reward. If the terrorist is apocalyptic in objectives or ethno-religious ideology driven, then the appearance of such a *"carrot"* may not alter their views towards the state at all. In fact, they may receive the *"carrots"* with an increased contempt for the state. The ultimate challenge is to make the state's motives unprejudiced in the eyes of the terrorists, the local, and stakeholders whose physical and moral assistance is needed in the war against terror.

However, even if the *"carrots"* is perceived as a bribe, there may be some utility in a simple bribe or use of force, but the returns could only be temporary and potentially short term as observed previously. If peradventure the state's motive does not fall in line with the motives of the recipients, the intermediate position is to at least make a compelling case that the state motive is just and unprejudiced, and to use the *"carrots and sticks"* approaches as commensurable rewards or punishments to support that motive. To complement the application of positive and negative incentives or to avoid the challenges of their misconception, some of the root causes of the terrorism and the peoples' disgruntlement must be properly identified and addressed; or the potential *"carrots"* given as a redress of the root causes of the terrorism and the peoples' disgruntlement.

When the terrorist is extremely advantaged (i.e., with a low unit cost of attack, taking into account any increases in unit cost due to negative incentives, or a high asset valuation), the *"carrots"* cannot incite meaningful internal defection or deter the terrorist from attacking, because the asset is too valuable to the terrorist relative to the cost of attacking. However, a less advantaged terrorist can be successfully deterred by weakening its strength through high internal defection incited by a viable *"carrots"*. If the terrorist violates the trust associated with positive incentives, which may occur when compliance cannot be adequately monitored and enforced, the state is assumed to eliminate the use of positive incentives. But if the terrorist is sufficiently disadvantaged, it is already deterred from attacking, therefore, offering of positive incentives may be of no economic significance.

We demonstrate a complex relationship between negative (sticks) and positive (carrots) incentives, which we believe has not been sufficiently shown quantitatively. In particular, we find that positive incentives can play a role when negative incentives have an intermediate impact on the terrorist. When negative incentives have too little impact, the terrorist is too advantaged for affordable levels of positive incentives to be

effective at achieving deterrence. This accords with Pruitt[46], observations that negotiations with terrorists are likely to be successful only when the goals of the terrorist group are relatively modest or pragmatic. By contrast, apocalyptic terrorists may be so "advantaged" by their fanatic devotion to their cause that the benefits of any positive incentives the state might be willing to offer would be pale by comparison. From this perspective, "appeasement" is not necessarily always undesirable, but will be so when the state has underestimated the goals and or devotion of the adversary. Conversely, when negative incentives have a sufficiently large impact, the terrorist is already disadvantaged and deterred by negative incentives alone, and there is no need for the state to offer positive incentives.

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