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ASEAN DEFENCE INDUSTRY COLLABORATION; POTENTIAL, CHALLENGES AND WAY FORWARD

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ABSTRACT

With the formalisation of the Association of Southeast Asian Nations (ASEAN) Defence Ministers' Meeting (ADMM), and the processes therein in 2006, defence has been the last sectoral body to be established within the formal framework of ASEAN. It is an important step in promoting multilateral defence and security collaboration in the region. However, the one area that has not been given attention by ASEAN countries is that of defence industry collaboration, one which fits very harmoniously into the pillars of the ASEAN Political Security Community as well as the ASEAN Economic Community. ASEAN countries have, thus far, developed different industrial and technological capabilities and capacity. In this regard, they have varied strengths and opportunities that could be integrated towards developing a more concerted regional based defence industrial growth with the aim of reducing overdependence on imports, and at the same time, sustaining economic development within the region in terms of research and development, jobs creation, and slowing down outflow of currency. The implementation of collaboration in the defence industry among the ASEAN countries could certainly move the regional grouping up another notch, as well as open up a new dimension of economic and defence collaboration, thus adding further meaning and strength to the ASEAN spirit, whilst further moving its people towards a common purpose and a shared destiny.

INTRODUCTION

With the formalisation of the ASEAN Defence Ministers' Meeting (ADMM) [1], and the processes therein in 2006 [2], defence has been the last sectoral body to be established within the formal framework of ASEAN. It is an important step in promoting multilateral defence and security collaboration in the region. The various meetings and activities under the ADMM process have contributed towards strengthening collaboration among the ASEAN defence organisations. However, the one area that has not been given attention by ASEAN countries is that of defence industry collaboration, one which fits very harmoniously, from the author's perspective, into the pillars of the ASEAN Political Security Community as well as the ASEAN Economic Community.

In this respect, it must be mentioned that defence industry sectors the world over have played a vital role towards building indigenous industrial capability, technological development, and economic spinoffs including exports and employment creation, as well as human capacity building. In the west, the defence industry sector has been

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instrumental towards various technological breakthroughs as well as creating spinoffs into the civil sectors. The defence industry has also been a major source of revenue for most of western countries in term of exports and the revenues that have been ploughed back into research and development activities in defence technology.

Several East Asian and Latin American countries have also adopted similar approaches by building-up their national defence industrial bases for both military and economic purposes. These include countries such as Japan, South Korea, Brazil, South Africa, India and China. Some of these countries have developed very competitive industries that leverage on dual use technology, which encompasses both the defence and civil sectors [3].

Indeed, the defence industry is a fairly new concept to some of the ASEAN countries. There are admittedly some ASEAN countries which have developed limited defence industry capabilities. However, ASEAN countries are net buyers of defence equipment and support. In other words, ASEAN countries are mostly dependent on imports of defence equipment from various Original Equipment Manufacturers (OEMs) around the world. According to the data published by the Stockholm International Peace Research Institute (SIPRI) [3], ASEAN countries (excluding Myanmar) spent in 2008 a total of USD 22.8 billion for new defence equipments. Although this figure is small compared to global defence expenditure, it does not include other associated expenditure such as service support, logistics and training.

At the same time, in terms of arms production in 2007, six of the ten arms producing companies originate from the United States (US), while the remaining four are from Western Europe. Of the top one hundred arms producing companies in the world, forty four are US based, with the lion's share of USD 212.4 billion, while thirty two are based in Western Europe, with a share of USD 107.6 billion [3]. These figures clearly go on to suggest that ASEAN countries are still import driven in this area, with major imports coming from the US and Western Europe.

FORMALISING AN ASEAN DEFENCE INDUSTRIAL PLATFORM

Over the years, some of the ASEAN countries have developed some form of industrial and technological capabilities. Each country has taken various policy initiatives to develop its own defence industry to the extent of being able to provide some degree of support to their respective armed forces. This has been done either through direct procurement, collaborations or offset programs.

The level of industrial and technological capabilities and capacity differs from one country to another [4]. Some countries are stronger in the aerospace sector, while others in weapons, automotives or naval sectors. Similarly, their industries have developed capabilities ranging from research and development to manufacturing, system integration, repair, maintenance and overhaul. In this regard, ASEAN countries have

different strengths and opportunities that could be integrated towards developing a more concerted regional based defence industrial growth with the aim of reducing the over dependence on imports, and at the same time, sustaining economic development within the region in terms of research and development, jobs and outflow of currency.

It must also be mentioned that there already exists some very limited collaboration on a bilateral level amongst ASEAN countries in the area of defence industry cooperation. However, this is a far cry from the desired collaboration at the multilateral level, such as amongst European Union (EU) countries to cooperate in the development of the Western European defence industrial base. Projects such as the Eurofighter, involving four European countries [5], and the A400M, involving a consortium of seven European countries [6], are some such examples. To that extend, organisations such as the European Defence Agency (EDA) and the European Defence Industries Group (EDIG) have been set up to promote such activities [7].

POTENTIAL OF ASEAN DEFENCE INDUSTRY COLLABORATION

It is felt that formalising the ASEAN defence industry collaboration at a multilateral level would have significant potential to the region not just in terms of the defence industry per se, but also towards technological and industrial growth in the region. This could indeed be viewed as moving further on the ASEAN Political Security and Economic Agenda. The benefits, among others, could include economies of scales, sharing of technology, country specialisation, and collaborative approaches. This will lead to rational utilisation of scarce financial resources through the consolidation of technical capabilities, and sharing of developmental expenses and large production costs.

It is a well established fact that manufacturing in large quantities attracts economies of scale. Instead of buying in smaller quantities, ASEAN countries could, through the concept of specialisation or outsourcing [8] among themselves, leverage this arrangement to reduce cost per unit of production.

In respect of technology, one could argue that the sharing of technology as well as research and development efforts could yield significant synergy amongst ASEAN countries. This also could include human capital development, educational collaboration, joint seminars and forums, industrial dialogues, joint production, maintenance, repair and overhaul (MRO), and the like.

Under the concept of country specialisation, each ASEAN country could specialise in different areas, depending on how it fits into the value chain of ASEAN defence industrial production. Indeed the region can opt for specialisation of specific defence product and need not compete against its own ASEAN countries [9]. For example, some countries could be the manufacturers of parts and components, others could undertake

assembly, while others could specialise in areas of design, integration and total platform, depending on the strength and competitiveness advantage of each country, be it labour cost, the existence of a defence industrial base, the level of defence technological sophistication and so on.

The other driver of defence collaboration is the evolving doctrine, given the varied demands on each country's armed forces. The objective is the establishment and improvement in interoperability and increased standardisation of military equipment. This is particularly significant in view of increasing military integration in the form of joint exercises and operations at regional and international levels. For example, the Malacca Strait Patrols, a multilateral collaborative initiative between Malaysia, Indonesia, Singapore and Thailand, has contributed to the sharp decrease in piracy attacks in the Straits of Malacca and Singapore. According to the Regional Agreement on Combating Piracy and Armed Robbery Against Ships in Asia or ReCAAP for short, the number of reported incidents of attempted or actual piracy attacks in the Straits have significantly reduced from a high of forty three reported incidents in 2004 to only nine reported incidents in 2009 [10].

Collaboration in defence industry activities will enhance trust and mellow down issues relating to potential conflicts. Improving levels of trust will provide the motivation and make defence industry collaboration much easier than would otherwise be possible. Such collaboration is an important political contribution to the further development of transparency and confidence building between countries.

Considering the different capability and capacity of every member state, the main areas for defence collaboration among ASEAN members are; upgrade and maintenance, research and development, and system integration and manufacturing. It is pertinent to emphasise that these three areas are not mutually exclusive but are mutually reinforcing [11].

Given the high costs of advance defence equipment and the opportunity costs of high defence expenditure, upgrading existing weapons systems to extend the life cycle is proving to be an attractive option throughout the armed forces in the world. In fact, it is no secret that even in the developed countries, all major weapon systems undergo at least one major mid-life upgrade. It is a known fact that majority of ASEAN countries are depending on the OEMs in maintaining and upgrading high technology equipment such as radars, and communication systems. Joint effort among ASEAN in term of expertise and infrastructure development will reduce the dependence on foreign services for upgrade and maintenance.

With the existing limited budget for research and development among member nations, there are needs among member countries to enter into several long-term co-operative arrangements on defence research and development activities. The collaboration will reduce costs, share risks and significantly shorten the time taken to realise advanced technologies. Furthermore, new weapons technology development is increasingly based

on commercially developed civilian technology [12]. Hence, collaboration in R&D among ASEAN nation may utilise existing civilian R&D facilities and expertise which can further reduce investments.

The other important area for defence collaboration is in system integration and joint production. System integration and joint production are a new area among ASEAN nations. As such the expertise in this area is still at its infancy. Other than Singapore which has progressed significantly, countries like Indonesia, Thailand and Malaysia and to some extend Philippines has started embarking into system integration and joint production with OEMs only for the past few years. Member countries together with OEMs can start joint programs initially participating as a minor partner in high-tech and specialised areas, allowing long-term benefits so that they can gain the required capability to position themselves for other high-end collaborative ventures. Besides, it is important to focus on systems integration rather than trying to manufacture every components. This will transfer capabilities and technology allowing for a gradual advancement into higher technology areas.

Finally, collaboration between ASEAN parties could be viewed as one that not only brings about spinoffs in an economic sense, but also one that underscores the ASEAN spirit of 'prosper thy neighbour'. In other words, whilst defence industrial collaboration could be used to narrow the defence technological gap between ASEAN countries, this more importantly must be seen in the true spirit of ASEAN of wanting to support and help each other as a community of nations. For that matter, ASEAN collaboration in the defence industry itself can be viewed as a valuable Confidence Building Measures (CBM) in term of defence and security collaboration.

CHALLENGES

In taking forward the proposed ASEAN industrial collaboration, one has to be mindful of the numerous challenges that must be faced. These would include, amongst others, the different stages of industrial development and knowledge base as well as resources allocated for defence by each ASEAN country [13].

In this instance, countries such as Singapore, Thailand, Indonesia and, to some extent, the Philippines have already embarked on defence industrialisation, and have moved up the learning curve of defence technology, while some have even entered into joint ventures with countries outside the region. Others, such as Vietnam, Laos, Cambodia, and Myanmar have not really done so. The technological gap that exists amongst them might pose challenges in terms of deciding what shape and form this defence industrial collaboration should take.

Similarly, resources allocated for defence also vary amongst the ASEAN countries. Some have much larger budgets then others, based on affordability and opportunity costs in expanding scarce resources to meet national socio-economic demands. For example,

Singapore, despite being the smallest ASEAN country in terms of size, has the highest military spending. Since the 1970s, it has allocated an average of 6 % of its GDP to defence expenditures, enabling it to acquire very capable, modern and well-trained ground, air and naval forces [14-15]. Its annual defence expenditure increased from USD 5.14 bil in 2004 to USD 5.83 bil in 2008. In comparison, Laos only allocates 0.4 % of its GDP for military spending, with its average annual military expenditure from 2004 to 2007 being USD 11.88 mil. The average annual spending of other ASEAN countries are; for the pediod of 2004 to 2008, Indonesia (USD 3.80 bil – 1.2 %), Malaysia (USD 3.20 bil – 2.2 %), Thailand, (USD 2.31 bil – 1.2%), Brunei (USD 249.60 bil – 3.6%), Vietnam (USD 1.11 bil – 2.0 %) and the Philipines (USD 911.20 mil – 0.9 %); and for the period of 2004 to 2007, Cambodia (USD 75.68 – 1.1 %) [16].

Other than the disparity amongst the level of current defence industry sophistication, and resource allocation, the potential rise of development costs due to the collaboration will also be a challenging factor before any collaboration takes place. Duplication of production facilities, resulting in subsequent integration, needs to be resolved before a decision on types of project is finalised [11]. Many of these challenges could be minimised if countries are able to identify military requirements far enough into the future so that requirements and time schedules can be harmonised sufficiently to permit co-operative research, development, testing and production. Unless this is done, collaboration efforts will continue to be hampered by such impediments.

Added to these could be other challenges such as national survival, strategy, sovereignty of technology, security issues, export controls, trust, structural processes, as well as issues of governance. Viewed from the purely public sector perspective, namely from the standpoint of political governance, each ASEAN country would want to ensure and enhance its own competitiveness, and find its own standing in the global economic environment. There would be political sensitivity issues arising if governments were seen to be prioritising regional objectives over and above national interests and goals.

However, in reality, working in collaboration with the competition in a regional context would enhance national economic resilience and strength, because well-strategised approaches towards integration in the defence industry can contribute towards adding value to individual national economic efforts [17]. This is clear when the external competition is too strong for the individual countries to face; but when collaboration amongst neighbours can be forged, it can ensure greater competitive strength among others; through resource complementation, sharing of know-how, synergistic R&D efforts, collaborative development of new technologies and processes, joint efforts for large scale production and collaboration in marketing, creation of strong ASEAN brands backed by quality, reliability and competitive pricing, and common approaches to capacity building in order to move the joint-capacity up onto a higher plane

PROPOSAL AT THE ADMM RETREAT

With the above mentioned issues in mind, Malaysia tabled a proposal at the ADMM Retreat in Bangkok, held on 3rd November 2009, on the idea of an ASEAN defence industry collaboration and the setting up of an ASEAN Defence Industry Council. It is heartening to note that while there were some reservations over the setting up of a Defence Industry Council at the present time, the idea of ASEAN defence collaboration was well received and endorsed by the ASEAN Defence Ministers. In this respect, it was agreed that this proposal be further developed and discussed at the future ADMM meetings and retreats [18].

The proposed collaboration would integrate various industrial and technological capabilities, such as aerospace, weapons, automotive or naval sectors, that have already been developed by some of the ASEAN countries. The collaboration at its best will involve both private sectors and government-funded projects, were not just for military purposes, but also for humanitarian efforts, disaster relief and joint exercises such as training, border patrols and peace-keeping missions.

THE WAY FORWARD

Since the proposal has already been endorsed by the ASEAN Defence Ministers, it is important that the concept of the ASEAN Defence Industry Collaboration be followed through to make it a reality in the not too far distance future. One could argue that the seeds of this beneficial and meaningful endeavour in the name, and for the benefit, of ASEAN have already been sown. What remains to be done is perhaps to put this concept through the process of refinement, as well as temper and moderate it with pragmatism, and develop framework for implementation.

The results of the defence industry collaboration may extend, and not be limited, to the following measures:

a. Setting up of a Defence Industry Council to facilitate confidence-building measures amongst ASEAN member states, and

b. Setting up of a Joint Working Group (JWG) to develop a roadmap that may include strategies, action plans and implementation processes.

Towards this end, it is the author's considered opinion that this concept be further discussed at seminars, workshops, forums as well as various ASEAN meetings, especially the upcoming ASEAN Defence Senior Official Meeting (ADSOM) to be held in the near future.

CRITICAL SUCCESS FACTORS

For the proposal of the ASEAN defence industry collaboration to be implemented, in its true spirit and intent, moving beyond rhetoric and political expediency, several critical success factors must be borne in mind, including the issue of trust, regional spirit and structural changes.

Trust underpins all relationships and transactions, business or otherwise. Therefore, there must be recognition and unreserved acceptance that the ASEAN defence industry collaboration is being propagated for the common good and with the best interest of the ASEAN community at heart. This perhaps calls for putting in place CBMs, and developing a greater understanding of the concept through dialogues and discussions at various levels.

With regards to the challenges of the regional spirit, it must be recognised that ASEAN spirit that now pervades all that is being done among ASEAN countries, and that which underpins the relationship amongst its people should buttress the proposal of ASEAN defence industry collaboration. This would mean that the larger good should be the cornerstone of this proposal and there must be the general acceptance that some compromises and sacrifices must be made by the more developed and fortunate countries in the interests of those who have not quite attained the level of defence industrialisation as compared to others, including their varying levels of imports and exports of defence platforms, weapons, and military solutions.

As for structural changes, the ASEAN defence industry collaboration also calls for initiatives which the ASEAN countries must be prepared to introduce, including those relating to the technology ownership and management, resource allocations, procurement processes as well as export controls.

To make the defence industry collaboration a success, it is important for the implementation to take into account the three principles of collaboration as mentioned by Dr Ng Eng Hen, Minister for Education and Second Minister for Defence of Singapore during the Fifth Asia-Pacific Security Conference (APSEC) 2010 which emphasised on the inclusiveness, flexibility and mutual understanding among the participating nations [10].

Firstly, cooperative arrangements must be inclusive, so as to bring all stakeholders on board. It must be recognised that both the major regional powers and smaller states have useful and necessary roles to play. At the same time, the role of extra-regional stakeholders who have significant interests in the region cannot be ignored, particularly in an interconnected world. Secondly, cooperative arrangements need to be flexible and take into account the different capabilities and comfort zones of partners. Stakeholders must be allowed to contribute in accordance with their own unique circumstances and capabilities. And thirdly, cooperative arrangements must have the flexibility to allow countries with different niche capabilities, expertise, cultural links and resources to form functional groupings that are best able to respond to common security concerns.

However, having said that, it is important to emphasise that ASEAN defence industry collaboration, at any level, cannot be expected to happen and materialise satisfactorily, through what are essentially public sector driven initiatives alone. For the ASEAN defence industry collaboration to become a reality, the private sectors of ASEAN must assume the role to share the collaboration process forward.

The defence industry community of ASEAN itself, must see the need for intra-firm and intra-industry collaboration and joint efforts, motivated by the need to survive well in the increasingly competitive and challenging market. Rapid advancements in the whole spectrum of technology, and rationalisation amongst firms and industries, at both regional and global levels, will continue to present serious challenges to the ASEAN defence industry collaborations.

CONCLUSION

As the concept of the ASEAN defence industry collaboration has been endorsed by the ADMM at its meeting in November 2009, it is important that we continue to keep up the momentum. Otherwise, this might just remain an elusive dream without being translated into reality.

Admittedly, a lot of work needs to be done, and the process of refinement and the proposed framework for implementation requires a lot more spadework to be carried out. Some recommendations have been offered and need to be seriously taken up by all quarters. The implementation of collaboration in the defence industry among ASEAN countries would certainly move the regional grouping up another notch, as well as open up a new dimension of economic and defence collaboration, thus adding further meaning and strength to the ASEAN spirit, whilst further moving its people towards a common purpose and a shared destiny.

Indeed, the realisation of the proposal for the ASEAN defence industry collaboration would certainly illuminate the ASEAN Motto of 'One Wisdom, One Identity, and One Community' and add impetus to the establishment of an ASEAN Community by 2015.

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TRANSFORMATIONAL LEADERSHIP: CHARACTERISTICS AND SPECIFIC PRACTISES AMONG MILITARY OFFICERS

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ABSTRACT

The purpose of this study was to understand the nature of transformational leadership among military officers. The study was conducted through the examination of the following: (a) what are the characteristics of transformational leaders; (b) what are the specific practises that transformational leaders engage in; and (c) what factors are associated with the emergence or practise of transformational leadership. The study employed the qualitative methodology and the data were collected through in-depth interviews, informal observations and examination of related documents. The participants include leaders who are senior military officers from the Army, Navy and Air Force. The study revealed five characteristics of transformational leaders, four aspects of transformational leadership practises, two main factors that influence transformational leadership practises and three main aspects of military leadership that emerged in leadership practises in the organisation. The study found that transformational leadership is practised among the military officers and that it has a wider context, as opposed to being limited to the existing related literature.

INTRODUCTION

The most significant challenge of leadership is to build and sustain an organisational culture that focuses on continuous improvement and effective change that adds value to the organisation and to society. Leadership is an important factor to enhance organisational effectiveness and to ensure the future of any organisation. The fast changing environment demands effective leadership that can transform organisations to adapt to the rapid changes. Therefore, organisations need to position themselves at the forefront of a shift that is essential for continuous development and for the organisation to remain competitive. The success of an organisation depends on the leadership role provided by top-level executives in steering their organisations through the ever-increasing uncertain, volatile and competitive environment.

Transformational leadership is a social phenomenon that has been researched, resulting in various conceptualisations, distinguishing it from the traditional transactional approach. Transformational leadership is very much needed especially in times of uncertain changes to uplift people, organisations and nations to greater heights. While

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leadership is generally unique in the military environment, officers are required to adapt to these changes effectively in order to align people in the organisation and to achieve its selected objectives.

Transformational leadership is about implementing new ideas. These individuals must continually change themselves; they stay flexible and adaptable; and continually improve those around them. The transformational leader encourages followers by acting as a role model, motivating through inspiration, stimulating intellectually, and giving individualised consideration for needs and goals. Overall, transformational leaders balance their attention between action that creates progress and the mental state of their followers. Perhaps more than other leadership approaches, they are people-oriented and believe that success comes first and last through deep and sustained commitment.

While transformational leadership also empowers people to greatly exceed their previous level of accomplishments, this dynamic and innovative leadership style challenges and motivates an entire organisation – top to bottom. They put passion and energy into everything. They care about people and want people to succeed. The result is individual, group, and organisational achievement beyond expectations. The actual goal of a transformational leader is to motivate and inspire people to perform at levels far beyond anything that they had previously thought possible. Transformational leaders empower others by keeping them "in the know", by keeping them fully informed on everything that affects their jobs. People want and need to know that they are "insiders", that they are aware of things that are going on in the organisation.

Bass [1] espoused a transformational leadership theory that adds to the initial concepts of Burn's. The extent to which a leader is transformational is measured in terms of his influence on the followers. The leader transforms and motivates followers through the four components of transformational leadership which are charisma or idealised influence, intellectual arousal, inspirational motivation and individual consideration. In addition, this leader seeks for new working ways, while he tries to identify new opportunities versus threats and tries to get out of the status quo and alter the environment. Bass's research shows that, transformational leaders are able to identify the required change, create a compelling vision to inspire their followers, secure their followers' dedicated buy-in, and finally execute the change effectively simply because it is executed through committed followers. Followers of transformational leaders tend to do more than they were initially expected because they have genuine feelings of trust, admiration, loyalty and respect for such leaders. With these attributes, transformational leaders possess the ability to grasp new opportunities, alter the status quo and transform the environment. A conceptualisation of transformational leadership as described by Burns is shown at Figure 1 [2].

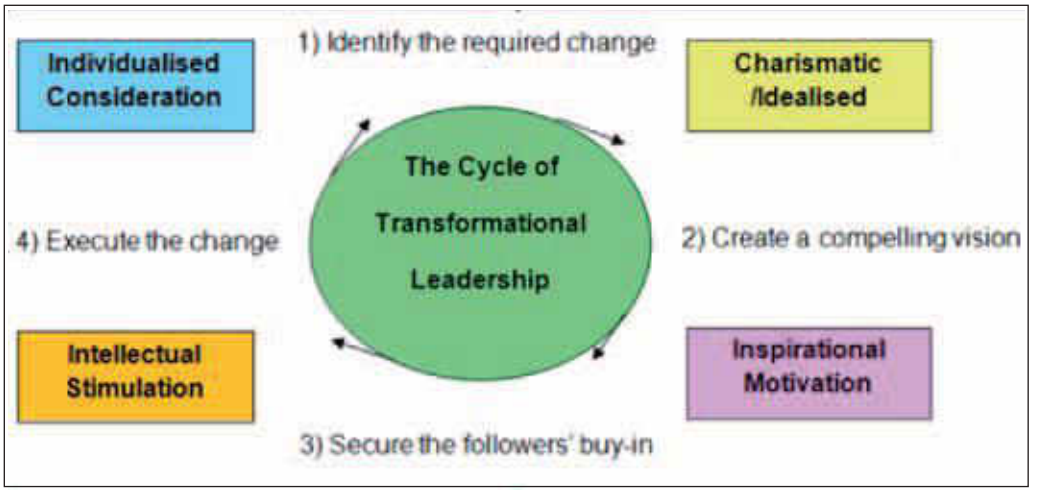

Figure 1. A conceptualisation of transformational leadership.

Yukl [3] added that "transformational leadership is generally referred to as "the process of building commitment to the organisation's objectives and empowering followers to accomplish these objectives". The main significance of organisations that have achieved business success indicates strong leadership capabilities of the corporate leaders. Since transformational leadership builds commitment among subordinates towards achieving organisational objectives, it invariably has an impact on the organisation's profitability. This has resulted in companies searching for top-level executives from other organizations, including the military, especially the retired senior officers. These officers are expected to provide sound leadership that is supposed to bring changes for the benefit of the enterprise. Yukl further explains that transformational leadership involves (a) developing a challenging and attractive vision, together with the employees; (b) tying the vision to a strategy for its achievement; (c) developing the vision, specify and translate it to actions; and (d) expressing confidence, decisiveness and optimism about the vision and its implementation.

An organisation doesn't change until the leaders do. In order to transform an organisation, there are sequences that must be followed and the leaders within the organisation must be the first to adapt and change. The precursor of organisational change is certainly through leadership transformation. However, changing the organisation does not guarantee a change in behaviour but changing behaviour decisively alters the organisation. All eyes are therefore on leaders when they change their behaviour in order to transform the organisation. It is apparent that there is no need to wait for others to change or hope that the organisation will wake up and transform. Transformational leaders have the power to influence change and it is done through various ways using different types of management approaches [4].

PURPOSE AND SIGNIFICANCE OF THE STUDY

Transformational leadership includes aspects such as charisma, individual consideration, intellectual stimulation and inspiring organisation members to achieve organisational goals. Based on this conceptualisation, it seems that there are elements in military leadership that are similar to the components of transformational leadership. In this context, transformational leadership is assumed to be an important factor through which the military officers provide direction and create a strong commitment among subordinates in the organisation. Although leadership practises in the military are generally viewed as being very autocratic, the principles of military leadership indicate that military leaders also focus on their subordinates, developing them as a team and ensuring their morale. Apart from this, other military leadership practises such as interacting with subordinates and inspiring them to achieve organisational objectives creates the assumption that military officers also practice transformational leadership. This assumption is strengthened by Bass's study that confirms the practice of transformational leadership in the military. Bass [5] in developing his model on transformational leadership conducted tests on military officers in the US army with ranks ranging from Lieutenants to Colonels and discovered that transformational leadership augments extra effort and performance beyond that of the transactional leadership approach. Furthermore, he also discovered that combat officers were found by their subordinates to display more transformational leadership, as compared to the combat-service officers.

Basing on Bass's study, it is apparent that military officers practise some form of transformational leadership. Military officers undergo systematic training and development processes that mould their character and behaviour. The continuous development and practice of such leadership skills is embedded into these officers as such, it is perceived that on moving to any organisation, they would continue to practice some or all of these leadership skills appropriate to the organisation setting. However, it was unclear as to the nature of transformational leadership practises among military officers in the organisation.

For the purpose of the study, transformational leadership was defined as a process of building subordinate commitment to the organisational objectives while empowering them to achieve those objectives. The purpose of this study was to understand the nature of transformational leadership among these military officers. This study was presented by specifically addressing the following questions that were of interest; (a) what are the characteristics of transformational leaders; (b) what are the specific practises that transformational leaders engage in; and (c) what factors are associated with the emergence or practise of transformational leadership in the military.

The study was intended to gain a better understanding of what constitutes transformational leadership practises among military officers in the organisation in relation to the existing theories. The study provided some explanation of the gap between the theories and realities of transformational leadership, in particular the practices and

characteristics of transformational leaders, including factors associated with the practise of transformational leadership among military officers in the organisation. Since transformational leadership can be developed through training, the findings therefore provide an additional perspective to the existing knowledge on transformational leadership and contribute significantly to the future development of organisations.

NATURE OF MILITARY LEADERSHIP

Military leadership is defined as a process by which a soldier influences others to accomplish a mission [6]. Leadership has always been considered as "a critical factor in military success since records have been kept, that is better led forces repeatedly have been victorious over poorly led forces" [7]. The soldier who leads, carries out this process by applying his leadership attributes which includes his beliefs, values, ethics, character and knowledge. Accordingly, based on the traits of military leadership professional beliefs, values and ethics are foundations of a leader's character that projects the leader's personality. The principles of military leadership include; (a) knowing yourself and seeking improvement; (b) being technically and tactically proficient; (c) seeking responsibility and taking responsibility for ones actions; (d) making sound and timely decisions; (e) setting example; (e) knowing ones soldiers and looking out for their well being; (f) keeping the soldiers informed; (g) developing a sense of responsibility among soldiers; (h) ensuring that the tasks is understood, supervised and accomplished; (i) training soldiers as a team; and (j) employ ones unit in accordance with its capabilities. Apart from this, military leaders are trained to provide direction, implement plans and motivate subordinates to achieve their objectives. Military leaders are also expected to inspire their soldiers to fight and carry out missions, at times beyond their capabilities and they should be concerned about their soldier's morale, since morale has a tremendous impact on motivation and can make a difference in the battlefield.

The term leadership generally connotes "images of powerful, dynamic individuals who command victorious armies, direct corporate empires from atop gleaming sky-scrappers or shape the course of nations" [8]. The command and leadership manual of the Malaysian Armed Forces Staff College explains that in the military, " combat is considered as the ultimate test of leadership", as it is the culmination of every effort expanded to train leaders to be able to motivate their subordinates to successfully accomplish a common goal. Although the general nature of leadership in the military is more autocratic, military officers are trained to adapt and conduct themselves to the environment, particularly when in the battlefield. Regardless of the leadership style used, a leader's effectiveness is largely measured in terms of the accomplishment of objectives and the mission.

The personality and character of a leader shape the leadership style to a certain extent that determines the influence over the subordinates. Military officers generally undergo leadership training and development throughout the process of their service career. Adair [9] once wrote that the five general areas of leadership training include;

(a) the opportunities which exists structurally within the organisation for the practise of leadership; (b) formal courses on leadership and training conducted to provide experience on the role of a leader; (c) the quality of staff training which includes a working knowledge of the general theory of leadership which is expected to be taught; and (d) the effective employment of staff as a specialist and in an advisory role to improve the quality of explicit leadership evaluation. Military officers of the MAF also undergo continuous leadership development and periodic formal training as they progress through the respective stages of their career. Such training is aimed at developing them as leaders at respective levels of the organisation, particularly as commanders which commensurate with their ranks. As a commander of a unit or formation, the officer provides the vision, direction and also influences his men to be able to undertake respective missions. Leadership factors as described in the Malaysian Army Leadership Doctrine is shown in Figure 2 [10].

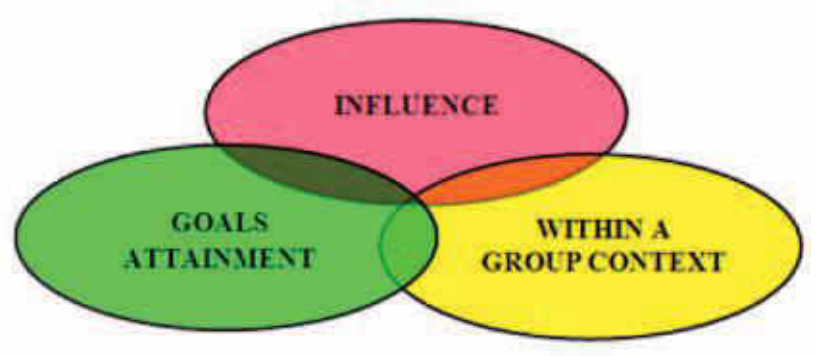

Figure 2. Leadership factors.

Transformational leadership emerged from the early conception of transforming leadership which was formulated by Burns [11] who believed that leaders and followers can raise one another to higher levels of morality and motivation. Burns as a political scientist, was of the view that "aspiration levels are raised, legitimised, and turned into political demands by the transformational leader and that such leadership can have similar effects in highly structured worlds of industry, government, and the military". Working on the theory that was espoused by Burns, Bass further researched on the theory of transformational leadership, and its outcome on the expected individual's performance in the organisation. Basing on the conceptualisations of transformational leadership, there are elements apparent in military leadership that is similar to the components of transformational leadership.

Bass in his research administered a multi-factor questionnaire on a sample of military officers of the U.S. Army and discovered three out of the five factors as being transformational and the other two being transactional [12]. These factors are charismatic leadership, individualised consideration and intellectual stimulation. From Bass's study, it is evidenced that transformational leadership is practised in the military. However, Bass views transformational leadership and transactional leadership as distinct but not only mutually exclusive, and that the same leader may use both types at different times in

different situations. Bass further explains that "numerous examples of transformational leadership can be cited which have occurred in modern industrial, educational, social, and military organisations". In another study, Yukl and Van Fleet content analysed critical incidents describing effective behaviour by military officers and identified characteristics examples of inspirational behaviour amongst these officers [13].

METHODOLOGY

Design of the Study and Selection of Participants

The qualitative research methodology was selected, as it was most appropriate for the conduct of this inquiry, particularly in understanding the phenomenon being studied. The inductive study included participants who were selected retired senior officers of the Malaysian Armed Forces. The study therefore involved a group of participants who had been selected based on a set of criteria. Apart from the senior military officers who were being studied, participants for this study also included, subordinates working with these leaders, particularly subordinates were involved in specific incidents that were considered important to enrich the data that was considered. The subordinates were also selected purposefully, to validate the data gathered on the leaders' leadership practises and also for the purpose of triangulating the data gathered.

Data Collection and Data Analysis

The data collected for the study was through in-depth interviews, informal observations at the work place and through the examination of documents that were made accessible. The interviews were tape-recorded since the study involved extensive open-ended interviewing. The general guide interview approach was employed, which entailed the use of semi-structured questions that were guided, concentrated, focussed and open-ended. The study was also conducted using the constant comparative method where the data collected was compared from one participant to another and also to the related theories of transformational leadership.

The analytic procedures involved reading and reading over the data, making relevant field notes and organising the data, generating categories and sub-categories, coding them to ease management of the analysis. Categories were constructed from the marginal notes on the printed copies of the interview transcripts and field notes. A number of categories and sub-categories were subsequently constructed. Categories were developed through a process of reading and reflecting on the data gathered from each participant and also relating it with the previous interview data, reading over and writing memos. Field notes were generated during the interviews, informal discussions with subordinates of the respective leaders, and through informal observations. Their notes and personal memos added to the richness of the data that was collected.

The participants were asked to describe how they perceived their role as a leader, and how they would deal with various aspects related to the provision of leadership in their respective organisation. During the interview, aspects pertinent to transformational leadership that emerged were subsequently pursued and discussed in-depth. The participants had described their experiences, views and convictions, which provided an insightful account of transformational leadership among military officers in the organisation. Their responses were examined and analysed to determine the characteristics of transformational leaders, specific practises that these leaders engaged in, contextual factors that were associated with the practise of transformational leadership, and the dominant aspects of military leadership that transferred to the setting

FINDINGS AND DISCUSSIONS

In researching the topic, it was assumed that transformational leadership is generally practised by military officers by virtue of the systematic training and development that they undergo, which moulds them as leaders who are able to inspire and motivate their subordinates particularly in achieving organisational objectives. It was observed that military officers from the Malaysian Army, Air Force and Navy, undergo a similar type of leadership training and it is assumed that these officers practice the same style of leadership after retiring and working in any sector or organisation.

A Model of Transformational Leadership among Military Officers

Transformational leadership is the process of developing higher motivation and commitment among subordinates to achieve organisational objectives. Transformational leaders have distinct characteristics and engage in specific practises that have an influence over the subordinates, especially in providing the direction and mobilising efforts towards the achievement of organisational objectives or goals. Contextual factors also have an influence on leadership practises among the military officers in the organisation. The outcome of the characteristics, practises with contextual factors result with higher motivation and commitment among the members or personnel of the organisation towards achieving organisational objectives. The findings of the study can be conceptualised into a model as shown at Figure 3.

The characteristics of transformational leaders include; (a) visionary; (b) people-centred which involves concern for individuals and being fair; (c) value driven; (d) continual learner; and (e) socially adept which involves, adaptable and self confidence. The findings also revealed the practices of transformational leaders which include; (a) empowering individuals which involves, delegation of power, development of subordinates and encouraging creativity; (b) inspiring; (c) proactive involvement which includes, interacting with subordinates involving constant communication and 'walking the ground' and facilitating teamwork; and (d) initiating change which includes, providing direction, mobilising commitment, and inculcating values. The contextual factors that

were found to be associated with the practice of transformational leadership includes: (a) organisational factors which involves collaborative governance and organisational structure; and (b) the external or environmental factors.

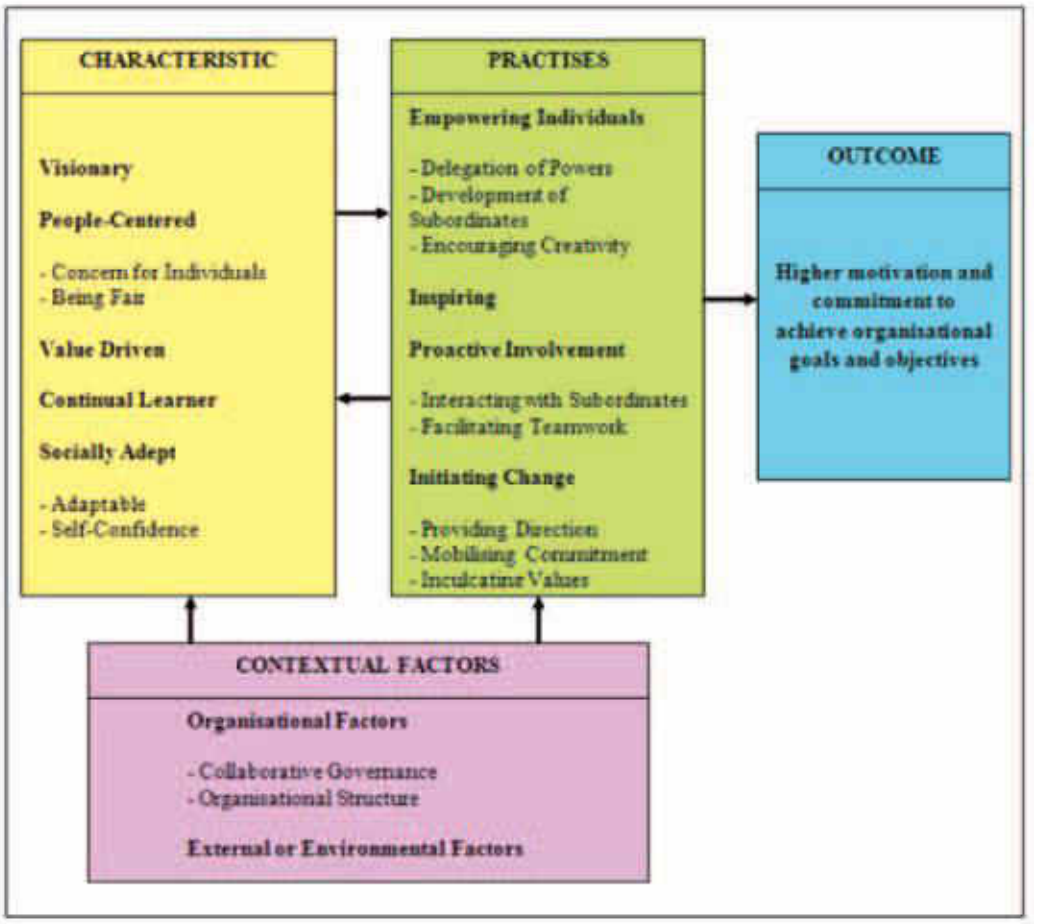

Figure 3. A model of transformational leadership among military officers.

CHARACTERISTICS OF TRANSFORMATIONAL LEADERS

The data revealed that transformational leaders have distinct characteristics that influence their leadership practises. These characteristics also influence their behaviour and actions as transformational leaders in their respective organisations. The categories that emerged from the data revealed five characteristics of transformational leaders that were apparent among the participants. These characteristics include; (a) visionary; (b) people-centred; (c) value-driven; (d) continual learner; and (e) socially adept. These characteristics are discussed below.

Visionary

Finding shows that many participants realised the importance of having a vision for the organisation. This confirms the theoretical expectations that transformational leaders tend to develop a vision, which provides a common purpose for their subordinates. The transformational leader has visionary characteristics and is able to develop a mental image of the future desired state of the organisation. The leader provides the direction for the future of the organisation through the vision. The vision therefore focuses the attention towards attainable objectives. A shared vision bonds members of the organisation together and inspires them work towards the future of the organisation. The vision is also realised particularly when it is translated into the strategic plans for the organisation. Through the strategic planning process, transformational leaders promote their vision and challenge their subordinates to achieve the vision. In order to achieve this, strategic plans were supported with action plans that could be understood and implemented by the members of the organisations.

People-Centred

The second characteristic that emerged is the transformational leader's concern for the people within the organisation. This characteristic includes; (a) concern for individuals; and (b) being fair. The leaders who were interviewed showed empathy towards their subordinates and were always trying to be equitable in order to motivate and to create a more conducive working environment. Transformational leaders are people-centered since they show concern for their subordinates and treat them fairly. Being people-centered which includes showing concern for individuals and being fair makes the subordinates feel valued, resulting in their morale being raised. The subordinates' motivation is invariably raised and they tend to work harder since they are treated fairly and as individuals rather then just another employee in the organisation.

Value Driven

Transformational leaders are driven by values that are personally held. These values which comprise of the leaders believe as to what is important determine personal standards and character of the leader. The fundamental values guide the actions of the leader and the way things are done in order to achieve organisational objectives. Transformational leaders tend to articulate their personal values that transcend through the organisational system. Transformational leaders derive respect from their subordinates based on the values that they display. The values displayed by the leader in turn permeate among the members of the organisation and shape organisational values.

Continual Learner

The participants expressed great concern for the need to continuously learn and be abreast of the latest developments. They were of the view that learning never ends and that a leader must always take the initiative to seek knowledge. A transformational

leader has an appetite to learn since he has a personal commitment towards bringing improvement to the organisation. The leader should be prepared to go down to learn and experience what is being done at the lower levels, only then will the leader be able to appreciate and communicate better with the subordinates. This includes experiencing the apparent difficulties which subordinates may have to go through. Transformational leaders are also self-directed learners, as they take the initiative to seek knowledge and to develop their skills from experience. Being continual learners, these leaders also adopt an attitude of developing their subordinates, which also facilitates individual and organisational learning.

Socially Adept

The fifth characteristic of transformational leaders that emerged is being socially adept. This characteristic involves two sub-categories; (a) adaptable; and (b) self-confidence. Most participants expressed the need for the leader to be sociable and to establish relationship that would facilitate the leader in his role. The participants mentioned that the leader should be able to adapt himself to differing situations, particularly when dealing with subordinates at various levels, and with people outside the organisation. The leader can therefore adjust according to the situation with a view of accommodating others and also establishing networks within and outside the organisation.

The transformational leader has self-confidence that contributes to being socially adept. Having self-confidence is essential, especially for the leader to be able to interact with others and to establish social relationships. This is the second sub-category of being socially adept that emerged, with the participants describing how they are able to handle changing situations. The leader's confidence has a motivating effect on the subordinates and their confidence in accomplishing certain tasks. Confidence is generally expressed in both ways the leader speaks to subordinates and the actions taken, particularly when undertaking tasks in an always changing situation. Military leaders developed self-confidence through the process of training. It is important for the leader to not only be confident in himself when facing any uncertain situations but also to foster confidence and optimism among subordinates when the tasks is difficult. Transformational leaders display self-confidence in their actions and in the decisions they make. The leader's confidence has a large impact on the subordinates, especially in embarking on new changes where uncertainty is prevalent. These leaders build confidence among the subordinates through their own ability and self-confidence. The transformational leader's confidence is attributed to them being socially adept.

SPECIFIC PRACTISES THAT TRANSFORMATIONAL LEADERS ENGAGE IN

Transformational leaders engage in specific practises that encourage subordinates, thus influencing the outcome of their actions. These practises are means through which leaders raise the motivation of their subordinates. The data revealed four main categories

that are specific practises that transformational leaders engage in, which include: (a) empowering individuals; (b) inspiring; (c) proactive involvement; and (d) initiating change. These practises that emerged from the data are discussed below.

Empowering Individuals

Empowering entails the delegation of power by the leader to the subordinates and creating the feeling of being autonomous. Subordinates will feel important if they have been empowered to undertake their tasks with the leader's trust. The transformational leader's practice of empowerment creates an impact on the subordinates as explained by the participants. The data revealed three sub-categories of empowering individuals that include; (a) delegation of power (b) development of subordinates, and (c) encouraging creativity.

Leaders who delegate powers to their subordinates create an environment of mutual trust which fosters commitment among the subordinates. Transformational leaders are sensitive to the need to delegate and allow their subordinates to undertake their jobs with the necessary authority and responsibility. This develops trust and it motivates the subordinates to be more responsible, committed to their work and feels responsible. The process of delegation also frees the leader from minor decisions and allows the leader to concentrate on the larger issues of the organisation.

Transformational leaders adopt a developmental attitude towards their subordinates. They encourage their subordinates to expand their knowledge and skills, which also increases their motivational level. The development of subordinates also creates confidence among them to undertake any challenging tasks. Transformational leaders take the initiative to encourage and develop their subordinates in the organisation. The process of development could entail the empowerment of subordinates in all possible aspects. The effectiveness of empowering subordinates also depends on the subordinate's capability to undertake certain tasks, and their ability to make sound judgements and decisions. It is therefore the leader's responsibility to ensure that their subordinates are prepared and also to develop them to undertake such roles.

Transformational leaders stimulate subordinates to think and encourage creativity allowing their subordinates to approach and solve problems in a more efficient ways. Transformational leaders recognise the need to encourage creativity and they tend to provide some latitude to subordinates in the use of their own minds. Apart from this, it also encourages innovativeness among them, particularly in developing new ways in improving the organisation. Members of the organisation will also take a more positive view on how to achieve the vision of the organisation. The transformational leader is aware of the benefits of encouraging creativity among subordinates and creates a conducive atmosphere among subordinates that empowers them to use their own mind especially in handling their work. The transformational leader is also willing to listen and discuss with subordinates on ways to solve problems and to achieve certain organisational objectives.

Inspiring

Inspiring subordinates is the second category that emerged from the data. Transformational leaders stimulate enthusiasm among subordinates and inspire them through the setting and achievement of goals. These leaders are always keen to talk to their subordinates and they arouse their subordinates' emotions towards their jobs and achieving organisational objectives. Inspiring is an important aspect of transformational leadership as it involves motivating members of the organisation to achieve higher performance. The way the transformational leader stimulates subordinates will have a tremendous effect on the organisation as a whole. The leader can use different ways to inspire subordinates, particularly in channelling efforts to the achievement of organisational objectives.

Proactive Involvement

Transformational leaders engage in the management of their organisations and allow their subordinates to participate thereby maintaining a closer relationship with subordinates. Proactive involvement relates to two sub-categories; (a) interacting with subordinates, and (b) facilitating teamwork. The leaders are more inclined to interact with their subordinates and it provides better channels for communication. Communication is essential in the provision of leadership and constant communication fosters better understanding between the leaders and subordinates. This includes consultation with subordinates where necessary to make the right decisions. In order to proactively get involved, the leaders cut bureaucratic barriers and go down to where the subordinates are to meet their subordinates. The term frequently used by the participants is 'walking the ground'. Leaders who go down to see their subordinates at work also show concern for their subordinates which has an impact on their motivation to work harder. Facilitating teamwork is another aspect that transformational leaders engage in. Teamwork fosters better co-operation among the subordinates, which creates synergistic effects from the efforts put in towards achieving organisational objectives.

Initiating Change

An important aspect of transformational leadership is the leader's ability to recognise the need for change. The leader takes the initiative to bring about the necessary changes in the organisation by getting the commitment from the subordinates and providing the direction for the required changes. The leader mobilises commitment and also inculcates values among members of the organisation to ensure that there is a lasting change. The data revealed three sub-categories that include: (a) providing direction; (b) mobilising commitment; and (c) inculcating values. In initiating these changes, the leader provides direction to ensure that efforts are focussed towards its implementation, reducing resistance to these changes. Transformational leaders mobilise commitment from their subordinates by constantly communicating with them, getting them involved in planning such changes, fostering teamwork and by displaying their own commitment

and values. Since transformational leaders have a strong set of values, which guides their behaviours and actions, instituting changes in the organisation can be successful through the inculcation of values among the members of the organisation.

CONTEXTUAL FACTORS THAT INFLUENCES TRANSFORMATIONAL LEADERSHIP

The research indicated that the contextual factors that were found to be associated with the practice of transformational leadership involved both the organisational and external factors and the categories include: (a) organisational factors involving collaborative governance and organisational structure; and (b) external or environmental factors.

Organisational Factors

Organisational factors are aspects associated with transformational leadership relating to the internal context of the organisation. The data indicated that there were two sub-categories that include: (a) collaborative governance; and (b) organisational structure. The mode of governance affects the efficiency of the organisation, particularly in decision making for routine and strategic aspects related to the organisation. Transformational leadership is affected by the mode of governance particularly in relation to receptivity of the transformational process by the organisation's members. Therefore, depending on the leader's position, whether as a Commander, Staff officer or in an executive position in the organisation, it is apparent that there must be collaboration between the top levels and the lower levels of the organisation. A collaborative mode of governance facilitates the practice of transformational leadership and fosters better management that benefits the organisation.

Organisational structure reflects the distribution of tasks and responsibilities within the organisation. It also facilitates the division of functions and co-ordination of the work processes. In a simple form, it determines how the organisation functions. Most of the participants expressed that the structure of the organisation facilitates the leader in his function, particularly in the allocation of work and the process of empowerment. It means, that the organisational structure dictates levels and facilitates the distribution of tasks and the delegation of authority. The structure of an organisation should be definable for members of the organisation to know exact functions and responsibilities in conjunction with their appointments. A simple and clear structure facilitates the transformational leader to empower individuals and to initiate and supervise changes that are necessary for the organisation. Apart from this, the leader must ensure that the correct people are put in the right positions and that they have the appropriate training to function in these appointments. The transformational leader therefore takes an effort to see that subordinates are also developed to fill higher appointments.

External or Environmental Factors

External factors relate to external environmental factors of the organisation that has an impact on the organisation. These influences also have an impact on the practice of transformational leadership especially when there are changes to the environment and the organisation has to adapt itself to the changes. Transformational leaders have the ability to scan and evaluate the environment and make necessary changes within the organisation. These leaders constantly communicate and explain the need for such changes to their subordinates to make them aware of the external factors, which makes receptivity to changes much easier. Environmental factors have an impact on the organisation and it influences the transformational leader to be proactive and to initiate changes, and to adapt to the environment. The extent of changes instituted within the organisation is also dictated by the changes in the external environment.

CONCLUSION

The findings reveal the nature of transformational leadership among military officers in organisations. Transformational leaders have distinct characteristics that also influence their practises. These practises are in turn influenced by certain contextual factors that facilitate transformational leadership. Apart from the characteristics, practises and the contextual factors that emerged, the study examined the military leadership influences since the participants are senior military leaders. Based on these findings, the general conclusion that has been made is that, transformational leadership is practised among the military officers in the organisation. This finding confirms the practise of transformational leadership among military officers and it corroborates with the studies conducted by Bass on military officers of the US army [14]. The study indicates that since the characteristics and practises that emerged prevail among military officers, such leadership practises can exist in both the military and corporate setting. Although the general perception on the military is that officers are autocratic in nature, it dispels the notion that military officers are not people-centered and that they can adapt to differing situations.

It is apparent that transformational leadership has a wider context as discussed in the findings as opposed to the existing literature on transformational leadership. There are various perspectives on transformational leadership based on different studies that have been conducted by respective researchers, and each of these studies introduced certain aspects of transformational leadership. Burns espoused the process of transforming leadership which focussed on Maslow's hierarchy of needs, whereby leaders activates the higher-order needs of the followers while Bass focussed on the components of transformational leadership that increases leadership effectiveness and performance beyond expectations [15]. Tichy and Devanna [16] highlighted the characteristics of transformational leaders and the way these leaders bring about change in the organisation. From these studies, various other studies have been conducted on the subject of transformational leadership, complementing the findings of other researchers. This study, while it compliments the earlier studies, provides a broader view of the aspects of transformational leadership.

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SECURITY CHALLENGES BEYOND 2010: BUILDING RESILIENCE

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ABSTRACT

Meeting the security challenges beyond 2010 is not just the responsibility of government and a nation's leaders. From a strategic perspective, building resilience is a shared responsibility which includes partnerships between government and the private sector, information sharing, building resilient organisations and building resilient critical infrastructure. Defence and security professionals face increasing challenges in the twenty-first century brought about by an unprecedented set of disruptions and catastrophic events. Traditional security threats have been compounded by the global economic crisis, increased piracy, pandemics, cyber-security and threats to energy availability. These factors added to global turbulence in the first decade of this century. To meet these challenges, greater flexibility and creativity are needed to make the transition from being reactive to proactive and to become adaptive. A resilient capability is needed to survive and thrive in the turbulent times beyond 2010.

INTRODUCTION

The challenges for national security in the twenty-first century are unprecedented and security is no longer defined only in terms of military response. Traditional security threats have been compounded by the global economic crisis, by piracy, pandemics, cyber-security and by threats to energy infrastructure. These factors have added to global turbulence since the beginning of this century.

In the context of security, resilience must extend beyond the traditional roles of protection and response. It is no longer sufficient to harden targets such as critical assets or to rely on technology to solve the problems. While these measures are important, they should form part of a broader national strategic resilience security framework.

Resilience addresses uncertainty, that is, our inability to know what combinations of conditions will occur in the future. If the future were predictable, resilience would lose its importance – nations, organisations, communities and individuals would simply need to plan for a known set of conditions. But because the future is unpredictable, it is necessary to plan for a wide range of possible conditions, including some which may be unlikely but which could result in significant harm if they are not anticipated [1]. The challenges and uncertainties of our current and likely future environments demand new approaches to security. Resilience has become an important dimension for critical infrastructure and a key element for partnerships with government because it

recognises both the need for security and the importance of reliable business operations [2, 3]. Owners and operators of critical infrastructures need to manage their operational risks in an all hazards environment. Building resilience can help leaders and security professionals meet these challenges by adopting a holistic perspective which integrates capabilities, resources and information to deal with disruptive events. National resilience demands organisational resilience through partnership arrangements between the public and the private sectors. Resilience provides a measure of a country's capacity to anticipate, to learn, to adapt and respond so that it can survive and thrive.

SECURITY AND RESILIENCE

When looked at strategically, resilience including security resilience, is the result of four factors being achieved [4]. The first is robustness, meaning an ability to maintain and to continue to function during a disruption. Second is resourcefulness, which means managing the response to a disruption as it unfolds. Third is rapid recovery or an ability to return to normal after a disruption and fourth is the ability to absorb new lessons learned after a disruption and thereby to reduce vulnerability. These factors combine to build resilience in organisations and nations to meet the challenges of national security and critical disruptions.

DISRUPTIONS

By definition, disruptions are difficult to anticipate and hard to predict. They often begin to unfold before they are noticed and can have unforeseen consequences. Disruptions can be devastating if they impact on critical infrastructural elements or organisations, such as power and water supplies, oil production, airports and harbours, information technology and communications systems.

Intentional disruptions can include industrial action, strikes, sabotage, electronic jamming, theft and computer hacking. Terrorism is another intentional disruption which remains a real threat around the world as well as piracy which is on the increase. The number of piracy and armed robbery incidents on the high seas rose for a third consecutive year in 2009. There were 406 cases of piracy in 2009, an increase of almost thirty-nine percent on the previous year [5]. Piracy, and disruptions to maritime shipping and supply chains, impact directly on international trade and national security.

Natural disruptions can also add to the complexity of national security challenges. The earthquake which hit Haiti in January this year is estimated to have affected three million people and the February earthquake in Chile and resulting tsunami which was felt on the islands of New Zealand was the focus of attention for all Pacific Rim countries. In Australia, there is a good understanding of disruptions caused by nature – fires, flood and drought are common occurrences. Natural disruptions impact can on power, communications and on food and water supplies.

Accidental disruptions such as unexpected mechanical and technical failure, slovenly practices, non-compliance with regulations and standards, cuts to power supply, contamination and chemical spills, can also add to the uncertainty of a changing risk environment and impact on security. In reality, any disruption can add to the turbulent environment and add to the complexity of meeting security challenges. This is because a disruption, whether it is intentional, accidental or natural, means that you do not know what will happen, when it will happen, how severe the impact will be or how long it will last. This means that security, business, organisational and community plans can no longer be passive or even simply reactive, instead they need to be sufficiently robust, flexible and adaptive to be relevant to any situation whether it is anticipated or not.

PLANNING

Usually organisations create plans to prepare for the inevitable, to pre-empt the undesirable and to control the controllable [6]. Plans based on known vulnerabilities can be developed. For example, there are several known world oil transport choke points. Choke points are narrow channels along widely used sea routes around the world and these vulnerable areas are a critical part of global energy security because of the high volume of oil traded through their narrow straits.

The Strait of Hormuz between Oman and Iran and the Strait of Malacca linking the Pacific and Indian Oceans are the two world's most strategic, and potentially vulnerable, choke points. Other critical maritime passageways are the Suez Canal, the Strait of Bab al Mandab, the Turkish Strait and the Panama Canal.

In 2007 approximately 85 million barrels per day (bbl/d) of oil were produced and almost half the world's oil production (over 43 million bbl/d) was moved by tankers along fixed maritime routes, including known vulnerable choke points [7]. The 900 km long Malacca Strait is just over 2.5 km wide at its narrowest point and every year it carries about forty percent of the world's traded oil and over 50,000 merchant ships along the waterway. Plans can be developed to address these types of vulnerabilities based on known threats. However, while this sounds rational, planning for known vulnerabilities has its limitations because planners plan in stable and predictable circumstances about known events and likely threats. This style of planning runs the risk of a narrow perspective and not anticipating or being alert to unforeseen threats and disruptions.

An example of an unforeseen vulnerability with equally unforeseen consequences is that of the strong earthquake which struck the Japanese city of Kobe in January 1995, with one of the indirect consequences being the collapse of the British Baring Bank [8]. One of the banks' derivative future traders in Singapore, Nick Leeson, was engaged in risky trading that relied on stability in the Japanese stock market to avoid major losses. The Kobe earthquake, however, caused the Nikkei Index to drop by seven percent in one week. Barings' losses escalated rapidly, in the end reaching £1.3 billion. The oldest merchant bank in Britain, which had financed the Napoleonic wars, the Louisiana Purchase and the Suez Canal was bankrupt.

LEARNING LESSONS

Most organisations and nations have strategic and operational plans and programs which address risk, security and business continuity. However, these programs are often managed in isolation from each other. Additional security challenges and the changing risk environment mean that security and other plans need to be flexible, interlinked and adaptive.

For an organisation to meet the challenges of today, including security challenges, plans and procedures need to be integrated, timely and relevant – we need to move beyond the silos. Plans also need to be tested independently and the lessons from them need to be implemented. Otherwise they are simply lessons observed, not lessons learned and resilience is not strengthened. For example, sea ports are a critical vulnerability in every country's defence against terrorism because they are a potential entry point for bombs and other devices smuggled into cargo ships. The sprawling nature of ports presents a number of natural terrorist targets. In recognition of these factors, the US Government Accounting Office [9] undertook a review of port security exercises and in 2005, the GAO reviewed eighty-two port-security exercises from the fiscal year 2004. The review noted that:

> *"while such issues are indications that improvements are needed, it should be pointed out that the primary purpose of the exercises is to identify matters that need attention and that surfacing problems is therefore a desirable outcome, not an undesirable one."*

In those eighty-two exercises, there were four recurring themes.

a. almost fifty-nine percent of the exercises raised communication issues;
b. nearly fifty-four percent of them identified concerns about the adequacy of coordination of resources;
c. over forty-one percent of the exercises highlighted command and control issues, most notably a lack of knowledge or training in the incident command structure; and
d. twenty-eight percent of the exercises raised concerns about participants' knowledge regarding who had jurisdiction or decision making authority.

These four recurring themes were identified as occurring repeatedly across eighty-two exercise. Consequently, because of the recurring nature of the issues identified these were lessons observed not lessons learned. The ability to absorb new lessons after a disruption can reduce vulnerability and is a factor in achieving resilience. Resilience does not replace existing plans or programs but provides the overall contextual framework, like an umbrella for them to work under. It brings them together to sit at the very centre of an organisation's management ethos and way of operating.

BLACK SWAN THEORY

We also need to think about those events and disruptions we have not planned for or foreseen. No leader can anticipate exactly the challenges their organisation or their nation may face. Talib [10] has given us the Black Swan theory. It is a metaphor for something which could not exist. It refers to a high impact, hard to predict and rare event beyond the realms of normal expectations. The term comes from the assumption by Europeans in the seventeenth century that 'all swans are white', but discovery of black swans in the eighteenth century in Australia shows that the perceived impossibility can be not only possible, but real. The idea is not to try to predict Black Swan events but to build robustness, reliability and resilience, especially to high impact and unexpected events.

Enhanced security and increased resilience will reduce vulnerability. By increasing security, an organisation will reduce the likelihood of disruption. By building resilience, an organisation will build its capability to resume essential and key services after a disruptive event. It will be more adaptive and flexible. A resilient organisation has the potential to turn crisis into opportunity. In fact, following a disruption, an organisation with a high degree of resilience can use the event as an opportunity to improve its effectiveness, enhance its reputation and to increase staff morale.

Glasgow airport is an example of a highly adaptive and resilient organisation. After the bombing in June 2007, the airport was operational again within twenty-four hours [11]. The risk to the national security of the United Kingdom through disabling one of its major airports is obvious. The organisational resilience of that infrastructural element minimised that risk.

This incident demonstrates that having a plan is not the sole key to surviving a disruptive event. Glasgow airport shows the importance of immediate and effective leadership, devolved decision-making, information sharing between public and private agencies, supportive external agencies and a highly motivated workforce. This combination resulted in a strong recovery with an attendant increase in reputation and staff morale in the face of a significant and very public disruption. Organisations can seek, unsuccessfully, to control disruptions or they can recognise their inevitability and develop adaptive and resilient traits to be able to cope and to minimise their impact.

PUBLIC PRIVATE PARTNERSHIPS

Public-private partnerships are integral to developing resilience for national security. Protection of national assets such as transportation hubs, bridges, water and power supplies and communications facilities are critical for a nation's security, its economy and its future as a trading nation. In the United States of America, approximately eighty-five percent of critical infrastructure is owned and operated by the private sector. In

Australia, it is up to ninety percent and, as the largest island nation, ninety-nine percent of exports are transported by sea with nearly 4,000 ships carrying goods and commodities to and from Australian ports.

Infrastructure should be an enabler of national security, prosperity, and progress: not a nation's Achilles heel. Direct collaboration between government and critical infrastructure owners and operators and the wider business sector is a cornerstone of building resilience. The United States National Infrastructure Advisory Council report [2, 3] noted that:

> *"it is essential for government to change the way they prepare and partner on resilience efforts, especially in our increasingly interconnected world."*

The Council noted that collaboration on resilience must be based on true partnerships of equals and not merely presented as an implicit threat of regulation. The Council report notes that past examples of partnerships have proven successful and cites the US Department of Energy's National SCADA Test Bed program which gave vendors an opportunity to use cyber attack tools to test their control systems. This project demonstrated the need for increased investment in more secure energy control systems.

INFORMATION SHARING

Information sharing is another cornerstone of building resilience. One such example is from the International Chamber of Commerce Piracy Reporting Centre in Kuala Lumpur which provides live piracy alerts and reports to assist the shipping community.

The Malacca Strait was once the most notorious area for pirates. It is now much safer with only two attacks reported in 2008, down from twelve the previous year. This is a direct result since 2004 of information and intelligence gathered on pirates being shared between the Governments of Malaysia, Indonesia, and Singapore. Together they began coordinated naval patrols around the narrow Malacca Strait and this has resulted in a discernible reduction of piracy in the area. Information sharing continues, in March 2010 the Singapore Navy warned it had credible information of possible attacks on oil tankers in the Malacca Strait [12]. In response, Malaysia and Indonesia in collaboration with Singapore increased security and intensified coast guard patrols in the area. It was recognised that any attack could have a disproportionate impact on the global economy and international trade as well as on those countries in the immediate vicinity of the Strait.

The advantages of information sharing is also evident in the United Kingdom where risk information is shared on the understanding that participants refrain from discussing who shared the risk information and instead focus on how to mitigate the risk [2, 3]. This approach dispels concerns that the information revealed will be leveraged against the

entity that revealed it and enables the private sector to share information on threats and vulnerabilities with government. In Australia, there is a similar arrangement known as the Trusted Information Sharing Network.

For its part, government can facilitate sharing information with, and between, the private sector and can clarify the risks faced within each critical sector. Sharing information within organisations builds resilience and prevents the development of silos and segregation. It is more cost effective and a better use of resources if work areas and business units share information, integrate their strategies and align them with the overall corporate direction and security objectives.

RESILIENCE STANDARD

In Australia there is a move away from the concept of protection of critical infrastructure to resilience of critical infrastructure. At the Critical Infrastructure Advisory Council (CIAC) meeting on 9 December 2009, the Australian Federal Attorney-General, the Honorable Mr Robert McClelland, announced the Australian Government's intention to shift the existing Critical Infrastructure Protection program to Critical Infrastructure Resilience. It is envisaged the new program will be launched in June this year and will include at least two components – organisational resilience and support for disaster resilience.

Infrastructure protection and infrastructure resilience represent complementary but distinct elements of a comprehensive risk management strategy. Infrastructure protection is the ability to reduce the effect of an adverse event. Infrastructure resilience is the ability to prevent and to reduce the magnitude, impact and duration of a disruption. Resilience is the ability to anticipate, to absorb, adapt to, to learn and/or rapidly recover from a potentially disruptive event. In support of this approach, Australia is developing a national Standard for organisational resilience.

That Standard will emphasise the adaptive capacity of an organisation in a complex and changing environment as well as the protection of critical assets. The proposed Standard offers a management systems approach for organisations which will assist them to survive and thrive by anticipating, preparing for, preventing (if possible), responding to and recovering from a disruptive event.

The draft Standard builds on the Plan-Do-Check-Act (PDCA) model. It is an iterative four stage process which is implemented in spirals of increasing knowledge as an organisation learns from each stage and implements improvements. The integrated management systems approach avoids segregating risks and provides an overall risk profile allowing an organisation to understand better the relationship between risks and to identify solutions to problems.

The draft Standard is being developed to integrate with a number of relevant International Standards dealing with quality, safety, environmental, information security, risk, and the supply chain. Many countries have recognised the importance of adopting a resilient framework. The United States published an Organisational Resilience Standard last year. The Netherlands, Denmark, Italy, South Africa, and India are just some countries which are also developing a similar Standard and the International Organization for Standardization (ISO) has established a committee to develop an international standard for Organisational Resilience.

A RESILIENT ORGANISATION

Resilience is a combination of a number of factors. A resilient organisation effectively aligns its strategy, operations, management systems, governance structure and decision support capabilities so that it can uncover and adjust to continually changing risks, endure disruptions and create advantages over less adaptive competitors or adversaries.

Resilience tends to increase if an organisation has diversity, redundancy efficiency, autonomy and strength of its critical components. This allows it to continue to function if a link is broken, if a particular resource becomes scarce or if a particular decision-maker or leader is unavailable. Resilience demands holistic, integrated and inclusive processes which recognise and benefit from, the inter-relationship of different work units and business practices within an organisation and at a national level, between different organisations and agencies. In doing so, resilience is a key component to meet the challenges of security.

CONCLUSION

The challenges of security at all levels, demand adoption of the principles of resilience. That entails an approach involving both public and private sectors and agencies, and inter-governmental cooperation. The attributes of robustness, resourcefulness, rapid recovery and learning new lessons after a disruption are the cornerstones of building resilience. Practical steps include partnerships between government and the private sector, information sharing, building resilient organisations and resilient infrastructure and adopting a national Standard.

In the event of a major Black Swan disruption or catastrophic event in this changing risk environment, organisations and nations need to be able to restore material services quickly to support the nation they serve. Security is a shared responsibility. It takes effort and time to build a broader national strategic resilience security framework, but the alternative can be devastating.

In the words of Charles Darwin:

> *It is not the strongest of the species that survives,*
> *Nor the most intelligent that survives.*
> *It is the one that is the most adaptable to change.*

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its role within the global political system. The second hypothesis relates to the nature and make of the OIC membership. The extreme ideological diversity, economic and social disparity as well as political differences amongst the states that comprise the OIC poses a serious challenge towards the grouping's internal cohesion. Such deep seated differences cripple the grouping's ability to function effectively and respond adequately to issues facing the Islamic world in general and its members in particular. The third hypothesis has to do with external cohesion. It is argued that two external factors act as serious challenges in the OIC's quest as a serious actor in the international arena. The first relates to the international community's perception of the OIC. Though established with specific roles and objectives, the OIC is generally viewed by the developed world within the framework of the North-South divide. It is seen as yet another organ of the developing world. The second factor is the advent of global terrorism, a phenomenon – at least in its current form - seen as linked intrinsically to the Muslim world. The failure of the OIC to respond effectively, either on its own accord, or in collaboration with other global actors, to the phenomenon of global terrorism has resulted in the inability of the OIC to win the trust of other global players and organisations.

The main hypotheses in relation to alleviating the challenges facing the OIC are four. Firstly, it is argued that the OIC needs a serious re-examination of its roles and functions, not unlike the re-invention undertaken by organisations such as the Non Aligned Movement (NAM) or even NATO in the post-Cold War era. Second, The OIC needs an overhaul of its structure, whereby developing close working relationships with other established global groupings is prioritised. Third, there is need to work diligently on enhancing the level of internal cohesion. Fourth, by virtue of its representation of the Muslim world, there is a need for the OIC to stand up and participate boldly and effectively in one of the world's most serious current problems – global terrorism. There is a real need to go beyond just issuing statements of condemnation.

The methodology of the paper integrates relevant theoretical constructs with data collection and analysis. The theoretical frame work draws from the general theory of international organisation as developed by Holsti [1], the theories of regionalism and globalisation as expounded by Clark [2], the theory of clashing civilizations by Huntington [3], as well as the writings on international terrorism by Dershowitz [4]. Due to the space constraints, the theoretical framework will not be developed for the reader, save for the brief mention of the main constructs in the following paragraph and the documentation of its origins in the reference list. Data collection has relied heavily on secondary sources, most of which were made available to the author via the libraries of the Institute of Diplomacy and Foreign Relations (IDFR), the Ministry of Defence and the Ministry of Foreign Affairs, Malaysia.

Holsti theorises that international organisations are major actors on the global stage in the sense that they are able to act on and influence the global environment [5]. The premise of this paper is that the OIC has failed as an actor and that it is in fact a subject of the system. It has not been able to influence global events as much as the organisation itself has been influenced by the system. Even if one insists that the OIC is an actor on

the international stage, it would have no significance beyond an "extra." Clark argues that globalisation and regionalism occur simultaneously, are in conflict with each other, and have serious impact on international organisations [6]. The premise of the paper is that both forces have affected the OIC negatively – globalisation has sidelined it and reduced its effectiveness, while regionalism has failed to give it the internal cohesion that has been accorded other organisations such as Association of Southeast Asian Nations (ASEAN) or the European Union (EU). It would follow therefore that the tensions between globalisation and regionalism have had no positive impact on the OIC. Huntington's theory of the clash between civilizations becomes relevant to the OIC because both the theory and the organisation have political Islam as a core component. Huntington theorises that amongst all civilizations, Islam has "bloody borders" [7], and hence, can be considered to have replaced global communism as the primary threat to the Western world; while the OIC in its claim to represent the Islamic world can thus be seen within the context of Huntington's theory as a possible response, if not solution, to the civilisational problem of the world. Dershowitz explains that terrorism succeeds in its aims because of the failure of the international community to respond appropriately [8]. He further theorises that the attempt by the world to understand and eliminate the "root causes" of terrorism further strengthens the cause of global terrorists. The OIC, as a non-state actor of the international community, falls within the gambit of Dershowitz's premises as an entity that ought to have responded appropriately. In its relative silence, the OIC is thus considered to have failed in its role of standing up to the recent wave of terrorism which is intrinsically linked, rightly or wrongly, to the cause of Islam. The OIC's subsequent obsession with "root causes" would still be considered as an inappropriate response – at least in the eyes of Dershowitz.

OIC BACKGROUND INFORMATION

The decision to establish the OIC was taken at the First Islamic Summit in Rabat in September 1969. The first Conference of Foreign Ministers the following year decided that the OIC's secretariat would be housed temporarily in Jeddah, pending the liberation of East Jerusalem – the envisioned location of the organisation's permanent headquarters.

The OIC Charter states that the *raison d'etare* of the organisation is to safeguard Islam's holy sites and to support the struggle of the Palestinians to liberate their territories. The principal objective of the organization's activities is to strengthen Islamic solidarity in the political, economic, cultural and social fields and to safeguard the dignity, independence and national rights of Muslims [9].

The OIC structure consists of three separate bodies; the Summit which is held tri-annually; the Islamic Conference of Foreign Ministers, held annually; and the General Secretariat and its subsidiary organs. The organisation has a number of specialised standing committees at the level of Heads of State or Foreign Ministers [10]. It also has a number of subsidiary organs to strengthen research, understanding and cooperation [11]. In addition, the organisation has some specialised organs [12] for the purposes of carrying out specific tasks.

The membership of the OIC stands at 57 countries. From the standpoint of the numbers and its geographical spread (across four continents), the OIC is outwardly a truly global body. Its international character is further enhanced by the fact that OIC's members are also members of other regional and international organisations such as ASEAN [13], the Organization of African Countries (OAU) [14], the Arab League[15], NATO [16], and the Organization of American States (OAS) [17]. The OIC represents one fourth of the membership of the United Nations (UN) and a third of the global population.

The OIC is not an organisation of the *Ummah*. Rather, it is an assembly of independent Muslim countries. Its original Charter [18] did not spell-out what constitutes a Muslim state. As a result some of its members are Islamic by constitution, while the vast majority is secular. It even has members amongst states whose Muslim populations are not in a majority [19]. In 2008, the Charter was amended to provide membership to "members of the UN having (a) Muslim Majority" [20].

Given all the above characteristics, the OIC, in accordance with Holsti's premises, is theoretically an influential actor in global affairs. Yet this is not the case.

THE CHALLENGES CONFRONTING THE OIC

Changed International Environment

The OIC was established during an era characterised by East-West tensions, the North-South Divide, Arab-Israeli Wars, the oil crisis and worldwide Islamic resurgence. The prevailing mood of the era provided both the organisation and its individual members a common bond or *ummatism* as described by one scholar [21]. Virtually all of OIC's original 25 members were on the same side of the fence as far as the North-South Divide, the Arab Israeli Wars and the East-West tensions were concerned. The successful use of oil as a political weapon by some of its members and religious resurgence in many Islamic states provided the organisation the euphoria of being in a position to influence global events. The humbling of many a western nation as a result of the oil embargo further propelled OIC members to embrace pan-Islamism or at least pan-Arabism – a sentiment that had suffered sudden demise especially after the defeat of the Arabs in the Six Day War.

Yet none of the above mentioned organising philosophies – *ummatism*, Islamic unity, or pan Arabism would last to keep the OIC sufficiently relevant. Too much has changed in the years after its establishment, and such change has affected the OIC's *raison d'etare*. With the Cold War's demise, East-West tensions have virtually disappeared. The Arab-Israeli Peace Accords, and the change in Palestinian attitudes and expectations in the post Yasser Arafat era have provided considerable space for the resolution of outstanding issues between these historical antagonists. On the other hand, inter-Muslim state rivalries and conflict have surged [22]. The euphoria of oil as a political weapon has

all but diminished. Islamic resurgence has produced mixed results with some Islamic and Muslim governments even fighting hard to keep the resurgence under reign. Furthermore, the unity of the Muslim world has remained imaginary.

New phenomena have appeared on the global horizons which have affected the effectiveness of the OIC. Globalisation and regionalism have both tended to work against the OIC's quest for uniting the Islamic world – mostly by affecting its level of internal cohesion. The quest for survival in a globalising world has forced some OIC members into new alignments with each other and with the West. The quest for collective security and economic linkages has produced the same results. The realities of such considerations could be easily seen in the diverse choices made by OIC members over the issue of support for the USA and its allies during the two most recent Gulf Wars, for instance. The overall effect of all the above has been loosening loyalties to the OIC amongst members [23].

The advent of global terrorism and the failure of the OIC to take a stand – especially one that is acceptable to the international community at large - on this issue have further put the organisation in poor light in the eyes of the international community. The overall ramifications of a changed international environment thus have been that the OIC is at a cross-road as regards its main goals and direction.

Lack of Internal Cohesion

OIC's membership has been both diverge and diversified. Its members constitute the poorest, smallest and the weakest, to the richest, biggest and most powerful of Muslim states. It can therefore be expected that there is a great deal of diversity amongst members in terms of their expectations from OIC membership, their political ideology, religion, size, and alignments with each other and the rest of the world.

The demise of the Cold War and East-West tensions and the spread of globalisation and regionalism have provided an added element of divergence. Some members – especially the rich and powerful of the OIC - have aligned themselves with the West and the United States in line with their national interests, while the smaller and poorer ones have remained steadfast to the belief that the West works against the desire for *ummatism*. Members are also increasingly divided on the issue of Islamic resurgence – with some states going to the extent of battling Islamic movements that have the stated aim of unseating the ruling regimes. The advent and spread of global terrorism in the name of Islamic interests has further divided the organisation. Member states that have had to bear the brunt of terrorist acts on their soil seem ready to align themselves with the United States and the West in the latter's military fight against the terrorists, while the more extreme ones do not even bother to deny their support for organisations that are termed terrorist even by the least stringent of definitions. Then there are member states who believe that the West – and much that is associated with it - is part of the problem. Such members tend to favour the use of non-military ways such as calls for the need to

look at the root causes of terrorism. If Dershowitz is accurate, then the OIC has been divided into those who are against terrorism and those who support it, or at least allow it to flourish.

The greater ramifications of the above have been the lack of internal cohesion within the OIC, which in turn has resulted in the organisation becoming ineffective [24]. The ineffectiveness can be seen in three major areas. Firstly, the outcomes of OIC deliberations tend to be little more than pious rhetoric [25]. The organisation has not been able to put up a united front, let alone reach consensus on a number of core issues affecting the Muslim world. For instance, the OIC failed to reach consensus on critical issues such as the Bosnia-Herzegovina issue, the Afghanistan War, the US invasion of Iraq, and conflicts in Chechnya, Nagorno-Karabakh, Kashmir and Cyprus. In present times, one could add international terrorism to this list. Some decisions of the OIC are openly ignored by member states themselves. Secondly, the OIC has remained in poor financial standing. Many members seem to have taken an indifferent attitude towards the OIC. Less than half pay up their mandatory contributions. Many merely maintain a perfunctory link without participating actively in the organisation's activities. The result has been that the OIC, having a meagre budget, is financially dependent on the Gulf States, in particular Saudi Arabia, and is oftentimes unable to meet its basic financial obligations[26]. Its Secretariat in Jeddah has for too long remained in a state of disrepair. At the very least, it is not reflective of the standing of an international organisation that claims to represent a large portion of the global population. Some states continue to remain members simply because it would be politically incorrect to leave the organisation. Thirdly, the lack of internal cohesion has disallowed the OIC from undergoing much needed administrative and structural reform to make the grouping more relevant to current times and needs. Appointments are generally made on the basis of political connections. Poor auditing, continue weak accounting procedures, and lack of financial oversight remain serious problems [27]. Despite knowing the nature of the administrative weakness, there exists no political resolve to remedy the defects [28]. Turkey, for instance tried to give fresh impetus to the OIC in the 1980's by steering it towards economic issues, but failed. Malaysia's proposals to have an Eminent Person's Group (EPG) evaluate the OIC's performance too failed [29]. Both failures were attributed to lack of political will amongst members to empower the OIC to undertake reform.

Lack of External Cohesion

Despite the fact that the OIC has been on the international stage for four decades, has non-Muslim states and international organisations as observers [30], and that a good number of OIC members simultaneously belong to a number of other international organisations as listed above, the OIC does not seem to enjoy good working relations with the other global players - something considered crucial in a globalised and inter-connected [31] world.

The OIC Charter and its activities in general do not seem to strive for any particular cooperative endeavour with other international organisations. While UN Resolution 63/114 is centred on cooperation between the UN and the OIC, and the OIC does have cooperation agreements with regional organisations such as the League of Arab States, there is no focus on specific or pressing matters that is the subject of the cooperation that is desired. It also seems that the international community has traditionally characterised the OIC as yet another organ of the developing world worthy of disregard. Given that most of its original members were seen as belonging to the Third World, and that some were active leaders of Third World causes, such a perception was perhaps natural. If Huntington is accurate, the fact that the OIC represents Islam – a religion tied closely with Third World issues and causes – has added to the above perception of its image. The inability of the OIC to take a strong and effective stand on the issue of global terrorism has not only compounded OIC's image perception vis-à-vis the rest of the world, but acted as a lost opportunity for the OIC to rectify such a defect [32].

The greater ramifications of the above have been lost opportunities for the OIC to bring benefits to itself and its members. A greater portion of the Islamic world is mired in poverty, conflict, human rights violations, social disadvantages, high levels of illiteracy and economic disparities. The OIC could play a major role by working together with international organisations, such as the World Heath Organization (WHO), the Asian Development Bank (ADB), the World Bank, and the Educational, Scientific and Cultural Organization (UNESCO), to help its members alleviate some of their internal problems [33]. Yet it has failed to do so.

In summary, therefore, the challenges confronting the OIC have rendered the organisation ineffective, subject to disregard, and generally inconsequential to the international community and even its members. In the event that no concrete measures are taken, the movement may well disintegrate. The following suggestions are intended to provide a framework for remedial action in this regard.

SUGGESTIONS FOR OVERCOMING CHALLENGES

Re-examination of Roles and Functions

As argued above, the changed international environment has put the OIC at a cross-road in terms of its *raison d'etre*. It is argued that Islamic Unity, *Ummatism*, Muslim Unity, and the Palestinian struggle - while having worked well to inspire the setting up of the OIC, especially within the setting of the desecration of the Al-Aqsa Mosque in 1969 [34], have proved to be too amorphous and ambiguous as goals and objectives in present times. It is time the OIC set its ambitions towards alleviating and resolving some of the Muslim world's real, manageable and serious problems, such as poverty, illiteracy, human rights violations, lack of democratic practices, conflict, gender inequalities etc. These problems are definite, quantifiable and resolvable. In the post-Cold War era, the *raison d'etre* of the OIC should thus be the social and economic development of its

members – irrespective of political and religious orientations. Not unlike Malaysia's Vision 2020, the OIC ought to envision and then operationalise a bold yet attainable development goal for its members. The 2005 Summit (Extraordinary) witnessed the tabling of a Ten-Year Program of Action (PoA) which talked about the promotion of tolerance, moderation, modernization, reforms, good governance and promotion of human rights in the Muslim world, especially with regard to rights of children, women and elderly and the family values enshrined by Islam. However, the PoA was too broad, too philosophical and too lofty. It lacks a focus and falls short in terms of attainability. In short, the OIC needs to re-invent itself. This re-invention has to have the capacity to energize and invigorate its currently detached membership.

Structural and Financial Reform

Once the goals and objectives have been redefined, the entire apparatus and structure of the OIC should be revamped towards achieving the set vision. Two major areas of reform need addressing.

Firstly, the principal organs of the OIC need to be revamped. A Conference of Economic / Finance / Development Ministers ought to be set up to deal with the agenda of development. Its specialised committees at the Head of State level ought to be revamped according to developmental issues – education, poverty, technological progress, human rights, democratisation etc. OIC's Standing Committee on Economic and Trade Cooperation is chaired by the Heads of State, which may augur well for its perceived status, but suffers from specific programs and actions as a result. Specialised committees at the Economic and Finance Ministers level too ought to de-emphasise divergent political and cultural issues, and concentrate instead on development, economic and social issues. The OIC's subsidiary organs too need to be revamped to concentrate on the conduct of research and data collection relating to economic and development issues of its members. There is a need to expand its Turkey-based Statistical, Economic and Social Research and Training Centre for Islamic Countries (SESRIC) to provide greater emphasis on research relating to economic and social data which can then be used as input into OIC's programs and actions. Similar centres geared towards conducting research, strengthening understanding and promoting innovative solutions towards developmental problems of members could be similarly initiated. There is also an urgent need to strengthen and expand vastly the Islamic Development Bank to enable it to contribute effectively towards the OIC's new-found goals.

Secondly, the financial and administrative structure of the OIC needs an overhaul. There is a requirement for urgent action to liquidate its debt [35]. Collection of membership dues (currently at around 45%) has to be enhanced. The underlying problems of the non-payment have to be identified and addressed. It appears that these problems are related to the perception amongst members that the organisation is unworthy of their contributions. There is also the perception that sloppy management, free-wheeling expenditures, political pressures on the Secretariat, waste, and weak or non-existent

auditing system plague the OIC. The former perception can be alleviated through the process of re-invention of OIC's *raison d'etre* as outlined in the preceding section. The latter requires an action plan in line with the following three steps.

Firstly, the OIC needs a collective commitment to identify the problems. The previous attempt by Malaysia at the 7th Summit in 1994 to establish an Eminent Persons Group (EPG) to do exactly this failed due to the appointment of members to the EPG "based on favoritism and friendship" rather than one based on experience and merit [36]. The EPG ought to be revived and given teeth to do its job. Second, the budget of the OIC has to be increased to reflect its boldness in taking on the real issues. Third, there is an urgent need to reform the Secretariat. The location of the Secretariat in Jeddah, and the aspirations of OIC to have it eventually located at Jerusalem do not jive with the re-invented OIC as envisioned above. It is suggested that the OIC headquarters be located at a modern, developed and successful Muslim country. Kuala Lumpur fits such a suggestion. Alternatively, it could be located in a western world capital such as New York, or any other European city – even if only to facilitate cross-civilisational interaction. Beyond the re-location of the Secretariat however are larger issues such as the reduction or removal of tasks of a political nature out of the job functions of the Secretary General and its staff, the adoption of a rotation system for member countries to appoint staff of the Secretariat, the creation of specialised posts to head the departments and specialised organs described above, and the selection of eminently qualified and dedicated persons to run the Secretariat.

Enhance Internal Cohesion

The OIC is in an urgent need for a multi-sectorial action program to strengthen cooperation amongst member states. Such a plan has to have an action plan in each of the fields of trade and scientific endeavours, education, informational and economic data, and development expertise. These fields are suggested because they are generally more apolitical than, say, culture and hence, less divisive. Such a program, implemented over a 5 – 10 year period will help lessen the diversities and sharp differences in ideologies that seem to exist amongst members. The added advantage of such a program would be that real issues affecting member states would be resolved in the process of strengthening cooperation – thus setting of a chain reaction that would ultimately benefit the organisation and its members.

Become an Effective Player in the International Arena

Under normal circumstances, such a task takes time and expertise. However, the OIC has been handed an opportunity, even if ironically, in the form of helping the world deal with global terrorism. The international community has suffered serious levels of anxiety over the resurgence of this scourge and powerful nations have been drawn into armed conflict over this issue. It is not too farfetched to surmise that global terrorism has become a core component of international peace and security. Hence, any serious attempt to deal with the issue from the OIC would be most welcomed by the global

community. The reputation and credibility of the OIC would be greatly enhanced if it could rise to the occasion and contribute constructively, engage itself with the other actors, and undertake a resolution or mediation program in this regard. The OIC, after all, has the perfect *locus standi* to play such a role. It represents the Muslim world, many of its members are affected directly by the terrorism threat, and a vast majority of the terrorists do come from member countries as well. Two Muslim nations are currently located at the core of the global terrorism issue, namely Afghanistan and Iraq, and both are at crucial cross-roads relating to their respective futures. Both states seem to have a fifty-fifty chance of progressing on the road of successful self-governance or becoming failed states. Given the links between global terrorism and some elements within both states, the future of Afghanistan and Iraq would, in many ways, determine the future of global terrorism. Both nations are facing immense political and social impasses, and are in dire need of assistance from trusted parties merely to ensure their continued survival as nation stages. In the case of Afghanistan, the pressures are even greater given its long history of instability. In the name of global peace, the OIC can and should play a role in mediating between the warring factions in both these states – ideally the same type played by a very credible third party at the Oslo Peace Accords between two traditional antagonists in the Middle East.

The OIC may not have the funds or the expertise but it has the credibility and trust. Given the global stake in the problem of global terrorism, one could assume correctly that the international community would be willing to share its resources with the OIC in this quest. The goodwill earned could go a long way in establishing the image and reputation of the OIC as a serious and responsible actor and partner in the international arena.

CONCLUSION

The challenges facing the OIC are deep-seated and serious enough to threaten the relevance of the organisation. The OIC has come to represent a grouping that has failed to adapt to the changing times, failed in its stated mission, and failed to command credibility in the eyes of the international community and its own members. In short, it has been overtaken by events and overcome by problems to the extent that it has lost its *raison de'etare*. Its problems are circuitous and cyclical in nature. The more its members and the international community lose faith in the OIC, the more the organisation will be mired into irrelevance.

The suggested way out is as follows. First, a hard look at its vision and mission is required. The result of this would be a re-invention. The new OIC would have to be content with resolving real, serious, quantifiable and manageable problems of member states. This paper suggests a focus on economic, social and development issues. Second, the organisation is in serious need of functional, administrative and financial overhaul. Third, attention has to be paid to internal cohesion. Its members need convincing that the OIC serves a purpose and that their financial contributions to the grouping are worth

it. A specific program is required to achieve this aim. Fourth, there is a need for external cohesion. The OIC ought to work with existing international and regional bodies to achieve its new objectives. It will undoubtedly have to build a reputation for itself in this regard. This paper suggests that the resurgence of global terrorism as a new global threat accords the OIC with an opportunity to do just this. The quagmire in Afghanistan and Iraq gives it another opportunity to get involved and contribute towards real problems.

The OIC will require the moral courage to rise to meet the above challenges. Its members will require the political courage to give the OIC the mandate to do just that. And the international community will have to trust the OIC enough to allow it due space to function - to serve both its members and the world in the process.

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[11] Examples of Subsidiary Organs include the Research Center for Islamic History, Art and Culture at Istanbul, The Islamic Center for Technical and Vocational Training at Dhaka, The Al-Quds Fund and its WAqaf at Jeddah, and the International Commission for the Preservation of the Islamic Heritage at Istanbul.

[12] The Islamic Development Bank (IDB), the International Islamic News Agency (IINA), and the Islamic States Broadcasting Organization (ISB) – all located at Jeddah are examples.

[13] Malaysia and Indonesia.

[14] Twenty-six OAU members belong to the OIC.

[15] All members of the Arab League are OIC members.

[16] Turkey.

[17] Surinam and Guyana.

[18] Article VIII of the Original Charter read: "Every Muslim state is eligible to join the Islamic Conference on submitting an application expressing its desire and preparedness to adopt its Charter."

[19] Gabon, Mozambique and Benin are examples.

[20] Chapter 2 of the 2008 Charter reads: "Any State, member of the United Nations, having Muslim majority and abiding by the Charter, which submits an application for membership may join the Organization if approved by consensus only by the Council of Foreign Ministers on the basis of the agreed criteria adopted by the Council of Foreign Ministers." In order not to affect the status of members who had no Muslim majorities, the Amended Charter stipulated that "Nothing in the present Charter shall undermine the present Member States' rights or privileges relating to membership or any other issues."

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SECURITY PLANNING AND TECHNOLOGICAL APPLICATION FOR HOMELAND SECURITY ITALIAN G8 SUMMIT: EXPERIENCES AND CONCLUSIONS

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ABSTRACT

This paper is focused on the study of the general security framework used during the Italian G8 Summit 2009, and the related methodological and technological adopted solutions. The study is aimed at being an opportunity to explore an Italian model of "Major Events" security planning, organisation and management.

INTRODUCTION

The experience obtained during the planning, organisation and management of the "Major Event" G8 Summit 2009 L'Aquila has some special and unique characteristics at the international level. Until today, in fact, we have always been accustomed to dealing with the methodologies and systems complexity regarding safety and security issues (management of natural disasters, such earthquakes, or international events such as a G8 summit), but generally in separate areas and contexts, both spatially and temporally. In the case of the L'Aquila events instead, we found ourselves in the position to share, in terms of both space and time, the need to manage both the emergency related to an earthquake, of significant size, magnitude and effect, and the security framework linked to an international summit that was attended by very big number of personalities.

This has, for the first time, required the collation, integration and sharing of action planning, organisation and management, for human and instrumental resources with different aims and objectives but all housed in the same local context, and where the effects and the consequences of an event were directly affected from the contiguous event. This experience has led to, also for the first time, the development of a methodology and a model of integration in which civilian and military capabilities, aimed at two different aspects of safety and security, have joined forces to create a unique and homogeneous framework in which two events took place in parallel but, at the same time, converging. For this reason we can say that, the Italian experience is a case study of exceptional importance, both for instrumental and methodological solutions adopted, and for the significance of the events that took place.

This paper is focused on the study of presenting the security framework of the Italian G8 Summit 2009, the adopted methodologies and technologies, the particular difficulties, and the implemented solutions, related to the Summit displacement from the city of La Maddalena to the city of L'Aquila in a complex scenario; little time

available to re-arrange the new devastated Summit site, the characteristics of locations, the geographical conditions, and the presence of a territory by effects and consequences of an earthquake.

The study of the Summit security planning and organisation is important considering also the fact that the event was placed in a delicate political moment characterised by the presence of serious international conflict, and a severe economic and financial crisis. The scenario has led to consider, in addition to the traditional forms of turmoil against the G8 Summit implemented by national and European movements, to novel forms of dissent related to global politic-economic situations. In addition, it be added that the Summit would represent a potential opportunity to focus the attention on the regional (Abruzzo) situation after the earthquake.

MAJOR EVENTS

The definition of *major event* includes those initiatives, single or repeated, which require significant investment, considerable planning and organisational effort, the adoption of marketing techniques, and the participation of visitors, public and media. The theme of this type of initiatives may be sporting events (Summer and Winter Olympic Games, World Cup), commercial events (auto and nautical shows), cultural events (art exhibitions, film festivals, music festivals), religious events (Jubilee), or political/economical events (international summits, G7/G8, WTO).

In general, the main feature of *major events* is their unique and exceptional profile, in addition to the fact that they operate for a limited time not comparable to the time required for their organsation and preparation. Hence, these events are characterised by having a major impact, both in their preparatory phase and during their progress. This makes particularly complex and sensitive the organisational phase, in terms of public order, security, mobility, health, and accommodation.

Prospects and Problems

While a major event has a limited lifetime, the implications associated with it can have long-term effects during its preparation phase, generating also permanent consequences physically linked to the territory. This leads to the introduction of the concept of inheritance of an event, an element which must be properly designed and planned as the study of symbols, values and messages, and the operations of direct and indirect marketing planning. The inheritance of a major event cannot be uniquely defined and also post-event effects are not readily determinable. Moreover, since these effects are not always positive, it is difficult to foresee reliable data and information on possible negative effects. In any case, the goal of host cities is to get a positive image.

In any case, the goal of the host city is to get a positive image. This element is very important for local authorities and national governments, and also for international organisations that plan and/or support the event, mainly for three reasons. A positive inheritance is proof that the event was good for the host city/nation, is a demonstration of proper use of funds for infrastructure, and is the best motivation for the candidacy of the local territories/nation for other events.

Based on lessons observed, it is possible to identify some key themes that characterise an event of this scale, which may represent the lowest common denominator to try to anticipate/predict the effects of a major event; including security, urban regeneration, infrastructure, services and logistics, territorial economic development, investment and marketing, international political legitimacy, skills and education development, and environmental impact.

Threat Scenario

At the international level, the general terrorist threat framework changed with Berlin Wall fall and the September 11 attack; from the last century, the dimension of terrorism risks has increased due to the combination of additional availability of technology, expertise and means. This asymmetric threat generates a lot of areas of instability, due to local tensions, social, ethnic and religious conflicts, and the presence of terrorist networks and organised crime.

Italy, as well as many other western countries, are increasingly exposed to potential risks of terrorists attacks because of changing of international geopolitical framework in recent years, characterised by instabilities. This risk is even greater for the Italian peninsula, because terrorism may build to be the weapon to strike western symbols and values, of which Italy is highly representative due to its historical and artistic heritage, and the presence of the Pope. Thus, major events are increasingly exposed to potential risk of terrorist attacks.

For these reasons, it is crucial to obtain the best results in the event security management through co-ordination and synergy of entities, institutions, individuals, organizations, resources, skills, knowledge, training and means involved in all the security activities.

ITALIAN NATIONAL PROTECTION SYSTEM

To understand how Italian *"Major Events"* security is planned, organised and managed, it is fundamental to know how the organisation of the Italian national territorial protection system is planned [1]. The main activities of the national protection system are

a. Mitigation or risk assessment
b. Preparedness or planning scenarios and security tasks
c. Response or national emergency response system
d. Recovery or consequence management.

Risk Assessment

The risk assessment activity integrates findings of intelligence and law enforcement with input from scientific and technical communities, and reflects suspected terrorist capabilities and known threats. The result of key findings in this assessment can be shown in a table (Figure 1), linking probability and consequences, and should be updated during the time and when appropriate.

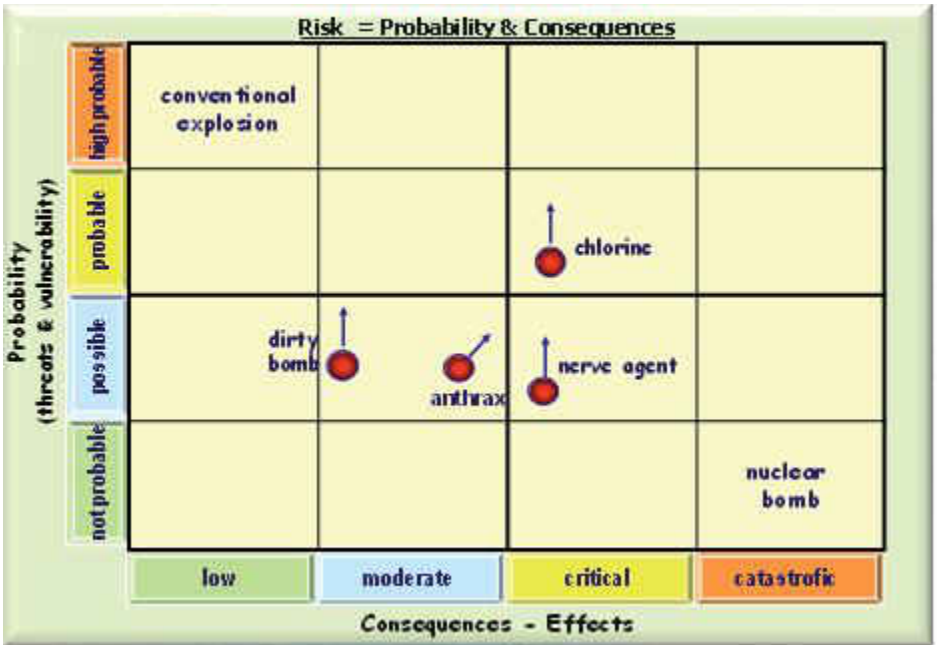

Figure 1. Risk assessment table.

Planning Scenarios

The main Italian threat scenarios, with related emergency response activities in case of terrorist attacks, can be categorised as:

a. The national plan against terrorist attacks
b. The response plans set up by the single state agencies on the basis of national plan guidelines.
c. The provincial civil defence emergency plans set up on the basis of the national plan and response plans.

Security Tasks

Regarding security tasks, they are divided between security tasks in Italy and abroad. Security tasks in Italy are mainly classified into infrastructure and sites protection, borders and coastlines surveillance, road and transport protection, networks and public protection, non-proliferation, and military and civilian operations. Security tasks abroad are mainly divided into disarmament and non-proliferation, and military and civilian operations (Figure 2). The general task, common for internal and abroad activities, is to ensure C3I (Command, Control, Communications and Information).

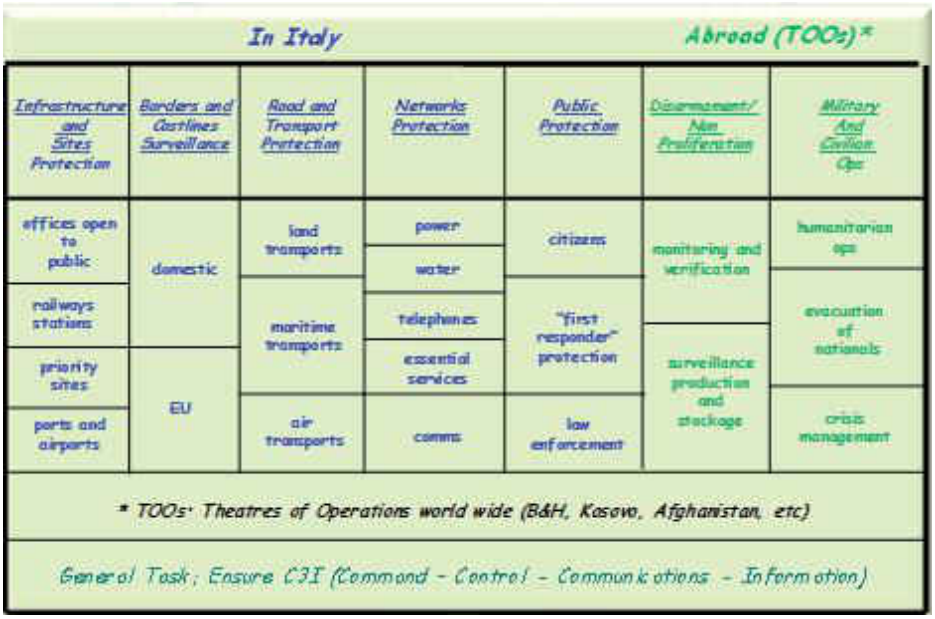

Figure 2. Security tasks Italy and abroad.

The Italian Civil Defence organisation involves all the actions to protect civilian population and public/private facilities in the following emergencies; national/ international crisis and conflicts. The Civil Defence is composed of six areas of intervention; continuity of government action, public information and training, telecommunications alarm systems, public health, and economic system protection.

As shown under Figure 3, the national civil defence organisation is structured as a chain, where command & control and national decisions are taken by the Presidency of the Council of Ministers, supported by Decision and Co-ordination Committees. Operating national coordination is conducted by the Ministry of Interior on the basis of two structures; the Crisis Unit, chaired by police head, for security management, and the Inter-ministerial Technical Committee for Civil Defense, chaired by the National Fire Brigade Head, for safety management. Onsite assistance co-ordination is conducted by the Local Prefect, and key operations are conducted by the Police Forces, the Armed Forces, the Fire Brigade and the National Health Services.

In summary, the Italian Civil Defence system involves, in its actions, several national public organs and organisations, developing preventive activities and co-ordination during emergencies; Presidency of the Council of Ministers, Civil Protection Department, Ministry of the Interior, Prefect, Police Head, Police Forces, Armed Forces, Fire Brigade, National Health Service, Italian Red Cross, Hospitals, Municipal Authority, Public Health and Environmental Protection Services, and Essential Services.

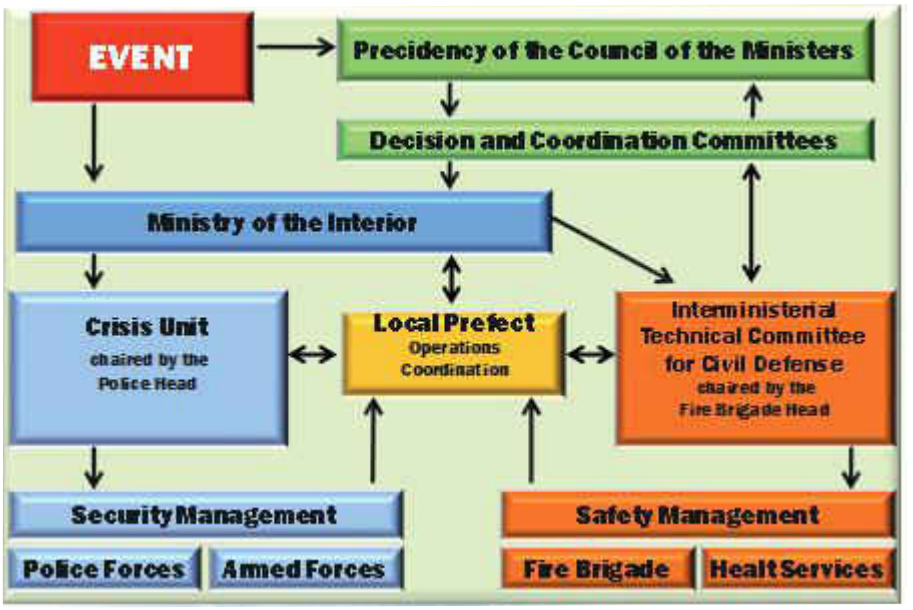

Figure 3. The Italian Civil Defence organisation.

The Italian Civil Protection organisation is based on four different levels of emergency; national, regional, district and municipal. They have specific administrative areas that are connected with specific type of events, as shown in Figure 4. These events can be categorized as follows:

a. Events which can be solved by applying available resources from the local community.

b. Events which need additional coordinated resources from outside the local community.

c. Events which, due to their intensity and size, should require extra-ordinary means and authorities.

The organization is composed of different levels of competence corresponding to the particular kind, for extension and magnitude, of the event. However, it is interesting to note presence of the rule of *subsidiarity* according to which, in case of lack of action by a level of competence, the next higher level is automatically activated.

The Italian national system of Civil Protection was established in 1992 and involves many different entities; National Civil Protection Department, operated by the Presidency of the Council of Ministers and with coordination functions, Fire Brigade, Police Forces, Armed Forces, National Health Service, Italian Red Cross, Hospitals, Municipal Authority, Public Health and Environmental Protection Services, Civil Protection Volunteers, Alpine and Speleological Rescue, Regions, Provinces, Municipalities and Mountain Communities, National Scientific Research Groups, Geophysics and Volcanology Institute, National Technical Services, and Essential Services.

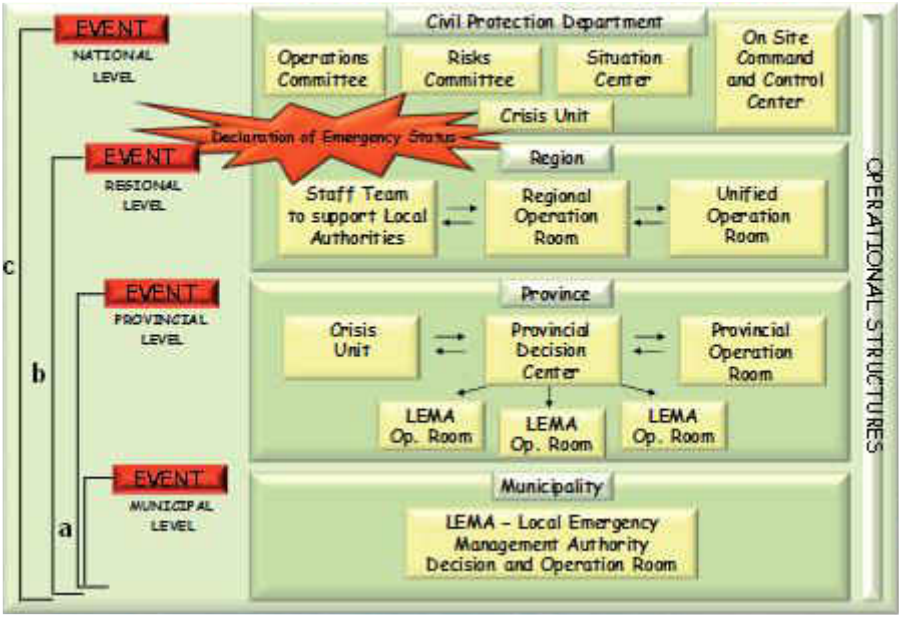

Figure 4. The Italian Civil Protection organisation.

Recovery and Consequence Management

The consequence management activity includes all the operations that must be taken as a result of an event in order to mitigate the effects to humans and the environment. Consequence management plays a vital role in safeguarding the health of the community and includes all the needed interventions, made by public and private organs and organisations, for removing the obstacles to the rehabilitation and restoration of the normal life conditions. The main involved entities and structures are:

a. National authorities
b. Regions
c. Provinces
d. Municipalities.

SYSTEM CRITICALITY

The analysis of the activities, during the Italian past major emergencies and disasters, has shown, in some cases, a lack in the appropriate event management and problem solution; the reason is that there are some system criticalities within both Civil Defence and Civil Protection responses.

Types of Criticality

The first criticality originates by the ever increasing worldwide number of terrorist attacks, also involving CBRN (Chemical, Biological, Radiological and Nuclear) or dual-use agents, for number, magnitude and damage effects.

At the same time, and this is the second criticality, there is a general reduction of human resources available for the operational countermeasures. In Italy, this reduction originates from the abolition of compulsory military service in 2004, resulting in a severe decrease of personnel to be deployed on the ground during a crisis event.

The third criticality originates due to the Italian territorial security management system which is composed of a lot of different entities, resources and tools that should interact. Hence, it is not easy to perform actions of mitigation, preparedness, response and recovery.

These criticalities determine the effects on all national emergency response systems, and the main consequences are generated on strategic planning and operational activities.

Criticality Compensation

In order to balance the negative consequences of system criticality, corrective actions must be implemented. First of all, organisation and management must be optimized. This can be achieved mainly through heterogeneous resources sharing, integrated security policy strategy, increase of risk knowledge, definition of a clear and exhaustive risk framework, and optimization of planning actions.

Then new operational capabilities to obtain better event management have to be developed. These capabilities should be dynamic, fast, effective, scaled down, respondent in case of multiple scenario events, and be able to integrate with of military and civil capabilities. All these actions are intended to achieve an integrated response system where national defence, composed of military defence and civil defence/civil protection, work closely with a high level of co-ordination involving various entities and operational structures.

Technological Criticality Compensation

The technological criticality compensation needs an evolution of organisation, technology and system architecture. As a matter of fact, nowadays, this architecture is based on different layers that do not allow enhancing and homogenising of field organisation with process management and technology areas with data acquisition, by implementing fusion, processing and decision support system, in order to forecast with scenario evolution.

Tomorrow, a systemic approach is imperative, where infrastructures and processes allowing organisation of logical and structural architectures lead to an integrated system. As a matter of fact, by using a service oriented architecture, we can reproduce, in a single

system, data, services and processes from different sources, thus allowing to create, integrate and coordinate, in real time, the right responses with a continuous matching with the evolving situation.

Systemic approach also concerns operative response integration. For the time being, we have a low co-operation system composed of several organisations with separated regulations and administrative actions, low integration and coordination between organisations, separated by different methodological and technological standards. For the future we need a strong high co-operation system using common methodological and technological standards.

This process of integration must be accompanied by a system engineering evolution. The current approach is that each system is designed according to specified parameters and performance. The evolution must lead to an approach where, starting from the full complex of requirements, considering the operational scenarios and making use of modelling and simulation, a *system of systems* approach is implemented that meets the overall performance requirements. The aim of all these actions must be the creation of a homogeneous and collaborative environment allowing a institutional, geographical, technical and operational connection to achieve a rational, coherent and interoperable response. The key point is that this is not only a technical problem, essentially manageable, but also an operational problem at the institutional level, one more difficult even to define, and then, solve. This is because is the human-being is not a computer; making a *computer grid* is easy, but this is not true for a *human-being grid.*

SUMMIT G8 SECURITY PLANNING

The aim of this section is to illustrate and describe all the structures, resources and tools adopted to ensure the G8 Summit Security at L'Aquila, Italy July 8-10, 2009. As already stated in Section 2, a *Major Event* is an event characterised by organisational complexity in terms of security, public order, mobility, receiving hospitality, welcome and healthcare, with the presence of a large number of personalities and/or participants, with the inevitable need to take extraordinary and urgent measures.

In Italy, this kind of event can be managed with the same tools and resources used in the management of emergencies due to natural or non-intentional man-made disasters. The declaration by which the event is classified as a Major Event occurs with the Decree by the President of the Council of Ministers. The Decree normally contains, in addition to the declaration, the duration and extension, in close relationship to the quality and nature of the event, and the appointment of a Delegated Commissioner to ensure the coordination of activities aimed at the conduct of the latter. Its implementation is enforced by means of Orders notwithstanding any provision in force and in respect of the general principles of law.

The G8 Summit was declared as a Major Event, with a Presidency of the Council of Ministers Decree in the year 2007 [2,3], under the responsibility of the Department of Civil Protection as other exceptional occurrences. The headquarters of the summit was initially identified on the Island of La Maddalena in Sardinia. By a Prime Ministers Order, the Head of the Civil Protection Department was appointed as Delegated Commissioner

for the coordination of interventions and initiatives related to the Summit organization. To carry out this activity, the Delegated Commissioner has used the structure of the Mission of the Presidency of the Council of Ministers, consisting of staff of the Civil Protection Department and the Presidency of the Council of Ministers, as well as military and civilian personnel employed by other State Departments and public or non-territorial Institutions.

On April 6, 2009, at 3.32 am, the city of L'Aquila was hit by an earthquake of magnitude 5.8 on the Richter scale. The city is located in the Italian region named *Abruzzo*, as shown in the map in Figure 5, and an idea of the intensity of the earthquake can be graphically deduced by looking at the photo where a badly damaged area in the centre of Onna, near L'Aquila City, as shown in Figure 6.

Figure 5. Region of the L'Aquila earthquake.

Following the earthquake of 6 April 2009, the displacement of the G8 Summit to the City of L'Aquila was decreed [4], in the framework of solidarity to the affected territories and improvement of devoted economic resources for the region recovery. With the decree, the Delegated Commissioner was responsible to arrange for reprogramming the organisation of the Summit and to take any action required by the new location of the international conference. The result was an integrated management of the earthquake emergency and the organisation of G8 Summit, as shown in Figure 7.

Figure 6. Damage caused by the earthquake.

Figure 7. Integrated management of the earthquake emergency and the organisation of G8 Summit

The integrated management of the Abruzzo earthquake emergency and the G8 Summit organisation has seen, as the main point of connection, the Head of Civil Protection Department as the delegated commissioner for both the events. For operation direction, The "Financial Police School" of Coppito (L'Aquila) was chosen as the earthquake emergency and G8 Summit headquarters. The integrated management determined two lines of activities, parallel and separate, concerning the two events.

Participants

The event has been very complex for the type and number of participants, and for the complexity of organisation in terms of security, law enforcement, mobility, hotel reception, hospitality and healthcare. The following quantitative numbers are of interest:

a. Attending delegations: 39
b. Participant delegates: 4,500
c. Media representatives: 4,500
d. Security personnel: 15,000
e. Staff personnel: 2,000.

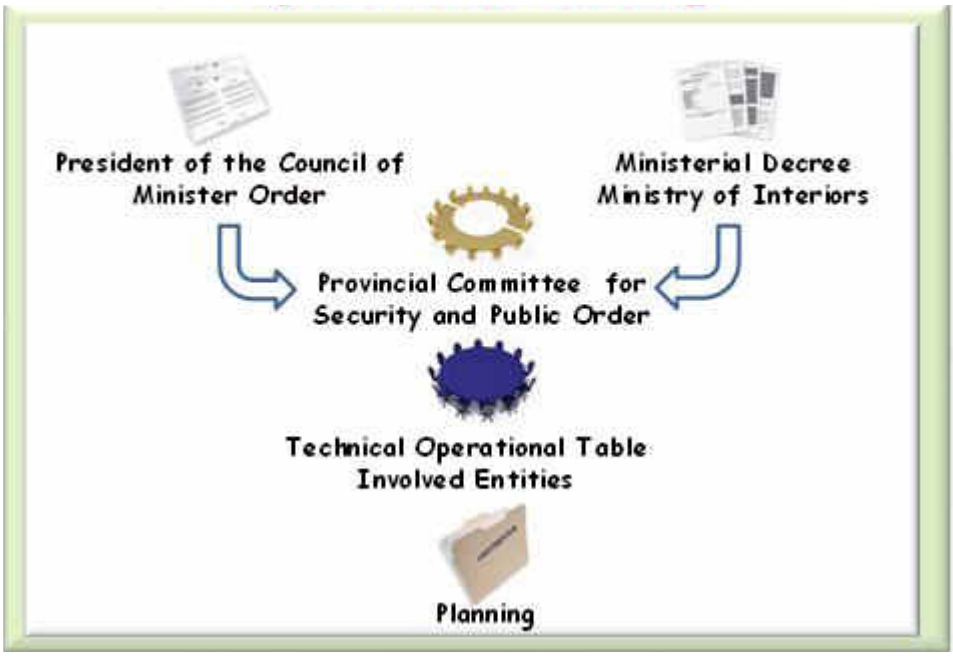

Figure 8. Operational planning.

Planning and Organisation

About the G8 Summit security system planning and organisation, the main targets were; guarantee protection of all the participants to the summit, normal conduct of summit activities, the civil rights to demonstrate and to express ideas in a pacific way, and harmonise necessities of the summit security with the liveable safeguard of the L'Aquila district with the consequences following the earthquake. The operative planning was built starting from an ordinance of the Prime Minister and a decree of the Ministry of Interior [5 – 16]. Then, the final design of the security plan, was made by the county committee for order and public security, as shown in Figure 8.

The main data accounted for the planning business were; delegations number and composition, territory characteristics and classification of involved areas, viability, places condition following earthquake consequences, summit agenda, summit venue features, accommodation features, delegations itinerary, participant transfer system, and press transfer system. These data were used to plan the Summit Land and Air Security.

Land Security

Land Security planning was divided mainly in the following sections: land security areas, territorial control, accreditation system, access control, areas mobility, exchange parking, delegations routes security.

The *land security area* was divided into three zones: *compliance area*, comprising the area not directly affected by the summit activities, but involved in the participants land movements; *reserved area*, comprising the areas immediately behind the zone directly affected by the summit activities; and *security area*, comprising all areas directly affected by the summit activities.

About the *territorial control* [17 - 19], to prevent criminal acts and to guarantee event security, the used resources were Police and Army, Navy and Air Force, whereas the used tools were fixed and mobile surveillance, video surveillance, radar systems, aircrafts, and unmanned aerial vehicles.

For the *accreditation system*, to grant a proper authorization to go inside security areas to people allowed to go in, the used resources were civil protection personnel and police forces units, whereas the used tools were computer systems.

About *access control*, to prevent not authorized people and vehicles presence within the areas, the used resources were police and armed forces, while the used tools were mobile and fixed surveillance, metal detector and radiogenic equipment.

For *areas mobility*, to guarantee area mobility of delegates, residents, information staff, authorized service staff and, in case of emergency, guarantee mobility of rescue vehicles, the used resources were police and armed forces, whereas the used tools were mobile and fixed surveillance, metal detector, and radiogenic equipment, similarly to the access control rules.

Use of Armed Forces in Security Activities

Within the activities of supervision, control and security of the areas affected by the Summit, a consistent use of manpower, resources and systems of the Army, Navy and Air Force was provided. This choice was dictated by the organizational level, the instrumental and human resource equipment, and available levels of training and expertise.

By Order of the President of the Council of and the Chief of Police Directive, regulated coordination between the Police and the Army, Navy and Air Force has also been implemented including the levels of relative responsibility. For this purpose, the Military personnel took part in a special course, organized by the General Command of Carabinieri (the Italian Army Police), to qualify them as *Law Enforcement Officer*.

The Military activity was mainly divided into the *terrestrial defense component and* the *air defense component.* As far as the terrestrial defense component, aimed to guarantee territory surveillance and security service, the used resources were army units, whereas the used tools were mobile and fixed surveillance. For the *air defense* component, aimed to guarantee the event air space control and defense, the used resources were air forces and army units, whereas the used tools were interceptors and drone, radar and anti-aircraft systems.

Contingency Plans

As part of the activities of planning and organization of the Summit security, particular importance has been devoted to the adoption of specific contingency plans: health, natural disaster and/or terrorist attack emergency plans, CBRN, and fire emergency plans were designed. These contingency plans were connected to the general security plan to manage specific emergency situations as natural (earthquake, fire and others) and man-made (terrorist attack) ones.

Command and Control Security System

The *Command and Control System* was composed of a *Coordination Table*, two *Operation Rooms* and two *Coordination Rooms*: Joint Operation Room, Technical Management Centre, Armed Forces Operation Room and International Operation Room, as shown in Figure 9.

Coordination Table

The *Coordination Table* is the structure designed to coordinate the security activity for immediate issues resolution: it was chaired by Delegated Commissioner and composed of several entities, as shown in Figure 10.

About *exchange parking*, to guarantee to delegates, residents, information staff, and authorized service staff vehicles parking within the traffic interdicted areas, and to guarantee the transport from/to traffic interdicted areas, the used resources were Police and Army, Navy and Air Force, as well as private security, whereas the used tools were mobile and fixed surveillance, metal detector and radiogenic equipment.

For *delegations routes security*, to guarantee the security of the delegations' members, the used resources were police and armed forces, whereas the used tools were protection services, and mobile and fixed surveillance along routes.

Air Security

Regarding air security planning organization this was mainly divided into air *security area*, and delegations air transfer and event security. Coming to the air security areas, the involved zone was divided into two areas: zone 2 with interdiction of all the Visual Flight Air Traffic, and zone 1 with interdiction of all the Air Traffic.

For transfer of delegations and event security, to guarantee protection from criminal actions coming from the air, the resources used were Police and Army, Navy and Air Force, whereas the used tools were mobile and fixed surveillance, aerial means, radar systems and anti-aircraft systems [20].

Special Security Activities

Due to the presence of many participants and personalities, the complexity of the scenario, the characteristics of locations, the geographical conditions, and the presence on the territory of the effects and consequences of the earthquake, particular importance has been also devoted to the adoption of special security activity and measures.

As stated in Section 1, the event took place in a delicate political moment, characterised by the presence of serious international conflict and a severe economic and financial crisis. This scenario has led to consider, in addition to the traditional forms of the turmoil by National and European movements, even to forms of dissent relating to global politic-economic situation. It must be also added that the Summit would represent a potential opportunity to focus the attention on the situation of Abruzzo after the earthquake.

The special security activity and measures were essentially devoted to prevent illegal actions and terrorist attacks; intervene in case of crisis caused by terrorist actions, even with use of chemical, biological, radiological and nuclear agents; guarantee surveillance, control and security into traffic mobility from/to areas of event; guarantee, in relation to the event, the national territory incoming control; prevent the execution of illegal acts through mobile phone systems, public and private broadcasting, institutional telecommunications networks, amateur radio and internet networks; guarantee security of the delegations' members and the territory surveillance and control; acquire documents to legal purposes. For all these activities, the used resources and tools were Police and Army, Navy and Air Force, special units, fire-fighters and health services units, aerial means, unmanned aerial vehicles, mobile and fixed video surveillance systems, and CBRN means and equipments.

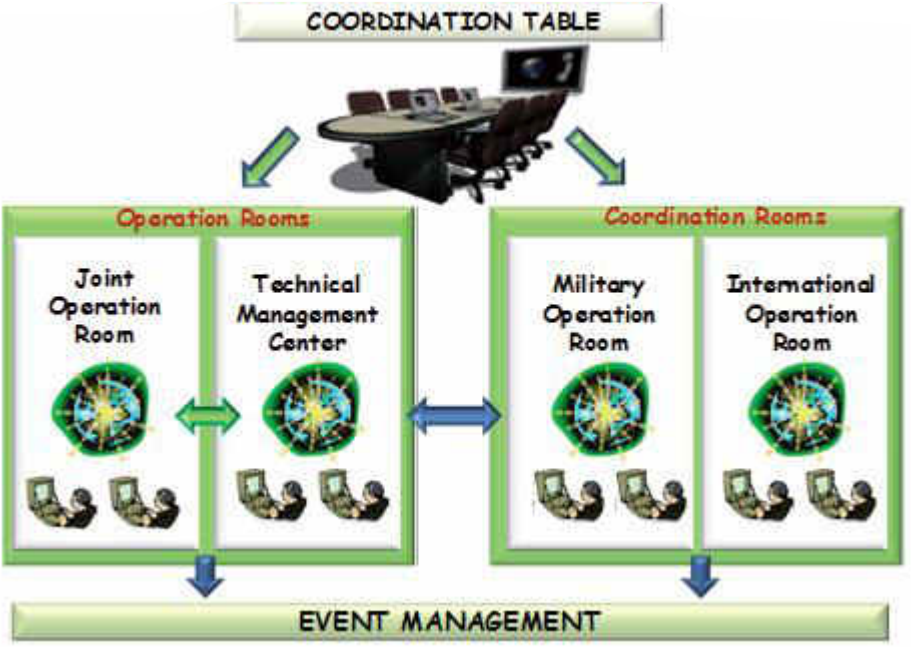

Figure 9. Command and Control System.

Figure 10. The Coordination Table organisation.

Joint Operation Room

The *Joint Operation Room* is the structure for coordination and management of all the resources used for surveillance and public security with operative connection between territorial and national level, as shown in Figure 11. It was connected with the police main remote headquarters, the main airports, and with the Civil Protection and Ministry of Interiors situation rooms.

Figure 11. The Joint Operation Room organisation.

The Joint Operation Room, to ensure communication with all remote sites, was connected through voice over IP, intranet and voice links, see Figure 12. Moreover, it was connected, with operational components, through radio networks of each single institutions. To ensure the supervision and control of the event, it was equipped, in its position and in remote locations, with a software for collection, storage, and management of data, images and information to share with all the operators.

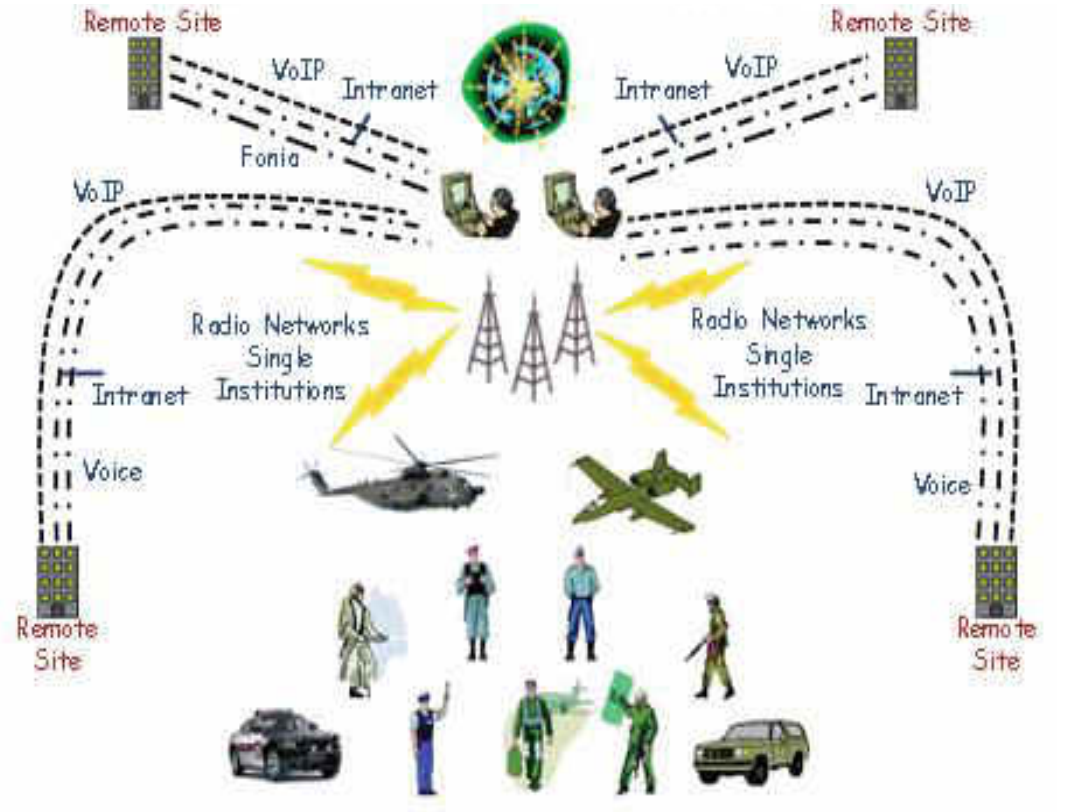

Figure 12. The Joint Operation Room technology.

Technical Management Centre

The *Technical Management Centre*, in charge of several functions, was the active instrument of the Coordination Table decisions for management and coordination of the activities, collection and sharing of information and coordination, and connection between the organizations activities and surveillance/public security activities, as shown in Figure 13.

Figure 13. The Technical Management Centre organisation.

The Technical Management Centre was provided with a decision room and furnished with a software for resources/infrastructure display and event management. The Centre was also connected through voice over IP, intranet, voice links to ensure communication with all remote sites and, in emergency, through a voice and data satellite backup. Moreover, it was connected, with operational components, through institutional radio, GSM, TETRA, digital mobile radio networks, and optical fibres. The Technical Management Centre, see Figure 14, dedicated to ensure events supervision and control, was equipped in the central location with a software for 2D/3D geographical information system for display of resources and infrastructures and for events' management.

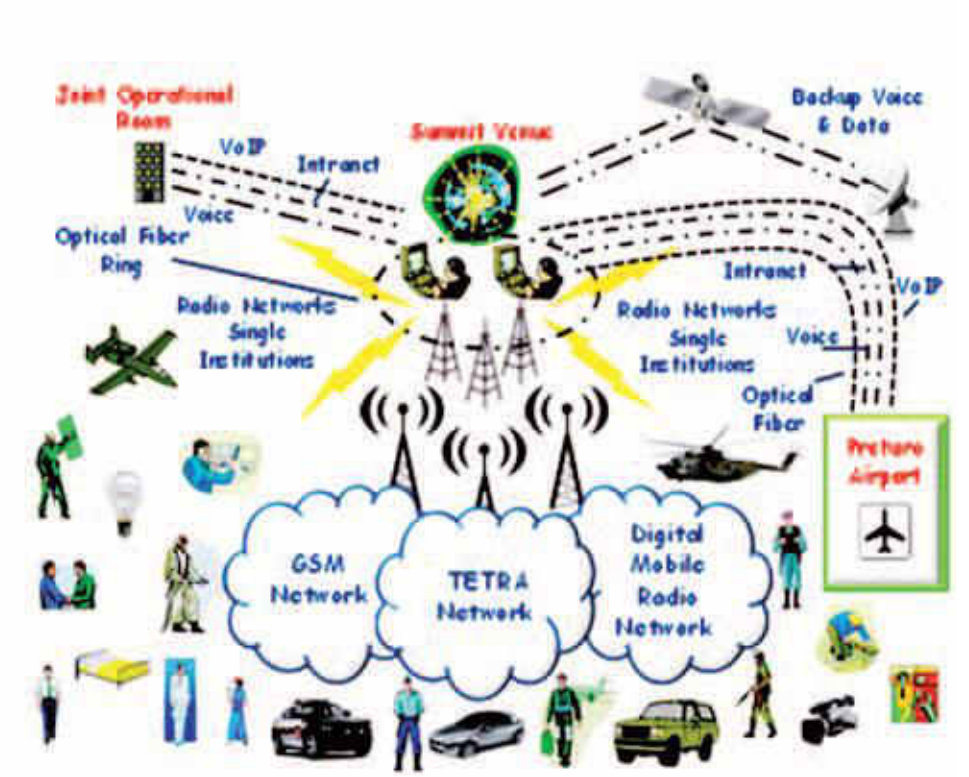

Figure 14. The Technical Management Centre technology.

The Armed Forces Operation Room

The *Armed Forces Operation Room* is the structure for activity coordination of Army, Navy and Air Force units, as shown in Figure 15. This was made through the operation room of the Army, Navy and Air Force headquarters to coordinate and connect the land command and the air command components.

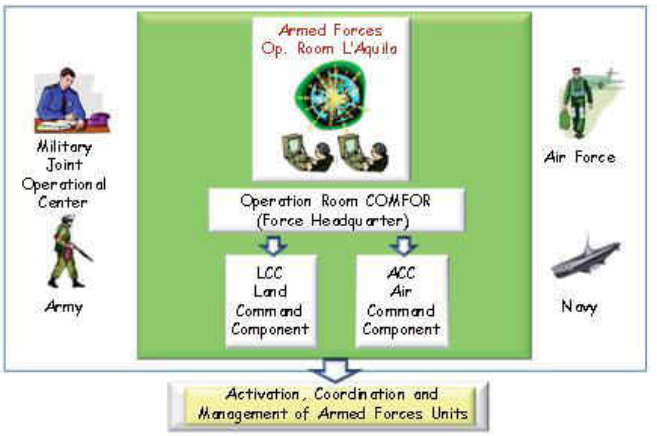

Figure 15. The Armed Forces Operation Room organisation.

The International Operation Room

The *International Operation Room* is the structure for joint operative and information exchange between National Police Forces and Foreign Nations Participants to the event: it was composed by an international cooperation team, liaison officers of the Summit attending countries, Europol, Frontex and Interpol, as shown in Figure 16.

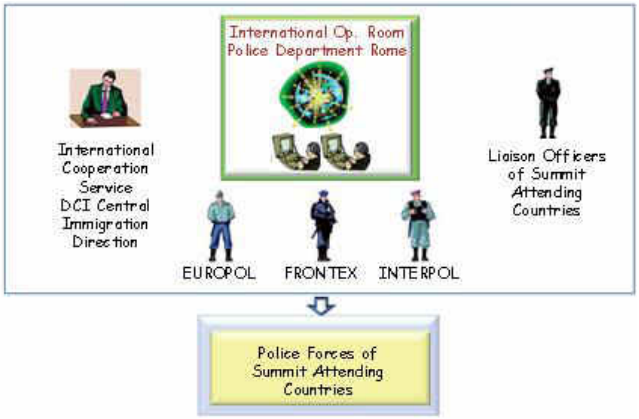

Figure 16. The International Operation Room organisation.

CONCLUSIONS

The analysis of the activities, during the Italian past major events, has shown in some cases a lack of standard security management and problem solutions that may have occurred during the period of its operation. The analysis of these events pointed out the following requirements as key issues to overcome the problems due to lack of an integrated model of planning, design and management:

a. To share resources, experiences and methods for all local and national authorities involved in the event management.
b. To need, for the operational structures, to perform simple and, at the same time, flexible actions to ensure efficient and enforceable operations upon the occurrence of their needs.
c. To acquire accurate and reliable information in order to improve the response times.
d. To establish a unique and multidisciplinary approach that can efficiently achieve and develop the proper conduct of the pre – event activities.

With the risk of annoying the reader, a lot of details have been quoted in this paper. The reason is that all those details point out the complexity of the event and may be useful for assessing some expertise for future similar cases. In the light of above considerations, the Italian G8 Summit held in l'Aquila on July 2009 was a significant effort toward achieving an integrated response security system where Military Defense, Civil Defense and Civil Protection worked closely with a high level of coordination. In fact, it was a huge *field exercise* in order to ensure the G8 delegations' and participants' security in the territory affected from the consequences following an earthquake: means, resources, tools and capabilities belonging to various military and civil administrations were used, all interacting among themselves to perform actions of mitigation, preparedness, and response in case of criminal actions or terrorist attacks.

The G8 Summit activity was also a step towards a new technological security system architecture: technology areas (data acquisition, fusion, processing and decision support system), including forecasting the scenario evolution and alternative developments, where merged in order to enhance and homogenize field organization with management processes. For these reasons, the study of the Italian G8 security planning, organization and management is a valuable opportunity to develop a major events security model, consisting of a homogeneous and collaborative environment where institutional, geographical and technical connection between different administrations and organizations is implemented, based upon a rational, coherent, and interoperable coordinated response.

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ADVANCED ELECTROMAGNETICS IN DEFENCE AND SECURITY APPLICATIONS

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ABSTRACT

Electromagnetic theory has been widely exploited in the defence and security applications. They include radio communication, navigation, radar, microwave remote sensing, microwave material and devices, electronic warfare, electromagnetic pulse and e-bomb, electromagnetic weapons and others. This article provides a review on some of the applications.

INTRODUCTION

Electromagnetic theory is one of the very important fundamentals of Electrical and Electronic Engineering. Electric charge will give rise to electric field and electric current will give rise to magnetic field. Therefore, any device which involves the use of electricity is related to the application of Electromagnetic theory.

The Maxwell's equations show that a change in magnetic field will produce a change in electric field and vice versa. A time-varying electric field is always accompanied by a time-varying magnetic field. The time-varying electric and magnetic fields will propagate at the speed of light, giving rise to radio wave. An electromagnetic wave from 10 kHz to 300 GHz is generally considered as radio wave, with the spectrum of 0.3 to 300 GHz further classified as microwave. Electric energy and signals transmitted over cables are actually guided electromagnetic waves. An antenna may be designed to radiate radio wave with the electric field vector always pointing in a desired direction, known as polarization, perpendicular to the direction of wave propagation. A moving charge or electric current within a magnetic field will experience a force, known as Lorentz force, acting in a direction which is perpendicular to both the magnetic field vector and the direction of moving charge. These properties, together with other behaviours of an electromagnetic field, are widely exploited in many commercial, industrial, scientific and medical applications. It ranges from cellular phone, to microwave oven, induction heating, electron acceleration in Physics experiments, non-destructive testing, MRI scan and many others. In the area of defence and security, the following sections describe some of the applications.

RF COMMUNICATION AND NAVIGATION

One of the first, and is still a, major application of Electromagnetic theory in military is radio frequency (RF) communication. Communication is vital in the battlefield for command, fire control, exchange of information, administration, and liaison between and within units. RF communication provides the essential mobility for the combat forces to repeatedly move in order to survive and fight the enemy. Legend has it that the frequency letter bands, namely the L-S-C-X-K microwave bands, were designated during the World War II to confuse the enemy. The actual frequencies of these bands were secret at that time, until they were standardised by the ITU in 1959 and by IEEE in 1984.

To prevent information from being intercepted by enemy, the simple AM/FM is not acceptable. Signal security techniques must be applied to ensure that all friendly use of the electromagnetic spectrum is not exploitable by the enemy. The techniques include emission control, transmission security, crypto security, and physical security. Emission control refers to minimising the electromagnetic emission (intentional and unintentional) from radios and other emitters (in terms of duty cycle and peak power) so that it is not detectable by the enemy. Transmission security refers to the methods information is transmitted such that it cannot be easily intercepted by the enemy. An example is the use of spread-spectrum techniques. The Direct Sequence Spread Spectrum (DSSS) technique uses pseudorandom codes to modulate the information signal. The resulting signal resembles white noise because the carrier signals occur over the full bandwidth of transmitting frequency. The only way this noise-like signal can be demodulated to recover the original information at the receiving end is by multiplying it by the same pseudorandom sequence which is only known by the intended party. Another technique is the Frequency Hopping Spread Spectrum where the transmitter rapidly switches the carrier among many frequency channels, using a pseudorandom sequence known only by the intended receiver to frequency hop in a synchronize pattern with the transmitter. The spread-spectrum signals are not only difficult to intercept, they are also highly resistant to natural interference and jamming. Crypto security deals with scrambling the message with codes and key lists so that it cannot be understood by the enemy.

Microwave is also used in terrestrial and satellite communications. It facilitates ship-to-shore, ship-to-air, air-to-air and air-to-ground communications over long distances. The use of different polarisations allow for different information to be transmitted simultaneously over the same frequency channel. The polarisation may also be switched in a pseudorandom sequence to provide transmission security.

Electromagnetic waves are also used in navigation systems. LORAN (LOng RAnge Navigation) is a terrestrial radio navigation system using multiple low frequency radio (90 to 110 kHz) beacon transmitters for the receiver to determine its location and speed. However, its use has steeply declined due to the availability of Global Navigation Satellite Systems (GNSS): GPS, GLONASS, Galileo and Beidou. The Global Positioning

System (GPS) was originally developed for defence applications to provide navigation and position information for military aircrafts, ships and personnel, and for weapons guidance. Although it can now be used for many commercial applications, it is under the control of the US military. Hence, Russia, the European Union and China are restoring or developing their own navigation satellite systems for national defence as well as complementing GPS for commercial applications.

RADAR AND MICROWAVE REMOTE SENSING

Radar (RAdio Detection and Ranging) has been widely used in military operations since World War II. It is used for detecting the presence of a target, determining where the target is (range, azimuth and elevation), measuring the speed of moving target, as well as identifying what the target is. It can operate by transmitting a pulsed-RF or a FMCW signal and detecting the reflected signal from the target. The range distance of the target can be determined by measuring the transit time of the radar pulse. The velocity of the target can be determined by measuring the frequency-shift due to Doppler effect.

The strength of the signal that is reflected from the target and returned to the radar antenna is generally related to the cross-sectional area of the target perpendicular to the propagation direction of the radar pulse. A radar cross-section (RCS) parameter which is independent of the range distance can be defined for the target. In practice, the actual RCS depends on the target's size, shape, orientation, and material properties as well as the radar source frequency and polarisation [1-2]. A stealth bomber may have an RCS much smaller than the physical cross-sectional area of the aircraft if the radar pulse is not reflected back to the radar antenna but to other directions. Techniques to reduce the RCS include designing the aircraft structure such that there is no sharp corner, which otherwise can act as corner reflector and enhance the radar backscattering. The major sharp corners in a conventional aircraft are where the wings join to the body and where the engines join the wings. Numerical Electromagnetic Codes are programmed to solve the Maxwell's equations and compute the RCS of the aircraft at various incident angles. This is important in the design process so that the desired RCS minimisation can be fine-tuned along with the aerodynamic design of the aircraft.

Another technique is to cover the jet engine turbines so that the radar pulse cannot reach the rotating engine blades. Single-frequency radome can be used to cover the aircraft's radar to provide the desired aerodynamic shape as well as small RCS. The dielectric radome will be transparent to the aircraft's radar but opaque to enemy's radar which is operating at a different microwave frequency. Finally, an absorptive coating can be used on the aircraft skin to dissipate the energy of the enemy's radar pulse hitting on the aircraft. Electromagnetic theory is applied in the innovation of the above dielectric material and absorbers.

Most radar systems use monostatic configuration where the same antenna is used for transmitting and receiving of radar pulse [3]. In other words, the transmitting point is collocated with the receiving point. Bistatic radar, with the receiving antenna located at a different point from the transmitting antenna, has been shown to have much improved capability to detect targets with small RCS. The anti-stealth performance can be further improved using multistatic configuration in which multiple receiving antennas are used to detect the reflected radar pulse at various locations.

Ship-borne and coastal radar used for maritime surveillance typically provides a Plan Position Indicator (PPI, a map-like display on cathode ray tube device to show radar target in the format of range versus angle) which is synchronized with the radiation beam direction of the rotating antenna. However, the azimuth resolution of the PPI image is very poor due to limitation in antenna size. Range resolution of 3 m can be achieved with 50 MHz bandwidth but the azimuth resolution increases with distance due to the diverging radiation beam. With a beamwidth of 1°, the azimuth resolution at 200 km range will be 3.49 km as illustrated in Figure 1. Small boat cannot be easily detected by the radar because the radar signature would be buried under the sea clutter as the radiation footprint covers a large sea surface structure surrounding the boat which produce much more backscattering signal. The beamwidth may be reduced by increasing the size of the radar antenna. However, a prohibitively large antenna would be required if a 3-m azimuth resolution at a range of 200 km is desired. As a large antenna is required (to provide 1-degree beamwidth), co-polarisation monostatic configuration is normally used so that the same antenna can be used as both the transmitter and the receiver in order to save cost and physical space. There is also a physical limitation on the height of the antenna mast. Hence, the radiation beam will be incident on the sea surface at a low grazing angle (< 15°).

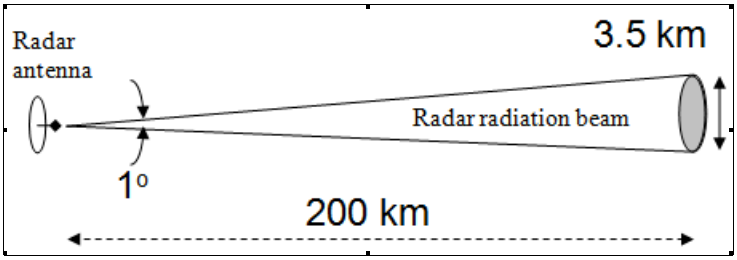

Figure 1. Diverging radiation beam gives rise to degrading azimuth resolution with increasing range distance.

Real-aperture Radar (RAR) was a common side-looking airborne system (SLAR). Having a higher altitude, the antenna beam incidence angle (normal to the sea surface) will be larger (20 – 50°). Modern airborne and space-borne radars use synthetic aperture radar (SAR) technique to produce good azimuth resolution [4-6]. Figure 2 shows the geometry of the SAR technique. It operates with a moving platform which synthesises an equivalently very long antenna, thereby an equivalently very narrow beamwidth can be synthesised using advanced digital signal processing technique. Figure 3 shows an example of SAR image. The high-resolution SAR image is very useful for surveillance and reconnaissance. Many recent researches are working on target identification and recognition using the SAR images.

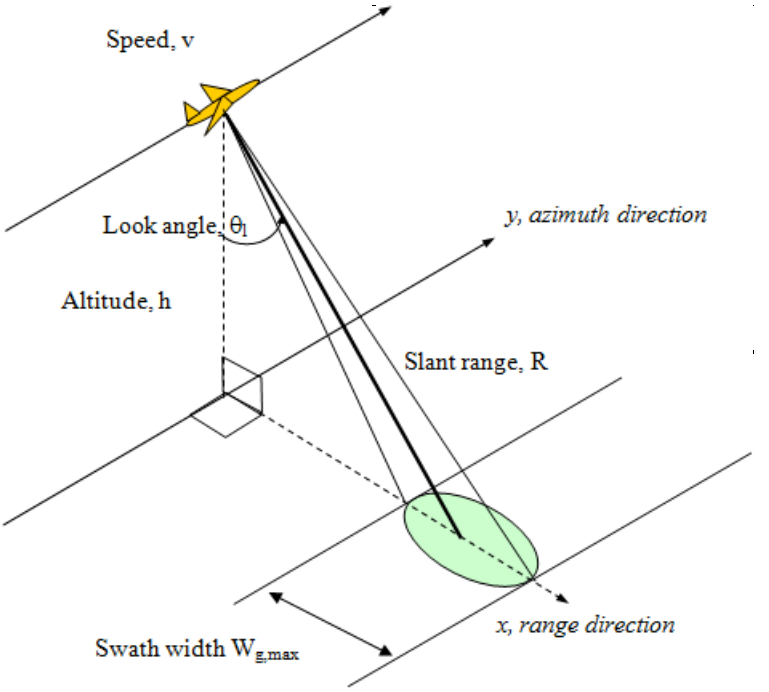

Figure 2. Geometry of a SAR technique. A moving platform synthesizes an equivalently very long antenna.

A radar system for target detection at very long ranges, typically up to thousands of kilometres, is the Over-the-Horizon (OTH) radar. It is particularly useful in the early warning radar role. It is used in maritime reconnaissance and drug enforcement. The ionosphere acts as a mirror in the sky. Radar pulse transmitted up towards the ionosphere is reflected down towards the sea surface. The backscattering signal from the target follows the reverse path back to the radar. Since the signal reflected from the target will be very small compared to the signal reflected from the sea, it is difficult to distinguish the targets from the background noise. It can only detect moving targets by using the frequency shift due to Doppler effect. Like the PPI radar, the resolution of OTH radar

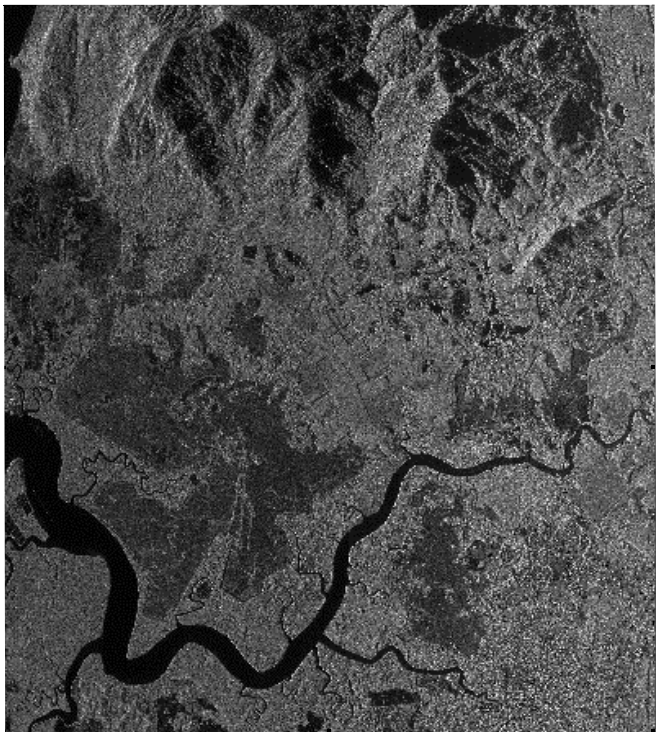

Figure 3. SAR image of Sungai Petani, Kedah (C Band, HV polarization).

depends on the beamwidth and the range to the target. Due to the long ranges at which OTH radars are used, the resolution is typically measured in tens of kilometres. This makes the radar system almost useless for target engagement, although this sort of accuracy is adequate for the early warning role. In order to achieve a beamwidth of 0.5° at HF, an antenna array several kilometres long is required.

Radar systems with line-of-sight ranges of a few hundred kilometres are also used in early warning purposes. They are used in air, sea and ground surveillance (search and detection). Tracking radars, using monopulse configuration and conical scan, are used in target acquisition systems and missile guidance systems. The ground penetrating radar (GPR) is a newer application of radar. An x-y scan is made above the ground and a high-resolution 3-D image of the underground can be reconstructed using a synthetic aperture technique [7]. The penetration depth into the soil can be enhanced using ultra-wide band signal [8]. The GPR system can be used for landmine detection.

The background noise in the received radar signal is known as clutter. It is due to echoes returned from natural objects such as ground, sea, precipitation (such as rain, snow or hail), sand storms, animals (especially birds), atmospheric turbulence, and other atmospheric effects, such as ionosphere reflections and meteor trails. Clutter may also be returned from man-made objects such as buildings and by radar countermeasures such as chaff.

Clutter can be reduced by detecting the frequency shift due to Doppler effect on moving target. For detection of stationary target, sea clutter can be reduced by using horizontal polarisation, while rain is reduced with circular polarisation. A few digital signal processing (DSP) methods have been developed to increase the signal-to-clutter ratio.

Target detection against surrounding clutter is usually accomplished using a method called Constant False Alarm Rate (CFAR, a form of Automatic Gain Control or AGC). The receiver's gain is automatically adjusted to maintain a constant level of overall visible clutter. The AGC can be electronically controlled or implemented in post-processing by computer software. A newer approach uses the theory of chaotic dynamics to model the sea clutter as nonlinear and deterministic dynamical system with few degrees of freedom [9-10].

Clutter sources may be undesirable for some radar applications (eg. air-defence radars), but desirable for others (eg. meteorological and remote sensing radars). The clutter signal contains the information related to the biophysical and geometrical properties of the objects that give rise to the clutter. Radar imaging sensors are widely used to facilitate the research and development in microwave remote sensing [11-12]. Figure 4 shows an example of computerised classification of different Earth features from SAR images.

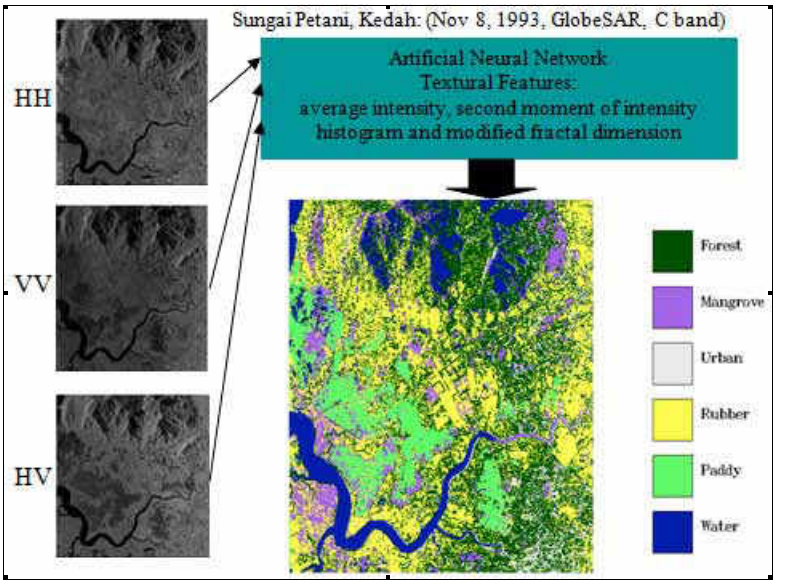

Figure 4: Classification of different Earth features from SAR images using artificial neural network technique.

The most important tools for remote sensing applications are the imaging sensors mounted on flying platform (aircraft or spacecraft) to produce pictures of the Earth surface. Optical sensors rely on the sun as the source of illumination. The intensity of reflected light or emitted infrared from the ground object depends on the time-of-day, direction of sunlight relative to the viewing angle, and cloud cover condition. Microwave sensors such as SAR operate based on the principle of radar. The main advantage of radar instruments is their ability to penetrate clouds, rain, tree canopies, and even dry soil surfaces depending on the operating frequencies. Objects below the forest canopy can be "seen" by the imaging radar. Also, due to the persistent cloud cover in tropical climate, the use of microwave remote sensing technology is crucial and advantageous over optical technology. In addition, since radar is an active instrument which provides its own illumination, it can operate in both day and night. The imaging outputs are more consistent because they are not affected by sunlight intensity or direction. Different polarisations of electromagnetic wave can be transmitted, and the multi-polarisation backscattering responses can provide additional information of the ground objects.

The images produced by SAR have many useful applications in natural resource management and environmental monitoring. These include agriculture, forestry, and range resources management; land use and mapping; geology; water resources management; oceanography; environmental management; and planning of infrastructure development and town. Advanced applications can only be developed with the supporting research and development in sensor systems [3-6, 13], theoretical modelling of wave-matter interaction [14-17], and controlled experiments [1-2, 18-19].

Remote Sensing sensors are regularly flown on satellites such as European Remote Sensing (ERS), Japanese Environmental Resources Satellite (JERS), Radarsat, SPOT, ALOS, and TerraSAR. The image products may be ordered from the respective satellite operating agencies. However, the delivery of the image product on CD or tape may take substantial time. Furthermore, the revisit time of commercial remote sensing satellites is in the range of 5 – 24 days. They cannot provide timely data for critical surveillance and reconnaissance applications. The desired temporal resolution (or frequency of imaging operation) can be obtained using airborne SAR. However, the operating and maintenance cost will be very high and the safety risk of pilot may be an issue if 24-hour operation is desired. UAV flown SAR sensors may be used but the low altitude of the UAV will give limited swath width. A possible solution for continuous maritime surveillance is to employ an array of coastal radar and apply the method of radio interferometry to obtain high-resolution mapping of the sea.

MICROWAVE MATERIAL AND DEVICES

In order to support the various RF and microwave applications, a vital aspect of applied electromagnetics is in the research and development of microwave material and devices. The developed RF polymer composites with specific engineered electromagnetic properties include radome dielectric, frequency selective surface, microwave absorber,

absorptive coating, low-loss magneto-dielectric composites, dielectric resonators, printed-circuit substrates, low-temperature co-fired ceramics (LTCC), Yttrium-Iron Garnet (YIG), etc. Microwave measurement techniques are also developed for assessment of the desirable material properties [20-21].

The construction of microwave systems requires the necessary microwave signal control components. Examples of these components include power dividers, directional couplers, phase shifters, filters, attenuators, and switches. A number of microwave semiconductors have been innovated such as High Electron-Mobility Transistors (HEMT), Hetero-junction Bipolar Transistors (HBT), Impact Ionization Avalanche Transit Time (IMPATT) diodes, etc. These devices are used in the design of microwave oscillators, amplifiers, frequency converters, and low-noise receivers. Multiple functional blocks are also fabricated on the same substrate in monolithic microwave integrated circuits (MMIC). GaAs is commonly used for MMIC.

The power capability of microwave semiconductor devices is limited to about 100 W at 1 GHz, decreasing to 1 W at 100 GHz. For high power microwave generation and amplification in the kW to MW range, microwave vacuum tubes are required. The common microwave tubes include Klystron, Magnetron, and Traveling-Wave Tube (TWT). The operating principle of these tubes involves interaction of electron with electromagnetic field. Extremely high power microwave tubes such as Relativistic Magnetrons (0.1 GW), Slow Wave Devices (4-8 GW), and Virtual Cathode Oscillator (Vircator, 1.2 GW) are used in microwave weapons [22].

Antennas are required to radiate microwave. The desired specification is highly dependent on the specific application [8, 23-25]. It may include omnidirectional radiation, high directivity, pencil beam, low sidelobe, wide or narrow bandwidth, linear or circular polarization, small size, lightweight, rugged, conformal array structure, electronic beam-steering, and others. An advanced research is in the area of smart antenna in which smart signal processing algorithms are used to identify the direction of arrival (DOA) of the signal and use it to calculate beamforming vectors required for shaping the antenna beam to the desired pattern, and steer the antenna beam to track the target.

Innovation and refinement in the design of microwave material and devices must be continuously undertaken to meet the ever increasing demand to push the performance limits of microwave systems, especially in the defence and security applications.

ELECTRONIC WARFARE

Electronic warfare (EW) involves the use of the electromagnetic spectrum or directed energy to monitor the electromagnetic environment, attack an enemy's electronic system, or protect against electromagnetic assaults from the enemy. EW may target communication, radar and other services. EW includes three major aspects: Electronic Surveillance (ES), Electronic Attack (EA), and Electronic Protection (EP).

Electronic Surveillance (ES) involves actions to search for, intercept, identify, and locate sources of intentional and unintentional electromagnetic energy for the purpose of immediate threat recognition, targeting, planning, and conduct of future operations.

Electronic attack (EA) or electronic countermeasures (ECM) involves the use of the directed electromagnetic energy to attack electronic equipment with the intent of degrading or destroying enemy combat capability. Examples of EA include communications jamming and expendable decoys (e.g., flares and chaff).

Electronic protection (EP) or electronic counter countermeasures (ECCM) involves actions taken to protect electronic equipment and combat capability from being degraded or destroyed by electromagnetic energy (coming from friendly or enemy use of the electromagnetic spectrum). Examples of EP include emissions control (EMCON), electromagnetic shielding, spread spectrum technologies, and stealth technologies. The use of flare/chaff rejection algorithm to counter enemy's use of flares/chaffs is also an EP technique.

EMP AND E-BOMB

Electromagnetic Pulse (EMP) can be used as a form of Electronic Attack (EA). An extremely strong burst of electromagnetic radiation can be generated from a nuclear explosion. An EMP bomb detonated hundreds of kilometres above the earth's surface is known as a high-altitude electromagnetic pulse (HEMP) device. It can cause electrical damage thousands of kilometres away from the detonation point [26].

A high-altitude nuclear detonation produces a flux of gamma rays. These photons ionize air molecules and produce high-energy free electrons at altitudes between 20 and 40 km. When these electrons interact with the Earth's magnetic field, they are deflected due to Lorentz force and start to move in a spiral pattern, giving rise to an oscillating electric current. This current gives rise to a rapidly rising radiated electromagnetic field, i.e. electromagnetic pulse (EMP). Because the electrons are trapped essentially simultaneously, a very large electromagnetic source radiates coherently.

EMP generated without the use of nuclear weapon is called Non-nuclear electromagnetic pulse (NNEMP) [27]. The NNEMP devices generally contain a large low-inductance capacitor bank discharged into an Explosively Pumped Flux Compression Generator (EPFCG) to produce a gigantic impulse of electric current. Chemical explosives are used in the flux compression generator (FCG). A magnetic field is generated by a flow of current pulse (due to discharge of the external capacitor) into a solenoid. Explosion ignited simultaneously gives rise to a rapid deformation of an inductive device (metallic cylinder or helically wrapped coil within the FCG) which in turn compresses the magnetic flux and cause a much larger current pulse (in the millions of amperes) to be created in the inductive device. In other words, the FCG acts as a current pulse amplifier. The impulse current energizes a microwave generator. A vacuum

tube particularly suitable to generate high energy microwave pulse is the vircator. The microwave pulse is then coupled to an antenna to radiate the EMP towards the targeted zone. NNEMP generators can be carried as a payload of bombs and cruise missiles, allowing construction of electromagnetic bombs or e-bomb.

Nuclear EMP is much more powerful than NNEMP because nuclear explosive has an energy yield on the order of one million times that of chemical explosives of similar weight. Hence, the range of NNEMP weapons is severely limited as compared to their nuclear counterparts, but allow for more surgical target discrimination. The effect of small e-bombs is sufficient to destroy certain fragile electronic control systems in many ground vehicles and aircraft.

EMP weapons could be used by the enemy. Military systems must be checked for their ability to survive specific EMP levels. Therefore, NNEMP generators are also constructed in the form of large structures to generate EMP for testing of electronics to determine how well it survives EMP. Electromagnetic shielding methods and devices are also innovated to provide the desired Electronic Protection (EP).

ELECTROMAGNETIC WEAPONS

Electromagnetic weapons can be used against humans, electronic equipment, and military targets, depending on the technology. For Electronic Attack (EA) against equipment, directed high power electromagnetic (HPEM) energy weapons can induce destructive voltage within electronic wiring.

Electromagnetic waves directed against human can have effects on the human central nervous system resulting in physical pain, difficulty breathing, vertigo, nausea, disorientation, or other systemic discomfort. It can be considered 'non-lethal weapons' if the power is controlled below certain limits. Pulsed microwave audiograms of words or oral sounds can create the bio-effect of hearing voices and closing the ears will not stop the effect. The MEDUSA (Mob Excess Deterrent Using Silent Audio) operating using this concept is a non-lethal electromagnetic weapon designed for crowd control [28]. It uses microwave pulses to generate uncomfortably high noise levels in human skulls, bypassing the ears and ear drums.

Microwave pulses can also affect the epidermis and dermis, generating a burning sensation. The Active Denial System (ADS) is a less-lethal, directed electromagnetic weapon developed by the U.S. military [29]. The weapon consists of a strong 95-GHz millimetre-wave transmitter and a highly-directional parabolic antenna to cause a burning pain from as far as 700 meters. The energy can penetrate less than 0.4 mm into the skin and it will not cause injury. The pain reflex makes people flee away automatically in less than a second. The intense burning sensation stops when the transmitter is switched off or when the individual moves out of the beam. Non-lethal weapons can be used

for crowd control as well as protection of defence resources and military personnel, peacekeeping, humanitarian missions and other situations in which the use of gun fire is undesirable.

HPEM ADS are used to disable vehicles. It can be used by police officers in law enforcement. Almost every car produced in the last 10 years or so is built with some microprocessor-controlled systems. The ADS can induce destructive current in the wiring and cause the microprocessor to hang or permanently burnt. The vehicle will gradually slow to a halt, allowing police to safely approach and apprehend the driver. The HPEM ADS can also be used to disable enemy's small robot spy-planes out of the sky.

Another electromagnetic weapon is the Rail Gun. It was actually invented by the German during World War II but continuously enhanced and refined to achieve the current state of technology. A rail gun is an entirely electrical gun that accelerates a conductive projectile along a pair of metal rails. A large electric current (on the order of one million amperes) flows through the projectile which is making a sliding or rolling contact with the rails to complete a closed circuit with a power supply. A strong magnetic field is generated by the current loop. The current flowing through the projectile interacts with the magnetic field. The Lorentz force accelerates the projectile to push it off the rails away from the power supply. The U.S. Navy has tested a rail gun that accelerates a 3.2 kg projectile to seven times the speed of sound [30].

CONCLUSION

Electromagnetic fields have many applications for defence and security purposes. A big portion of these applications have been invented more than 50 years ago. Continuous improvement and enhancement were made through research and development and yet there are substantial rooms for further refinement of the technology in the areas of microwave systems, electronic warfare, electromagnetic material and devices, theoretical modelling of wave-matter interaction, and controlled experiments. New innovation can be generated from cross-disciplinary collaboration.

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SUICIDE TERRORISM: DEVELOPMENT, IDENTIFICATION, MODUS OPERANDI, POTENTIAL THREAT AND RESPONSE – SRI LANKAN PERSPECTIVE

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ABSTRACT

The Liberation Tigers of Tamil Eelam (LTTE) has been indisputably the most efficient and brutal terrorist organisation ever to utilise suicide terrorism, which it did for the advancement of its struggle to establish a separate state of Tamil Eelam in Sri Lanka. During the three decades of terrorism, Sri Lanka experienced many suicide attacks that resulted in the assassinations of many political and military leaders, heavy losses to civilian lives, and major destruction of the country's infrastructure. This paper discusses the tactical aspects of suicide attacks in Sri Lanka, and analyse and examine: firstly, the origins, ideology and development of the suicide phenomenon; secondly, identification of the key elements behind suicide operations; thirdly, the modus operandi of suicide operations on land and sea; fourthly, the impact of suicide terrorism; and finally the potential threat and examination of an effective counter strategy to break the cycle of violence and evolve possible solutions to suicide terrorism.

INTRODUCTION

The basic definition of suicide terrorism varies between academics and official agencies, resulting in widely differing statistics. However, all agree that "modern" suicide terrorism reflects the phenomenon of terrorism in its most extreme form. For the purpose of this presentation, suicide terrorism is defined as the readiness to sacrifice one's life in the process of destroying or attempting to destroy a target to achieve a political goal [1]. Of the many terrorist organisations which have resorted to suicide attacks over the period of the last three decades, the Liberation Tigers of Tamil Eelam (LTTE), can be identified as the most efficient terrorist organisation in the world ever to utilise suicide terrorism for the advancement of its struggle to establish a separate state of Tamil Eelam in Sri Lanka. The LTTE is prepared to use every weapon, exploit any situation, influence the impressionable, and sacrifice anyone to achieve its aim. During the period between 1987 and 2009 [2], the LTTE has carried out a total of 123 suicide attacks in Land, Sea and Air. The LTTE is the only organisation that succeeded in assassinating two national leaders in two different countries. In May 1991, the LTTE assassinated Rajiv Gandhi, former Prime Minister of India, and in 1993 the LTTE assassinated R Premadasa, former President of Sri Lanka. The LTTE also made an abortive attempt to take the life of former President Chandrika Kumaratunga in December 1999. Other than assassinations

and attempted assassinations of national leaders both in the country as well as outside, the LTTE had also succeeded in utilising this tactic to destroy many religious, economic and military infrastructure facilities in the country with far reaching consequences, until LTTE was militarily defeated by the Sri Lankan Armed Forces in May 2009. In this context, the Sri Lankan experience in dealing with suicide terrorism over a period of more than two decades provides a sound background to identify the key elements behind the successes of suicide operations and to formulate an effective counter strategy.

The aim of this paper is to trace the origins, ideology and development of the suicide phenomenon, to identify key elements behind suicide operations, and to examine the potential threats and effective counter strategy.

ORIGIN, IDEOLOGY AND DEVELOPMENT OF BLACK TIGERS

Origin and Ideology

The orgin of the unit of fighters committed to suicide can be traced to the death of Ponnathurai Sivakumaran @ Sivakumar. He bit into a vial of Potassium cyanide on 5 July 1974 but he was not a member of LTTE [3]. The LTTE leadership seized this idea to draw youth to the organiation. Prabakaran, who was watching the latest developments in the art of suicide terrorism, following the Hizbullah attack against the US marines in Beirut, killing 241 US soldiers in 1982, immediately grasped this single act to form the LTTE Suicide Unit in July 1987. The first suicide attack was launched by LTTE against the Special Forces (SF) deployments in the Jaffna peninsula on 5 July 1987 where an explosive laden vehicle was rammed into a SF camp, killing 19 soldiers [4]. The LTTE suicide cadres are also designated as "Karum Puligal" or "Black Tigers" and carry cyanide capsules round their necks. With the formal introduction of the cyanide capsule in 1982, Prabakaran declared that "to terminate one's life voluntarily to liberate his motherland is the highest and the noblest achievement". This ideology has helped the LTTE to survive more than three decades and to advance its struggle.

Development of the Black Tiger Unit

The development of the Black Tiger Unit can be broadly categorized as follows:

i. **Eelam War I (1983 -1989):** Although, the first suicide attack created a strong impact on the organisation in July 1987, the LTTE failed to continue the trend when the Indian Peace Keeping Force (IPKF) was inducted into Sri Lanka, following the agreement reached between Indian Prime Minister Rajiv Gandhi and Sri Lanka President JR Jayawardhana on 29 July 1987. Three main reasons for the LTTE's failure to continue its suicide attacks against IPKF are: Firstly; the LTTE could not concentrate in one location due to intensified IPKF operations/presence. Secondly; the explosives which were brought from South India for the use of suicide missions had been restricted due to

tightening of naval security between two countries. Thirdly; Pottu Amman, head of the LTTE Intelligence Wing and mastermind behind suicide operations was injured with the eruption of clashes between IPKF and the LTTE, and was evacuated to South India.

ii. **Eelam War II (1990-1994):** With the commencement of Eelam War II in June 1990, it expanded its suicide operations from the areas where the conflict prevailed to the areas outside the North and East of country, including to India. The main targets were political and military leaders, who had been identified by the LTTE leader as potential threats to the attainment of his ultimate objective. This period also marked the beginning of suicide attacks against naval crafts operating in the sea off the Eastern coast of Sri Lanka. The first sea borne suicide attack was reported on 10 July 1990 at Velvettithurai, Jaffna, where, the suicide cadres made an attempt to ram an explosive laden boat into a Sri Lankan naval vessel, "Edithara" [5].

iii. **Ealam War III (1995-2001):** With the commencement of Eelam War III, following a three and half month long ceasefire agreement with the Government, the LTTE recommenced its suicide operations, even targeting religious places and economic establishments. The attack launched on the "Dalada Maligawa", the Buddhist Shrine, housing the sacred tooth relic of Lord Buddha using an explosive laden vehicle was the first suicide attack launched by the LTTE on a religious place. The suicide attack launched on the Oil Refinery Complex at Kolonnawa, and Oil Tanks at Orugodawatta in Colombo on 20 October 1995 can be identified as the first suicide attack conducted by the LTTE on an economic target [5].

iv. **Eelam War IV (2006-2009):** Although the LTTE continued its suicide operations targeting political and military leaders, and also destroying the country's infrastructure facilities, most of its operations launched outside war zones were failures and could not bring about the desired results and the same impact that it caused during the Eelam War II and III periods. The key reason was that the SF and the public were enlightened on how to deal with suicide threats and also due to the fact that the Government intensified military operations against the LTTE where they could not concentrate in one location.

The development of LTTE suicide operations can also be discussed under tactical and technological advancements. As far as the tactical advancements of suicide operations are concerned, the LTTE has laid more emphasis in improving the aspects of motivation, recruitment, training, gathering of information, maintenance of surprise and security etc. The training programmes designed for suicide cadres and methods used to gather intelligence and maintain surprise and security are being frequently changed to meet tactical requirements on the ground. As far as the technical advancements are concerned, the LTTE which initially commenced its suicide operations with vehicle-borne suicide

IEDs (Improvised Explosive Devices), subsequently expanded it to human-borne IEDs, IEDs, sea-borne IEDs and air-borne IEDs. In most suicide attacks, the LTTE has used cellular phones to communicate with each other during the planning, coordination and execution stages. Subsequently, they also used satellite communications for this purpose. As far as the use of IEDs for suicide operations is concerned, the deadliest is the human-borne IEDs, since it can reach the target while maintaining surprise and security. The design of the suicide jacket was changed frequently to meet tactical requirement:

i. **First Generation (1991-1995):** The jackets were large in size and used gelignite combined with C-3 explosives. This type of jackets had been primarily designed to assassinate its opponents and also to create a huge psychological impact on the minds of public. As a result, a large number of innocent civilians were also killed and injured during these types of attacks. Two LTTE female and male cadres, who carried out the suicide attacks to assassinate the former Prime Minister of India, Rajiv Gandhi, and former President Premadasa had worn suicide jackets of this generation.

ii. **Second Generation (1995 – 1999):** The jackets were small in size in comparison to the First Generation and were filled with TNT explosives. Ball bearings and explosives were used in a ratio of 1:2 to cause maximum destructions. The jackets were primarily designed to take the targets even at a distance.

iii. **Third Generation (since 1999):** The jackets were small in size in comparison to 1st and 2nd generation jackets and were filled with C-4 explosives. Undergarments were designed to replace jackets in accordance with its requirements. These specially made undergarments filled with explosives were primarily designed in order to facilitate the suicide cadre to reach the target without much suspicion.

IDENTIFICATION OF THE KEY ELEMENTS BEHIND SUICIDE OPERATIONS

Motivation and Propaganda

Violence cannot be continuously sustained without active motivation and effective propaganda. Therefore, it is necessary to examine the factors that helped the LTTE to motivate cadres in resorting to such deadly tactics. Through their propaganda campaigns, both through electronic and printed media, the LTTE highlighted the heroism of those who carried out suicide attacks. Kennedy, who led the suicide attack on Palaly Air Base on 2 August 1994 and was later arrested by the SF, once stated that he had been lucky enough to be selected for the mission and to undergo suicide training since there were many who had opted to undertake the mission [6]. This sort of propaganda provides inspiration for young boys and girls to join the cause. The Tamil youth who had lived in the areas controlled by LTTE, knew nothing more than what has been instilled into them

through the propaganda machine of the LTTE. The Tigers effectively crushed parental care and direction through its propaganda and psychological campaigns. The process of molding Tamil youth into suicide killers began long before their teens. From their earliest days in school, a garbled version of the roots of the ethnic war was drilled into them. Various video clips depicting the heroism of Black Tigers are shown regularly to the schoolchildren. The incidents relating to alleged human rights violations by the Army in the North and East areas had been instilled into the children in the schools in the North and East areas [7]. The Black Tigers found it easy to recruit youth for suicide operations particularly when family members of the youth were either killed or wounded due to SF operations. This sort of propaganda was effective and the cult of martyrdom created among the Tamil youth probably surpassed what is seen among many other extremist groups in the world.

Recruitment

The LTTE considers the following aspects before recruiting cadres/youth to the Black Tiger Unit; (a) Loyalty towards the leader. (b) Should be above 15 years of age. (c) Unmarried. (d) State of physical and mental fitness. (e) Loss of any family member or damage to the property due to conflict. (f) Displacement due to conflict. (h) Depression due to conflict situation. (i) Unemployment. (j) Natural / war disabilities. (k) Heroism and revenge against opponents. (l) Should be conversant with Sinhala language.

Procedures adopted in recruiting youth to the Suicide Wing can be categorized as follows:

i. **Within the Organisation:** Whenever Prabakaran sent his annual message to the LTTE bases requesting volunteers to join Black Tigers, the response was overwhelming. Yet Prabakaran was highly selective in his choice until 2006 and this was the hallmark of the success of the LTTE suicide operations over the other terrorist groups, from its inception. In this scheme, the names of the volunteers are noted annually within the organisation. However, anyone can withdraw their name in a subsequent year, if they do not wish to join the suicide wing. Those who have consented should renew their letters of consent annually.

ii. **From Villages and Schools:** The LTTE political cadres also visit remote villages and schools in the North and East to pressurize and motivate children to join the LTTE. Thereafter, it is the responsibility of the Intelligence cadres to identify and select some of these youth for Black Tiger Wing.

iii. **Through the Foster Children Programme:** Another scheme through which young children are recruited to the Black Tiger Wing is through the Foster Children Programme. Under this project, two orphanages, namely, "Sencholai" and "Kandaruban", were set up for girls and boys respectively in the Wanni,

in the northern part of the country. These were directly under the patronage of Prabakaran and provided a convenient channel for funds from abroad to be diverted to the LTTE coffers and recruitment base for suicide operations. These orphanages looked after children of between 3 to 15 years [8]. However, during the Eelam War IV period, the LTTE had been very careful in selecting children from these orphanages for suicide operations due to growing concerns of the international community, particularly the UN, against exploitation of children for the war.

Training

The suicide training process can be broadly divided into group and individual training, depending on the suicide mission. Cadres who have been selected for the mission have to undergo basic military training initially and then have to follow up with model and specialized training in accordance with the mission. The training programmes are directed to creating a halo around an image of martyrdom through which suicide cadres get the feeling that they are belonging to elite category of fighters for their cause. The significant features of Black Tiger individual and group training are as follows; (a) Have to undergo basic military training programme for a period 3 months. (b) In completion of basic military training, the cadres have to undergo model training on a replica of the identified target (c) Simultaneously, the cadres also have to undergo a specialized training that includes riding motorcycles, driving lorries / cars, piloting of boats, handling of explosives / jackets, handling of high-tech equipment etc. depending on the type of mission. (d) Training is also given to maintain surprise and secrecy until the completion of the mission. (e) Frequent visits to orphanages run by the LTTE are organized to maintain motivation (f) English adventure movies and videos on successful suicide missions undertaken by cadres previously are shown during leisure time to boost confidence. (g) On completion of training, the individual or the group was given an opportunity to have a meal with the LTTE leader. The photographs of the cadres who sacrificed their lives in the past suicide missions, including those who were selected to carry out the mission, are displayed in this location as martyrs in order to show that they have already sacrificed their lives for their cause.

MODUS OPERANDI OF BLACK TIGER LAND AND SEA OPERATIONS

Black Tiger Land Operations

The planning and execution of suicide operations are extremely secret. The success of a mission depends on the level of motivation, training and intelligence available on the target, maintenance of security, and use of technology and tactics. It is important to note that once a target is selected by the LTTE leader, the training of suicide cadres and gathering information on the target commence simultaneously. The training and

gathering of information is done by different groups which are not connected to each other, in order to maintain a high level of secrecy. The entire process of Black Tiger land operations, from the selection of target up to the execution of the mission could be broadly categorized into following:

i. **Selection of the Target:** The target for the suicide mission is selected by the LTTE leader and the operation planned by the LTTE Intelligence Wing. The main factors considered in the selection of targets are: (a) Potential threat to the attainment of organisation objectives, (b) How far the attainment of its ultimate objectives will be furthered, (c) Accessibility to the target and destruction/ damage that it can cause, (d) Political, military and economic impacts on the country. (e) International reaction in the case of certain missions.

ii. **Gathering Information on the Target:** Once the target is selected, a separate Intelligence Cell is established closer to the target area a few months before the date of execution of the attack. Gathering information and surveillance on the target are conducted by the intelligence wing employing a minimum of three agents who would work independently, unaware of each other's tasks, although all three are engaged in the same mission. The means of gathering information for suicide operations are: (a) Intelligence operatives assigned to cover a particular region. (b) Infiltration of intelligence operatives / agents to the region of the selected target. (c) From sympathizers / supporters of the LTTE particularly those with access to the selected target. (d) Civilians who have come from cleared areas to LTTE controlled areas and vice a versa. (e) Using maps, aerial photographs and satellite images (f) Information obtained through open sources such as electronic and printed media.

iii. **Selection of Cadres and Conducting of Model Training:** The information obtained through above sources enabled the Intelligence Wing to plan the operation. Preparation of a model and training are conducted, based on information gathered by the LTTE Intelligence Wing. Once the model is prepared, the suicide cadre or the group undergoes training.

iv. **Induction of Cadres to the Target area and Execution of the Mission:**

    a. **Establishment of an Operational Cell:** The suicide group or the cadre is usually given accommodation in an operational cell, which can also be called as a safe house, in an area close to the target. In some cases, an intelligence cell established to gather information on the target is also used for this purpose. This cell is responsible for providing all requirements of the individual / group including transport, food, clothing and security. The operational cell is also responsible to provide the arms / ammunition, explosives, suicide jackets required to execute the mission.

b. **Moving to the Operational Cell:** Generally, the suicide cadre or the group moves to the cell a few days prior to the execution of the mission, and the individual or the group is accompanied by an intelligence cadre, who is also in charge of the operational cell / safe house. Suicide cadres are also accommodated in houses of LTTE sympathizers. Mostly, the suicide cadre moves from LTTE controlled areas to government controlled areas with fake documents, citing reasons such as seeking foreign employment, medical treatment, higher education and also employment as drivers / personal assistants of Tamil parliamentarians / NGOs.

c. **Execution of the Mission:** In the case of a group attack, the leader of the suicide group first visits the target area, accompanied by the leader of the reconnaissance team to make final preparations, a day prior to the mission. Then, the suicide group moves to the target area and executes the mission. If it is an individual attack, the individual is taken to the area a day prior to the mission in order to become familiarized with the surroundings. In some instances, an individual who is well aware of the surroundings is sent to the location of the target just prior to the mission.

d. **Withdrawal / Escape:** In suicide attacks, there is no withdrawal plan as all cadres earmarked for the mission are expected to die whether the mission is successful or not. Therefore, suicide cadres do not have to concern themselves with developing a withdrawal plan, often the most difficult phase of an operation. The certain death of the attacker enabled the group to undertake high quality operations while maintaining the highest security. This has been identified as one of the main factors which bound the suicide cadre to ensure successful completion of the mission.

Black Tiger Sea Operations

The planning of suicide operations against naval targets is different from land operations, except the training and gathering information on the target. The LTTE Sea Tiger leader is responsible for the coordination and execution of all Sea Tiger suicide operations. The boats for Black Tiger sea operations are manufactured by the LTTE. The special features of these boats are; the front part of all boats are pointed and a control panel including the switch, which activates the IED, is fixed in the front, so that it explodes when pressure is put on the switch. The type of engines fitted into these boats depends on the type of the mission. Generally two engines of 250 HP are used for attacks against naval crafts operating in the deep sea. The majority of cadres employed to carry out these suicide missions were disabled cadres [9]. The modus operandi of Sea Tiger suicide attacks on naval craft is as follows:

i. **Stage 1 – Isolating the target:** Once the target is identified, approximately 5-10 LTTE attack crafts apprtach the enemy vessel initially, and engage it from several directions in order to isolate the enemy vessel from other enemy crafts.

ii. **Stage 2 – Movement of the suicide boat at the scene of the incident:** While the LTTE attack crafts surround the enemy vessel and engage it with maximum firepower, the suicide boat approaches the enemy vessel under the cover of the command craft.

iii. **Stage 3 – Approaching the target and executing the mission:** While the attack crafts get closer to the enemy vessel from all directions, the command craft tries to cause damage to the hull of the enemy vessel. Once the damage is caused, the suicide craft stealthily moves to the targeted enemy vessel and rams it at the point where the damage had been caused by the command and the other attack crafts.

Analysis of Types of Suicide Operations, Male and Female Ratio, and Age Group of Black Tiger Cadres from 1987 to 2009.

A number of suicide operations conducted by LTTE from 1987 to 2009 can be broadly categorized into Land, Sea and Air operations. Land operations could be further categorized into suicide jacket operations, vehicle operations and group attacks. The total number of operations conducted during the said period is estimated at 123. Figure 1 indicates that LTTE mostly used explosive jackets on land and explosive laden boats in the sea to carry out its missions.

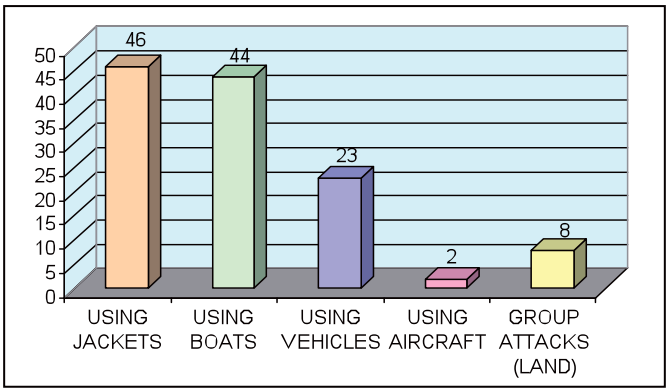

Figure 1. Type of suicide operations.

The number of Black Tiger cadres killed from 1987 to 2009 is estimated at 432 [2]. The percentages of the male and female cadres killed during land and sea suicide operations are 74% and 26% respectively. Figure 2 shows the number of male and female cadres killed during land and sea operations. These records indicate that for almost all group suicide missions, the LTTE employed male cadres and for individual missions, it employed mostly female cadres [10].

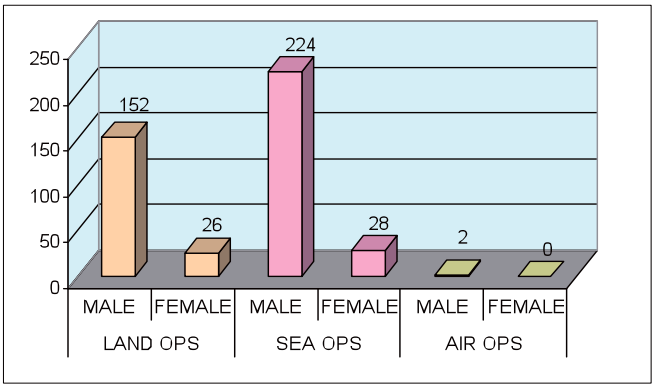

Figure 2. Male and female ratios of suicide cadres killed in land and sea operations.

Figure 3 shows the age groups of the Black Tiger cadres who have been killed from 1987 to 2009 [2]. The majority of cadres involved in suicide missions are belonging to the age groups of 20-25 and 25-30 years, which is more than 80% of the total suicide attacks. The higher percentage of suicide missions in this age category indicates that the LTTE has given priority to mature youths who have the mental and physical capacity.

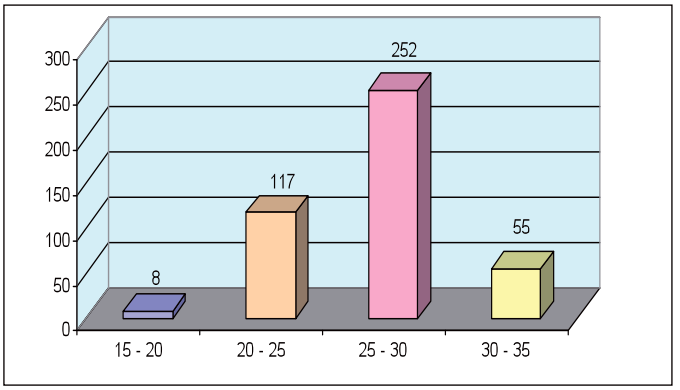

Figure 3. Age groups of suicide cadres killed in suicide operations.

IMPACT OF SUICIDE TERRORISM

Psychological Impact

Suicide attacks have brought about a drastic change in the Tamil society, influencing their thinking patterns and giving prominence to the Liberation struggle. The LTTE attempted to glorify suicide and tried to foster the belief that it is suicide that has given a common bond to the Tamil people. Anton Balasingham, theoretician of the LTTE based

in London, stated that the LTTE does not have any suicide squad and what they have is only sacrificial squad, which means it is in act of a militant to sacrifice his body and soul for a cause determined by his leader [11]. The effect on the mental state of the Tamil youth due to the suicide phenomenon, is well illustrated in an article entitled "Psychological Impact of Acute War" written by D J Somasundaram of the University of Jaffna [12]. He states that, in the long term, the future of children growing up in an atmosphere of violence and destruction causes great concern as these result in turning the children into future militants. It is also considered that in the current social ethos, youths faced with severe family conflict or environmental stress will choose one of two possible alternatives, one being suicide, and the other to join the militants and die for a cause.

Political Impact

Prabhakaran stated; "With perseverance and sacrifice, Tamil Eelam can be achieved in 100 years. But if we conduct Black Tiger operations, we can shorten the suffering of the people and achieve Tamil Eelam in a shorter period of time" [13]. As indicated previously, the LTTE is the only organisation which assassinated two State leaders, Indian Prime Minister Rajiv Gandhi and Sri Lankan President Premadasa in May 1991 and May 1993 respectively. The LTTE almost took the life of Mrs. Chandrika Kumaratunga, former President of Sri Lanka, in December 1999. All these leaders became victims largely due to the active role played by them in countering LTTE activities. In addition, it has also carried out a number of assassinations targeting national/political leaders who opposed the LTTE and challenged the claim off the LTTE to be the sole representative of the Tamils. As a result, most of the past leaders both in Sri Lanka and India have shown some reluctance to deal with the LTTE directly or to declare an all out war against the group until the present President of Sri Lanka, Mr. Mahinda Rajapaksa, declared all out war against the LTTE to liberate the people in North and East areas from LTTE clutches in July 2006.

Economic Impact

The LTTE had carried out a number of attacks targeting the country's economic infrastructure facilities. Of them, the attack on the Central Bank, the World Trade Centre, the Oil Storage Installation in Kolonnawa and the Bandaranaike International Airport are significant. These destructions have adversely affected many industries in the country including tourism, which is a significant earner of foreign exchange. Foreign investment has also been seriously affected due to the impact created by these attacks, thus resulting in far reaching consequences for the economy of the country.

Military Impact

The LTTE has carried out a number of attacks against military infrastructure facilities and SF personnel. The highest military personality who has become victim of LTTE's suicide operations was Chief Admiral Clancy Fernando, former Commander of the

Navy. In addition, a number of Senior Army Officers who played a major role in fighting terrorism have become victims of suicide attacks. LTTE also made an abortive attempt to take the life of Mr. Gotabhaya Rajapaksa, the Secretary of Defence who spearheaded the operations against the LTTE, and General Sarath Fonseka, then Commander of the Sri Lanka Army. The LTTE neutralized a number of State Intelligence Operatives and active members of Tamil groups which opposed the LTTE, and have entered into the democratic stream through suicide missions. In addition, suicide attacks on key defence establishments such as Joint Operations Command (JOC), a nerve centre of SF in Colombo, Air Force bases in Katunayake and Anuradhapura, and the Naval Harbour in Trincomalee are significant. These attacks have had a far-reaching impact on the national security of the country.

POTENTIAL THREAT AND COUNTER STRATEGY / MEASURE

Potential Threat

In analysing the developments in suicide terrorism in Sri Lanka, it is clear that suicide terrorism posed a major threat affecting the social, economic and political stability of the country until the military defeat of the LTTE in May 2009. As far as suicide operations of the LTTE from 1987 to May 2009 are concerned, it had clearly shown its capability of reaching at any target and executing the mission whether in or outside the country. Although there was not much activity seen with regard to LTTE suicide operations during the Ceasefire Agreement from 2002 to 2006, the LTTE used the ceasefire period to conduct reconnaissance on military, political and economic targets including almost all key political leaders and Service Chiefs. This was apparent with the commencement of Eelam War IV in July 2006, when the LTTE launched a number of suicide attacks against these targets. For the first time, it also used two aircrafts to carry out suicide missions in Colombo. However, these missions failed due to advanced preparedness of the Security Forces. Although the LTTE has been militarily defeated and their infrastructure facilities that were used to plan and conduct suicide operations in the country were destroyed, a number of suicide cadres who have undergone training on suicide operations in land, sea and air, and their expertise and knowledge in this field are still largely intact as most of them have fled the country and are in the process of regrouping themselves. This situation can be exploited by any interested extremist groups or parties, thus posing a greater threat to the peace and stability to Sri Lanka, as well as to the world at large.

Counter Strategy / Measures

Throughout the world, terrorism reinvents itself in new and more dangerous forms. Although, it would be a difficult task to eradicate terrorism or suicide terrorism completely, certain measures that could be taken at national, operational and tactical levels would facilitate the formulation of an effective counter strategy to deal with suicide terrorism. In this context, the Sri Lankan experience in dealing with terrorism and how

it succeeded in defeating LTTE militarily will be of immense value in formulating an effective strategy to deal with suicide terrorism. Given below are some of the measures that could be taken at strategic, operational and tactical levels to minimize the threat posed by suicide terrorism.

i. Strategic Level:

a. Clear political and military objectives to be established in fighting against terrorism.
b. Formulation of a political solution acceptable to all communities affected.
c. Taking of possible measures to improve the lifestyle of the people affected.
d. Transformation of military forces to meet modern threats.
e. Reforming of intelligence services to meet current and future threats.
f. Formulation of strategic psychological, and propaganda campaigns.
g. Revising of the criminal justice system in order to enable the authorities to deal with the terrorism without any legal barriers.
h. Encouraging the conduct of research on political, economic, military and psychological factors that generate suicide terrorism.
i. International cooperation to formulate a global strategy to counter the threat.

ii. Operational Level:

a. Formulation of operational policies and rules of engagement.
b. Coordination of the intelligence gathering process.
c. Training of Security Forces personnel to deal with suicide terrorism/ threats.
d. Educating the public on how to deal with suicide terrorism.
e. Measures to minimize the psychological damage of suicide attacks.
f. Involving the population in the fight against suicide terrorism.
g. Continuous review of the tactics and modus operandi of suicide attacks.
h. Security surveys on vulnerable installations / VVIPs.
i. Coordination of Security Forces, Police and civil security services / agencies.

iii. Tactical Level: Since direct action against the suicide cadre himself is usually a complicated operation, tactical measures should be focused on the application of pressure on those elements involved in the planning and implementation

of these attacks. Therefore, to identify effective measures to curb suicide terrorism, it is important to identify the process of suicide operations from the time of recruitment until the execution of the mission.

a. Preventing Recruitment and Training:

- The hearts and minds of the public who have been affected due to war, particularly those who have become victims because of Security Forces operations, have to be won by implementing strategic psychological operational concepts at a tactical level.
- Finding employment for the underprivileged youth in the conflict zone areas before the LTTE chooses them to undertake suicide missions.
- The bases where the cadres are trained for suicide missions should be identified and destroyed through aerial interdiction.
- Long Range Reconnaissance Patrols to be employed to identify and destroy bases where the cadres are undergoing training for suicide missions.

b. Preventing the Establishment/Functioning of Intelligence/Operational Cells:

- Educating the public to be vigilant.
- Formation of civil security committees in every village.
- Maintaining records on newcomers to the city / village by Police / Village Heads.
- Interception of suspected radio, cellular and satellite communication.
- Maintaining records on those residing in lodges / hotels.
- Frequent conduct of cordon and search operations.
- Obtaining proper identification when issuing SIM cards.
- Use of modern technology to verify the personal identity.

c. Preventing a Suicide Cadre / Group Reaching the Target Area:

- Educating the public on the behavioural patterns of suicide cadres and making use of them as a source of information to detect movements of suicide cadres. Some of the identified behavioural patterns of suicide cadres are; they generally appear to be nervous, rapid eye movements, constant wetting of lips, suspicious movements in the vicinity of the target, wearing inappropriate or oversized clothes and on questioning, stammering and sweating.
- Employment of intelligence personnel to monitor the movements of suspected personnel near vicinity of the potential target / area of interest.

- Monitoring communication surrounding areas of the potential target / area of interest.
- Use of CCT cameras / explosive detectors / sniffer dogs to monitor or detect the movements of suicide cadres.
- Restriction on movements of vehicles into vulnerable places.
- Number of entry/exit points into vulnerable places to be reduced.
- Establishing snap roadblocks, using of decoys during VVIP movements, frequent change of mode of transportation of VVIPs etc.

CONCLUSION

In summary, suicide attacks are the latest "trend" followed by various terrorist groups in the world to achieve their political objectives. However, as various terrorist groups resorted to different tactics in the past, the suicide phenomenon too is also likely to diminish and be replaced with other new phenomena and tactics. As stated above, suicide terrorism itself is a well planned process where the terrorist capitalizes on the political, economic and social differences and injustices that exist in society to achieve its political objective. Therefore, countering such phenomena requires a combination of effective national strategies and operational policies/plans to be implemented at tactical level. Furthermore, since a single country cannot fight the battle against suicide terrorism alone, it is important to share knowledge on this subject with other countries who have similar experiences and also to establish a common global identity in fighting terrorism. However, in case of LTTE, it is unfortunate to note that, even after the Government of Sri Lanka successfully defeated LTTE terrorism and is in the process of establishing permanent peace after three decades of fighting, certain countries continue to provide a safe haven for key LTTE elements and their front organisations to promote the LTTE ideology under the pretext of engaging in political activities. This situation is likely to revive the LTTE's hope for victory, thus posing a greater threat to peace and stability of the country as well as having international repercussions.

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MORPHOLOGICAL SPATIAL PATTERN ANALYSIS OF MOUNTAINS EXTRACTED FROM MULTISCALE DIGITAL ELEVATION MODELS

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ABSTRACT

In general, analysis of mountains is often performed at singular scales of measurement. However, analysis of a location at multiple scales allows for a greater amount of information to be extracted from a digital elevation model (DEM) about the spatial characteristics of a feature. Hence, the variation in the spatial resolution over which mountains are defined has been used by a number of researchers as the basis to perform the characterisation of mountains. This study is aimed at analysing the behaviour of classification of mountains extracted from multiscale DEMs into seven mutually exclusive categories (core, islet, bridge, loop, edge, perforation and branch) using morphological spatial pattern analysis (MSPA). MSPA employs concepts of mathematical morphology to segment input binary objects into a series of categories revealing information about size, shape and connectivity. It emphasises on connectivity between the objects' parts as measured via various values of size parameters s. The results obtained in this study indicate that MSPA is sensitive to changes of scale and size parameter s. Changes in values of s maintains the landform structure and describes pattern classes at different scales of observation. An increase of s does not change the terrain of the DEM or the extracted mountains, but increases the width of the non-core categories at the expense of the core category. In general, an increase in scale results in decrease of area of extracted mountains, and reduction in proportions of core and small scale non-core categories, with increasing islet proportion. The maximum structural detail of landform structure is obtained when using the highest possible spatial resolution of DEMs and the smallest possible value of s. Various scales and values of s should be experimented to determine the appropriate levels of classification for various applications.

INTRODUCTION

Mountains are the portions a terrain that are sufficiently elevated above the surrounding land (greater than 300 to 600m) and have comparatively steep sides. In a mountain, two parts are distinctive:

1) The summit, the highest point (the peak) or the highest ridges
2) The mountainside, the part of a mountain between the summit and the foot [1].

The mapping of mountains is generally performed manually through fieldwork and visual interpretation of topographic maps, which is time consuming and labour intensive. In recent times, extraction techniques have evolved from manual through computer assisted to automated methods with digital elevation models (DEMs) as the input data. In seeking the efficient extraction of mountains from DEMs, various algorithms have been proposed [2-5].

Scale variations can constrain the detail with which information can be observed, represented and analyzed. Changing the scale without first understanding the effects of such an action can result in the representation of patterns or processes that are different from those intended [6-11]. Hence, feature detection and characterization often need to be performed at different of scales measurement. Wood [12-13] and Wu et al. [11] demonstrated that analyses of a location at multiple scales allow for a greater amount of information to be extracted from a DEM about the spatial characteristics of a feature. The term scale refers to combination of both spatial extent, and spatial detail or resolution [8, 14-15]. A number of research efforts have been conducted to characterise mountains using the variation in the spatial resolution over which mountains are defined [16-18].

Morphological spatial pattern analysis (MSPA) [19, 20] employs concepts of mathematical morphology [21-23] to segment input binary objects into a series of categories revealing information about size, shape and connectivity. It emphasises on connectivity between the objects' parts as measured via various values of size parameters s. MSPA has been has become a popular tool for landscape modelling [19, 24-28], but has yet to receive significant attention in other areas of applications. Dinesh [29] studied the effect of various values of s on the classification of mountains extracted from singular scale DEMs.

In this paper, MSPA is employed to segment mountains extracted from multiscale DEMs into seven mutually exclusive categories. The effect of varying scales on the classification of these categories is studied. The results of this study will allow for effective classification of mountain regions, in particular for military operations planning. The seven categories, as defined by Soille and Vogt [20], are:

Core

Core pixels are defined as foreground pixels with distance to the background greater than s.

Islet

Islet pixels are defined as disjoint foreground connected components that are too small to contain core pixels.

Connectors: Bridge and loop

Connector pixels are groups of foreground pixels linking core connected components so that their removal would modify the homotopy of the object. Connector pixels are subdivided into two categories depending on whether the same core connectors link the same core connected component or not:

(a) Bridge pixels are connector pixels emanating from two or more core connected components.
(b) Loop pixels are connector pixels emanating from the same core connected component.

Boundaries: Edge and perforation

Boundary pixels are defined as yet unclassified foreground pixels with distance to the core pixels lower or equal to s. Boundary pixels are subdivided into:

(a) Edge (outer boundary) pixels are boundary pixels forming the outer perimeter of the core connected components.
(b) Perforation (inner boundary) pixels are boundary pixels forming the perimeter of holes within core connected components.

Branch

Branch pixels are pixels that do not belong to any of the previously defined categories. They emanate either from boundaries or connectors. It should be noted that connector and branch pixels that are adjacent to core pixels could be called junction pixels and classified as such if required by the application.

MATHEMATICAL MORPHOLOGY

Mathematical morphology is a branch of image processing that deals with the extraction of image components that are useful for representational and descriptional purposes. Mathematical morphology has a well developed mathematical structure that is based on set theoretic concepts. The effects of the basic morphological operations can be given simple and intuitive interpretations using geometric terms of shape, size and location. The fundamental morphological operators are discussed in Matheron [21], Serra [22] and Soille [23]. Morphological operators generally require two inputs; the input image *A*, which can be in binary or grayscale form, and the kernel *B*, which is used to determine the precise effect of the operator.

Each pixel in *A* is compared with *B* by moving *B* so that its centre hits the pixel. Depending on the type of morphological operator employed, the pixel value is reset to the value or average value of one or more of its neighbours.

Dilation sets the pixel values within the kernel to the maximum value of the pixel neighbourhood. Binary dilation gradually enlarges the boundaries of regions of foreground pixels, resulting in areas of foreground pixels growing in size, and holes within those regions becoming smaller [30]. The dilation operation is expressed as:

$$A \oplus B = \{a+b: a \epsilon A, b \epsilon B\} \quad (1)$$

Erosion sets the pixels values within the kernel to the minimum value of the kernel. Binary erosion gradually removes the boundaries of regions of foreground pixels, resulting in areas of foreground pixels shrinking in size, and holes within these areas becoming larger [30]. Erosion is the dual operator of dilation:

$$A \ominus B = (A^c \oplus B)^c \quad (2)$$

Morphological reconstruction allows for the isolation of certain features within an image based on the manipulation of a mask image *X* and a marker image *Y*. It is founded on the concept of geodesic transformations, where dilations or erosion of a marker image are performed until stability is achieved (represented by a mask image) [31].

The geodesic dilation δ^G used in the reconstruction process is performed through iteration of elementary geodesic dilations $\delta_{(1)}$ until stability is achieved.

$$\delta^G(Y) = \delta_{(1)}(Y) \; o \; \delta_{(1)}(Y) \; o \; \delta_{(1)}(Y) \ldots \text{until stability} \quad (3)$$

The elementary dilation process is performed using a standard dilation of size one followed by an intersection.

$$\delta_{(1)}(Y) = Y \oplus B \cap X \quad (4)$$

The operation in Equation 4 is used for elementary dilation in binary reconstruction [31].

A skeleton is a one pixel thick line representation of an object that summarizes the overall shape, size and orientation of the object. Skeletonisation is the process of reducing foreground regions in a binary image to a skeleton, while discarding the remaining foreground pixels. The resultant skeleton is used for the computation of length and direction, or for the detection of special topological structures such as end points and triple points [32].

In this paper, skeletonisation is implemented using the morphological thinning algorithm proposed in Jang and Chin [33]. Skeletonisation by morphological thinning is defined as the successive removal of outer layers of pixels from an object while retaining any pixels whose removal would alter the connectivity or shorten the legs of the skeleton. The process is converged or completed when no further pixels can be removed without altering the connectivity or shortening the skeletal legs.

IMPLEMENTATION OF MPSA

Core

Core pixels are identified by eroding the mountain pixels with a disk kernel of size *s*. This removes mountain pixels that have distance of less than *s* pixels from the background. The difference between the core pixels and the original foreground pixels defines the pixels that are candidates for the remaining classes, known as non-core pixels.

Islet

Morphological reconstruction is implemented using the core pixels as the marker and the original mountain pixels as the mask. This step flags all core pixels and mountain pixels that are connected to the core pixels. Islet pixels are identified by computing the difference between the original foreground pixels and the reconstructed pixels.

Connector

The skeletons of the core connected components are computed. Conditional dilation is performed on the skeletons for *s* iterations. For each iteration of conditional dilation, the skeletons are dilated with a square kernel of size 3, and the dilated pixels that do not correspond to non-core pixels are deleted. The resulting pixels form the connector pixels. Connector pixels that are connected to two or more core connected components are identified as bridge pixels. The remaining connector pixels are identified as loop pixels.

Boundary

Only the remaining mountain pixels are considered for boundary classification. The complement of the core pixels is eroded with a disk kernel of size *s*. This removes non-core pixels that are less or equal than *s* pixels from the core pixels. The boundary pixels are identified by computing the difference between the non-core pixels and the eroded pixels. The holes in the core connected components are filled. The filled core connected components are eroded with a disk kernel of size *s*. The perforation pixels are identified by performing an intersection between the filled core connected components and the boundary pixels. The remaining boundary pixels are identified as edge pixels.

Branch

The mountain pixels that have not been classified to the previous categories are identified as branch pixels.

GENERATION OF MULTISCALE DEMS

In this paper, multiscaling is performed using the lifting scheme [34-35]. The lifting scheme is a flexible technique that has been used in several different settings, for easy construction and implementation of traditional wavelets and of second generation wavelets, such as spherical wavelets. The lifting scheme has proven to be a powerful multiscale analysis tool in image and signal processing [36-38]. Lifting consists of the following three basic operations (Figure 1):

Step 1: Split

The original data set $x[n]$ is divided into two disjoint subsets, even indexed points $x_e[n]=x[2n]$, and odd indexed points $x_0[n]=x[2n+1]$.

Step 2: Predict

The odd and even subsets are often highly correlated. This correlation structure typically local and hence, it is possible to accurately predict the wavelet coefficients $d[n]$ as the error in predicting $x_0[n]$ from $x_e[n]$ using the prediction operator P:

$$d[n] = x_0[n] - P(x_e[n]) \tag{5}$$

$$P(x_e[n]) = \frac{1}{2}(x_e[n] + x_e[n+1]) \tag{6}$$

Step 3: Update

Scaling coefficients $c[n]$ that represent a coarse approximation to the signal $x[n]$ are obtained by combining $x_e[n]$ and $d[n]$. This is accomplished by applying an update operator U to the wavelet coefficients and adding to $x_e[n]$:

$$c[n] = x_e[n] + U(d[n]) \tag{7}$$

$$U(d[n]) = \frac{1}{4}(d[n-1] + d[n+1]) \tag{8}$$

The above three steps form a lifting stage. The lifting scheme scans 2D images row-by-row. Using a DEM as the input, an iteration of the lifting stage generates the complete set of multiscale DEMs $c_s[n]$ and the elevation loss caused by the change of scale $d_s[n]$.

The DEM in Figure 1 shows the area of Great Basin, Nevada, USA. The area is bounded by latitude 38° 15' to 42° N and longitude 118° 30' to 115° 30'W. The DEM was rectified and resampled to 925 m in both *x* and *y* directions. The DEM is a Global Digital Elevation Model (GTOPO30) and was downloaded from the USGS GTOPO30 website [39]. GTOPO30 DEMs are available at a global scale, providing a digital representation of the Earth's surface at a 30 arc-seconds sampling interval. The land data used to derive GTOPO30 DEMs are obtained from digital terrain elevation data (DTED), 1-degree DEMs for USA and the digital chart of the world (DCW). The accuracy of GTOPO30 DEMs varies by location according to the source data. The DTED and the 1-degree dataset have a vertical accuracy of ± 30 m while the absolute accuracy of the DCW vector dataset is ± 2,000 m horizontal error and ± 650 m vertical error [40]. Tensional forces on the terrain's crust and thins by normal faulting cause the formation an array of tipped mountain blocks that are separated from broad plain basins, producing a basin-and-range physiography [3, 41-44].

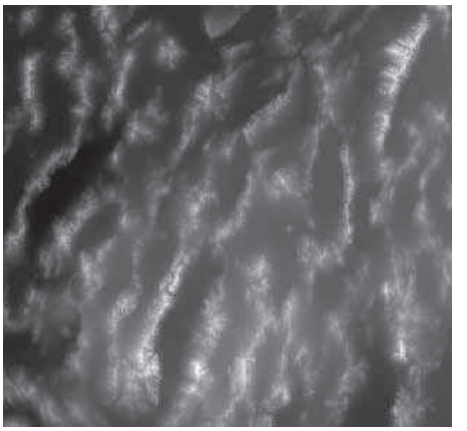


Figure 1. The GTOPO30 DEM of Great Basin. The elevation values of the terrain (minimum 1005 meters and maximum 3651 meters) are rescaled to the interval of 0 to 255 (the brightest pixel has the highest elevation). The scale is approximately 1:3,900,000.

Multiscale DEMs of the Great Basin region are generated by implementing the lifting scheme on the DEM of Great Basin using scales of 1 to 20. As shown in Figure 2, as the scale increases, the merging of small regions into the surrounding grey level regions increases, causing removal of fine details in the DEM. As a result, the generated multiscale DEMs possess lower resolutions at higher degrees of scaling.

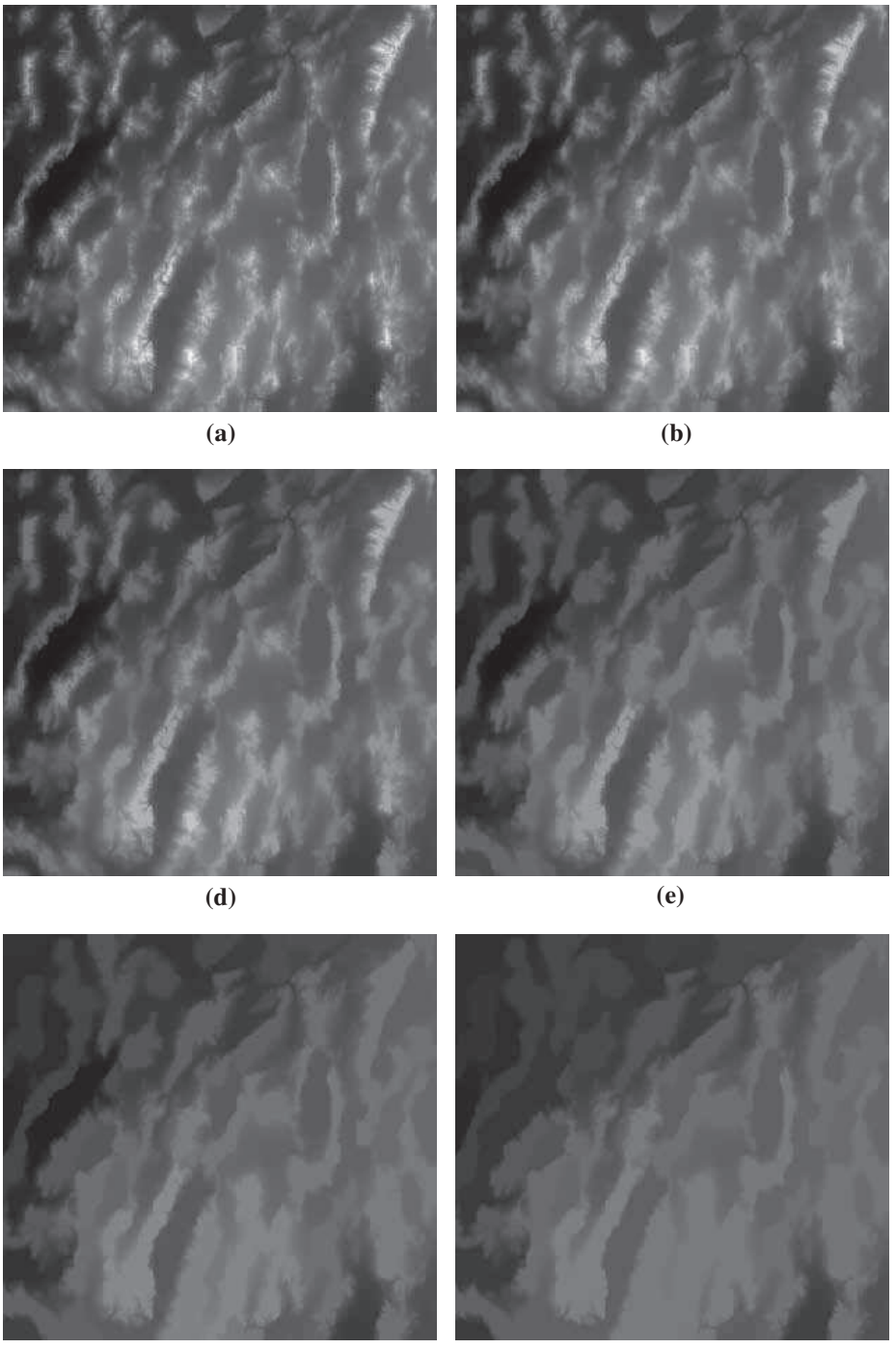
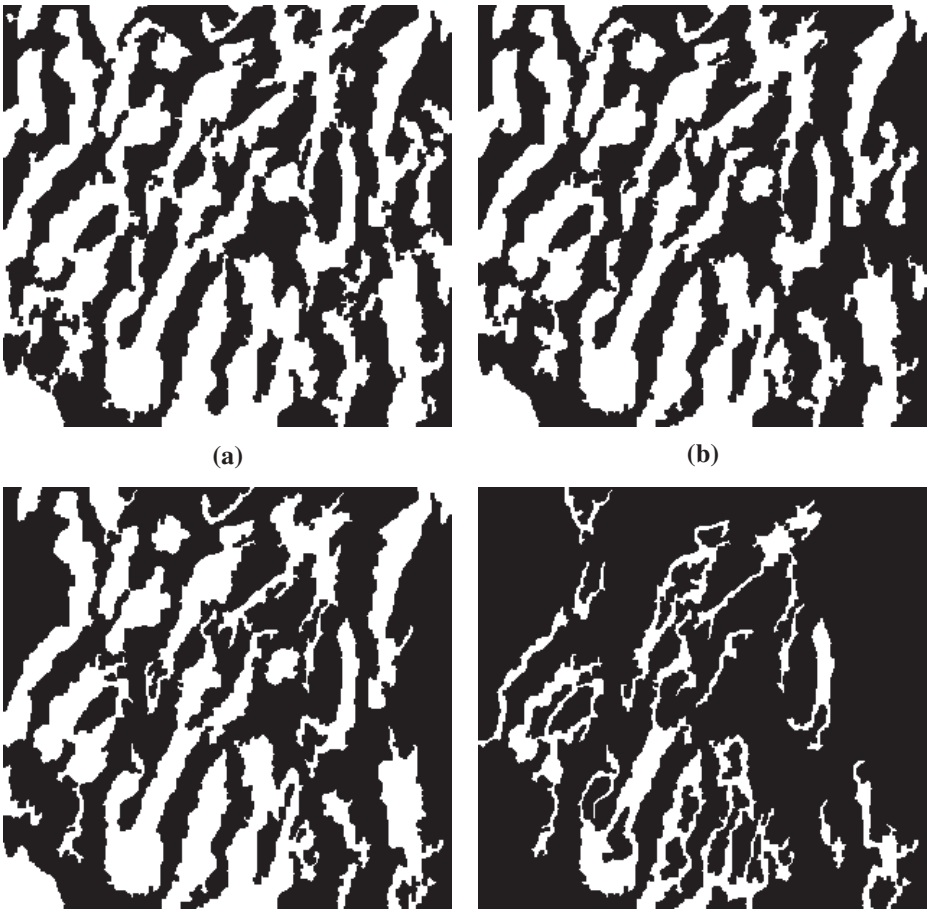


Figure 2. Multiscale DEMs generated using scales of (a) 1 (b) 3 (c) 5 (d) 10 (e) 15 (f) 20.

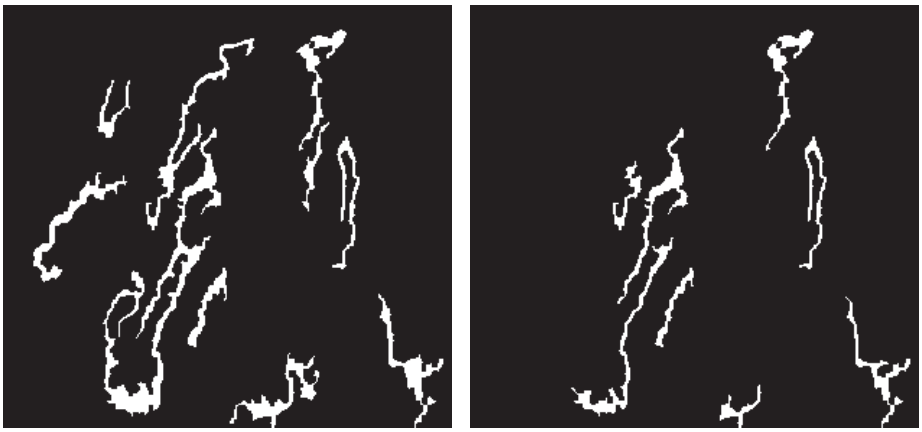
MOUNTAIN EXTRACTION

The mountains of the DEM of Great Basin (Figure 2(a) are extracted using the mathematical morphological based algorithm proposed in Dinesh [5]. First, ultimate erosion is performed on the DEM to extract the peaks of the DEM. Conditional dilation is performed on the extracted peaks to obtain the mountains of the DEM. As shown in Figure 3, the merge of small regions into the surrounding grey level regions and removal of fine detail in the DEM cause a reduction in the area of the extracted mountains.



(a) **(b)**

(c) **(d)**

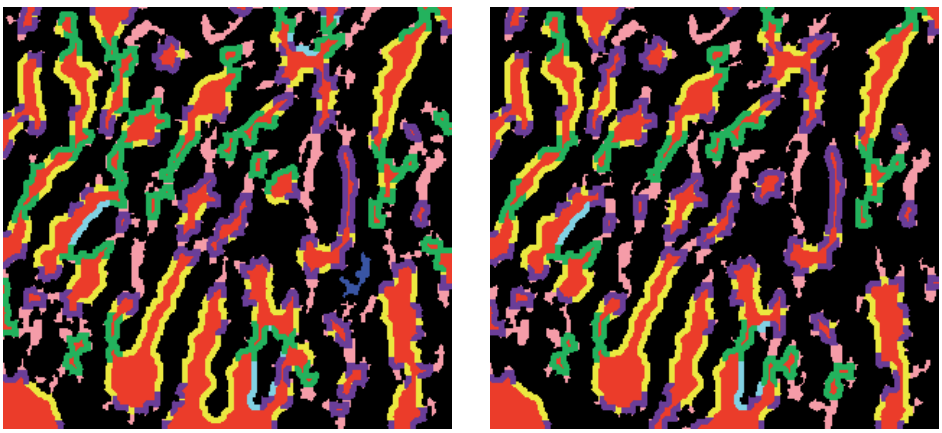


(e) (f)

Figure 3. Mountains (the pixels in white) extracted from the corresponding multiscale DEMs in Figure 2.

ANALYSIS OF MORPHOLOGICAL SPATIAL PATTERNS OF MOUNTAINS EXTRACTED FROM MULTISCALE DEMS

MSPA is used to segment the extracted mountains into the seven categories using size parameters *s* of 1 to 40 (Figure 4). Figures 5 and 6 shows the proportions of each category for increasing values of *s*, while Figure 7 shows the proportions for increasing scales. At singular scales, the value of *s* drives the proportions of the core and non-core categories. Initially, at $s = 0$, all the mountain pixels are assigned to the core category. When s is larger than the size of the individual mountain objects, all the mountain pixels are assigned to the islet category. Simultaneous existence of core and non-core categories



(a) (b)

occurs when the value of *s* varies between these two boundary values. With increasing values of *s*, the core proportion decreases, while the islet proportion either increases or remains stable. For increasing scales, the reduction in area of extracted mountains results in higher rates of decrease of core proportion and increase of islet proportion.

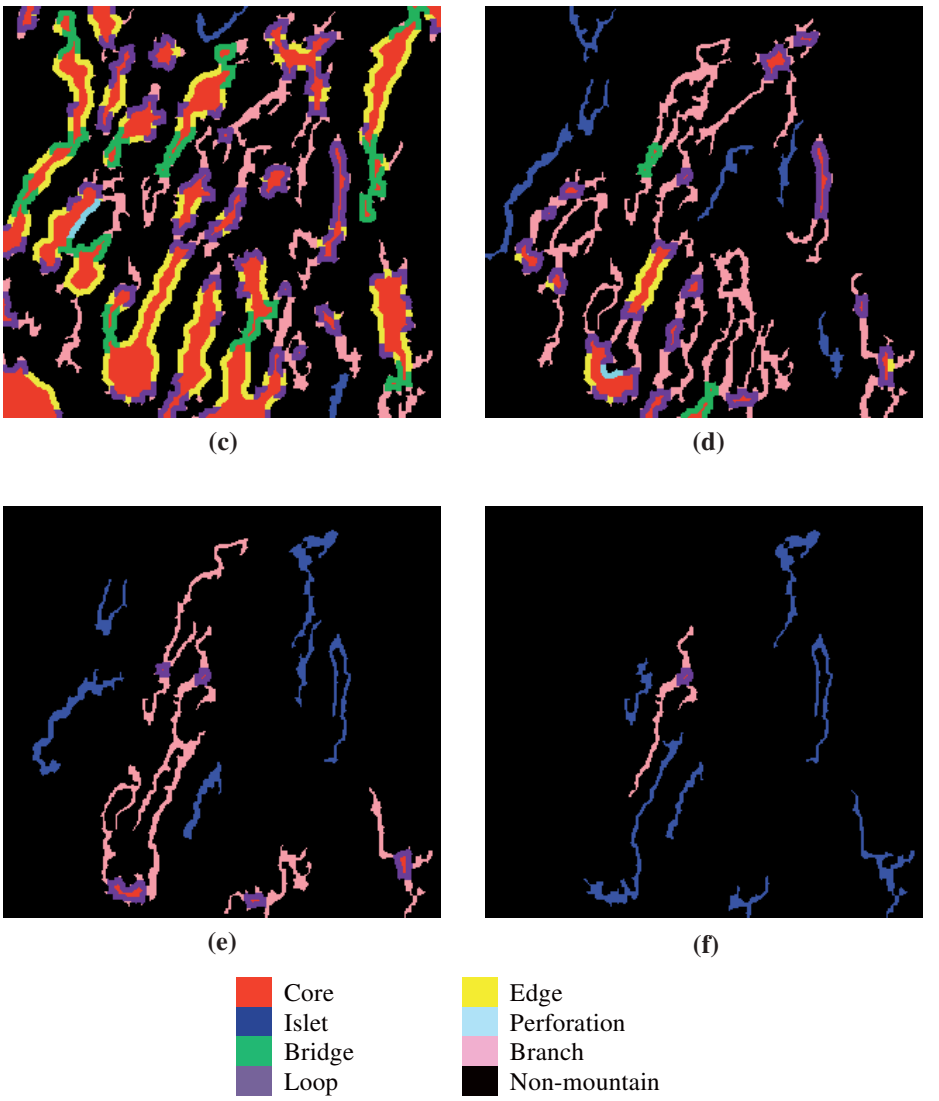


Figure 4. Morphological spatial patterns (size parameter *s* = 5) of mountains extracted from the corresponding multiscale DEMs in Figure 2.

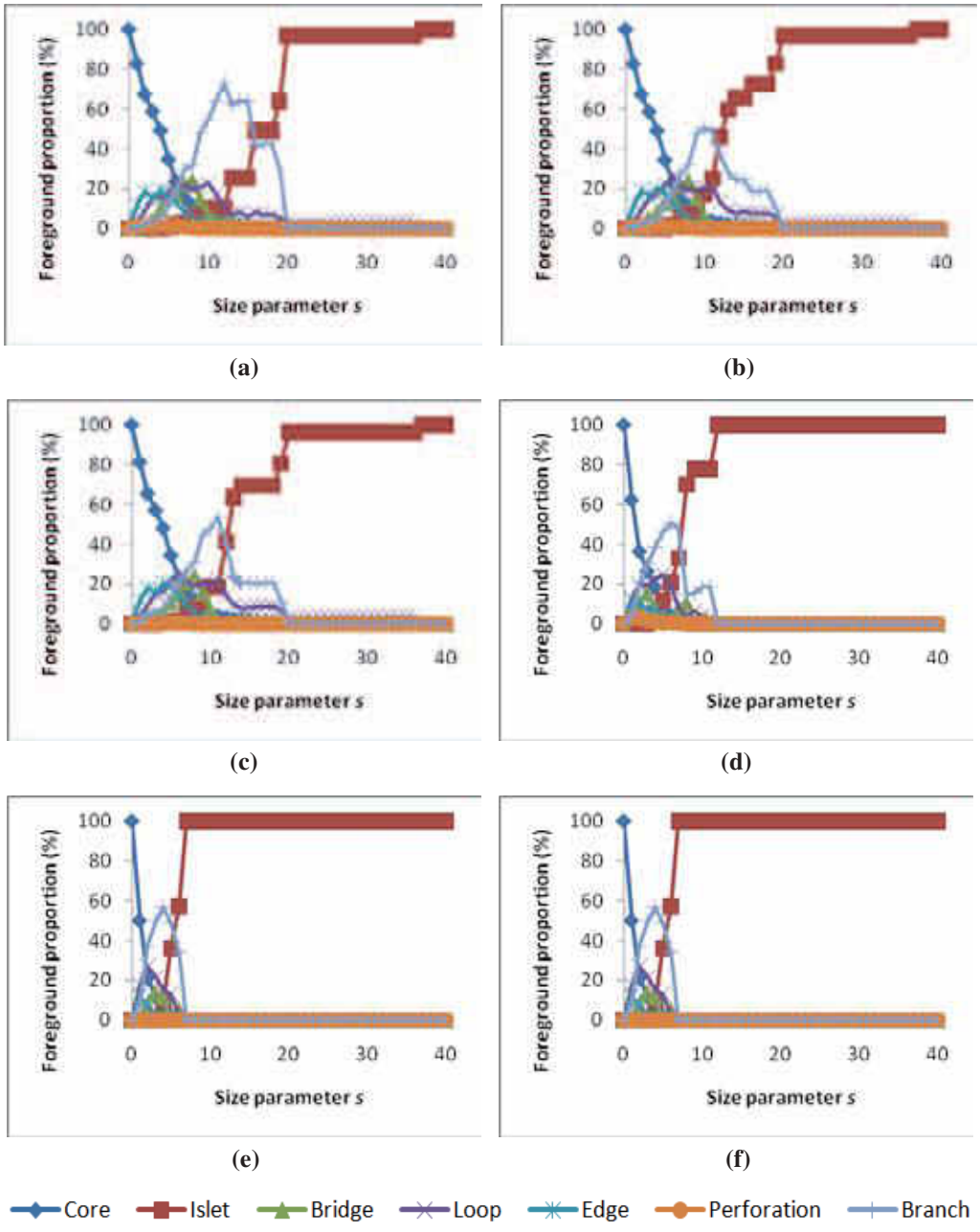
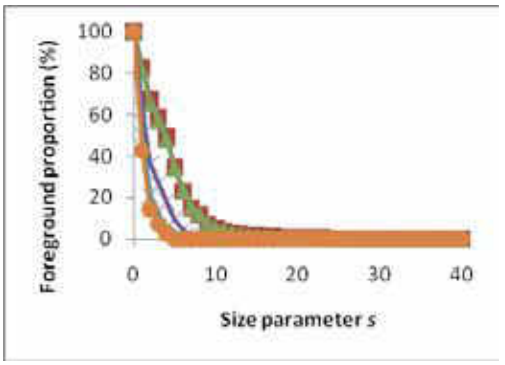
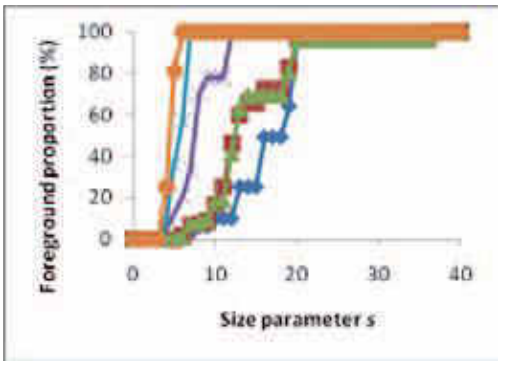


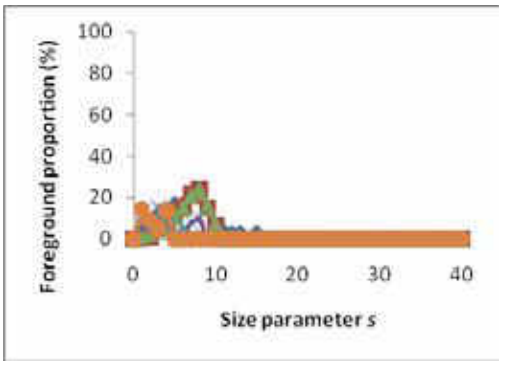
Figure 5. Proportions of each category of the extracted mountains for increasing size parameter *s* for the corresponding multiscale DEMs in Figure 2.


Foreground proportion (%)
100
80
60
40
20
0
0
10
20
30
40
Size parameter *s*

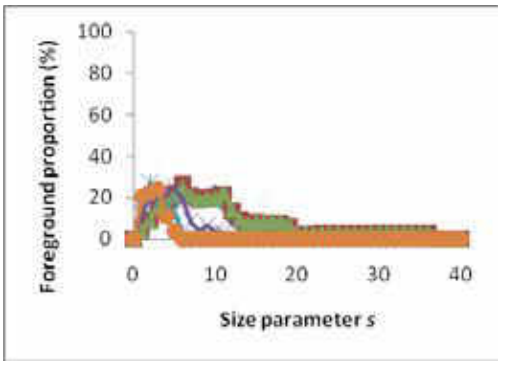
(a)


Foreground proportion (%)
100
80
60
40
20
0
0
10
20
30
40
Size parameter *s*

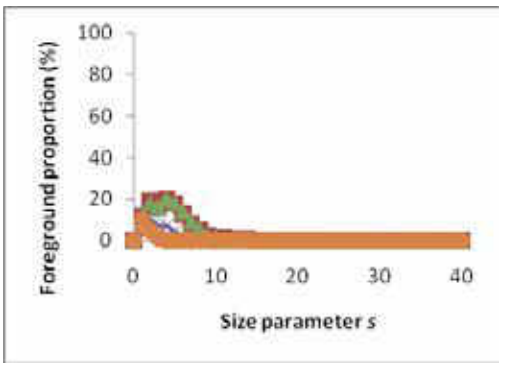
(b)


Foreground proportion (%)
100
80
60
40
20
0
0
10
20
30
40
Size parameter *s*

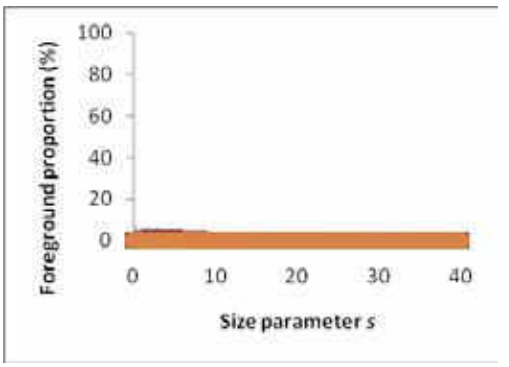
(c)


Foreground proportion (%)
100
80
60
40
20
0
0
10
20
30
40
Size parameter *s*

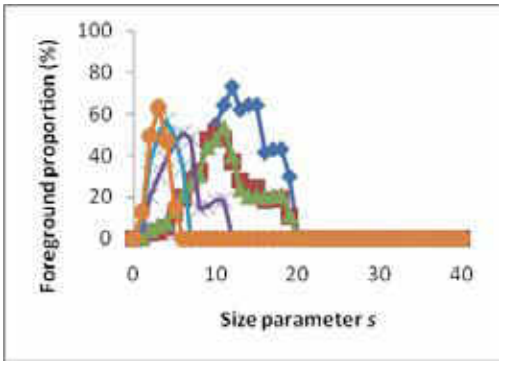
(d)


Foreground proportion (%)
100
80
60
40
20
0
0
10
20
30
40
Size parameter *s*

(e)

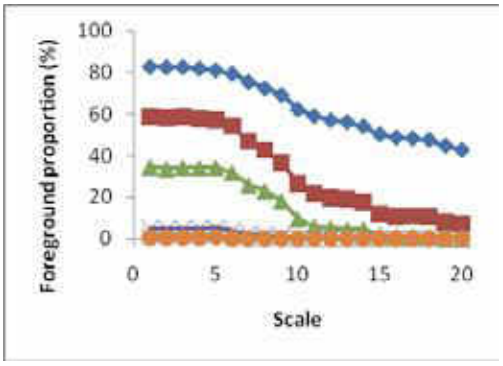

Foreground proportion (%)
100
80
60
40
20
0
0
10
20
30
40
Size parameter *s*

(f)

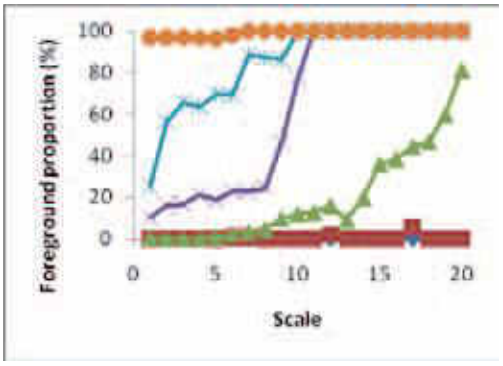


(g)

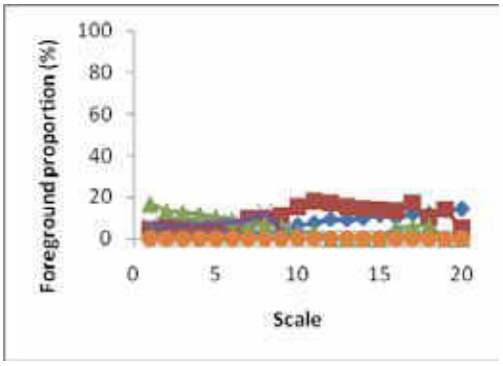
Figure 6. Proportions of each category of the extracted mountains for increasing size parameter s over the varying scales of measurement: (a) Core (b) Islet (c) Bridge (d) Loop (e) Edge (f) Perforation (g) Branch.



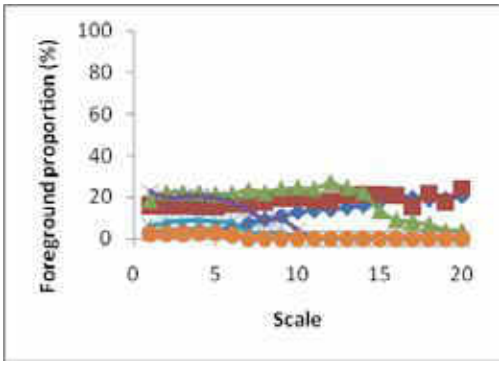
(a)



(b)



(c)



(d)

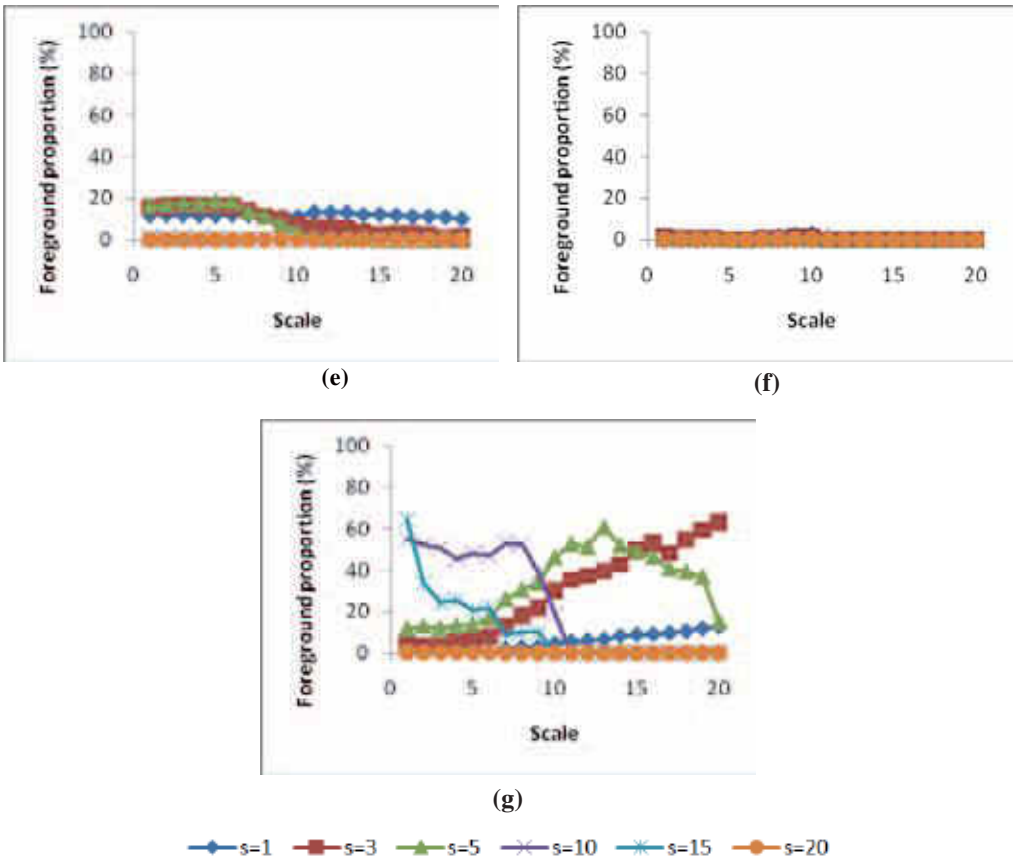


Figure 7. Proportions of each category of the extracted mountains for increasing scales over the varying size parameters s: (a) Core (b) Islet (c) Bridge (d) Loop (e) Edge (f) Perforation (g) Branch.

The change in proportion of the remaining categories with increasing values of s depends on the number and distribution of the remaining core connected components. Starting at $s = 0$, as s is increased, the number of distinct individual core connected components increases, while the width of bridges, loops, edges and perforations increases. This results in increases in proportions of the bridge, loop, edge and perforation categories. However, as s is further increased, the number and area of core connected components reduce, resulting in reduction in the proportions of the four categories. Increase of scale also causes reduction in the number and area of core connected components, resulting in decrease of the proportions of these four categories.

With increasing s, smaller portions of the individual mountain objects are assigned to the core category, with the remaining parts of the mountain objects being assigned to branch category. This results in a significant increase in proportions of the branch

category. As *s* is further increased, these mountain objects are increasingly assigned to the islet category, resulting in reductions in the proportions of the branch category. Increase of scale reduces the size of the mountain objects, increasing the rate of increase of islet proportion and decrease of branch proportion.

It is observed that smaller values of *s* provide more differentiation among the categories, and hence, better information about the classification of the extracted mountains. Hence, in general, for smaller values of *s*, increase of scale results in the proportions of the bridge, loop, edge, perforation and branch categories to increase or remain stable. For larger values of *s*, increase of scale causes the removal of these small scale non-core categories due to the increase of islet proportion. The changes in proportion of non-core categories are due the combined effect of increasing width of non-core categories and reduction in area of extracted mountains.

CONCLUSION

The results obtained in this study indicate that MSPA is sensitive to changes of scale and size parameter *s*. Changes in values of s maintains the landform structure and describes pattern classes at different scales of observation. An increase of *s* does not change the terrain of the DEM or the extracted mountains, but increases the width of the non-core categories at the expense of the core category. In general, an increase in scale results in decrease of area of extracted mountains, and reduction in proportions core and small scale non-core categories, with increasing islet proportion. The maximum structural detail of landform structure is obtained when using the highest possible spatial resolution of DEMs and the smallest possible value of *s*. Various scales and values of *s* should be experimented to determine the appropriate levels of classification for various applications.

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DEVELOPMENT OF BLAST RESISTANCE CONCRETE

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ABSTRACT

This paper discusses the development of blast resistance concrete for defence applications using hybrid steel fibres. The aim of the tests was to develop a blast resistance concrete. The materials for the blast resistance concrete are made from the combination of ordinary Portland cement, aggregates, sand and hybrid steel fibres which possess high strength and ductility. These materials provide high compressive and flexural strength compared to normal reinforced concrete. Through the high explosion blast test conducted, the material had shown a significant resistance from high explosion blast. This shows that there is a potential for these materials to be used for defence applications, particularly in military explosive storage buildings or bunkers, and also can be used in protective structures, government buildings, commercial shopping complexes, hotels, airports and in the high risk terrorist threat environments.

INTRODUCTION

Recent terrorist attack on Moscow Metro Train (2010), Marriott Hotel in Jakarta (2009), and Mumbai (2008) had shown that the destruction of hotels and other facilities such as public transports and military bases has become the target of terrorists [1-3]. In most of the cases, the terrorists use explosives loaded in a vehicle at a close distance from the target. The explosion creates intense shock waves which propagate outward at hypersonic velocity accompanied by a release of heat and light that induce pressure on the structural members, and causes significant damage to the structure and loss of life.

Therefore, there is a need to develop blast resistance materials, for critical government buildings such as military headquarters and facilities, explosive storage facilities, strategic bridges, hotels, airports, dams, and also chemical or petroleum plants, which are capable of providing adequate protection against terrorist attacks. The most important objective is that the materials shall be cost effective and the construction procedures shall not be much different from those found in the conventional construction method.

EXPLOSIONS AND BLAST PHENOMENON

An explosion is defined as a large-scale, rapid, and sudden release of energy. The detonation of a condensed high explosive generates hot gases under pressure of up to 300 kbar and a temperature of about 3000 to 4000°C. The hot gas expands, forcing out the volume it occupies. This is followed by the formation of a blast wave. The blast wave instantaneously increases to a value of pressure above the ambient atmospheric pressure which is referred to as the side-on overpressure and decays as the shock wave expands outward from the explosion source. After a short time, the pressure behind the front drops below the ambient pressure. Finally, in the explosion event, the shock wave will become negative, creating vacuum and high intensity pressure that, accompanied by high suction winds, carry the debris for long distances away from the explosion source [4]. The blast phenomenon is as shown in the Figure 1.

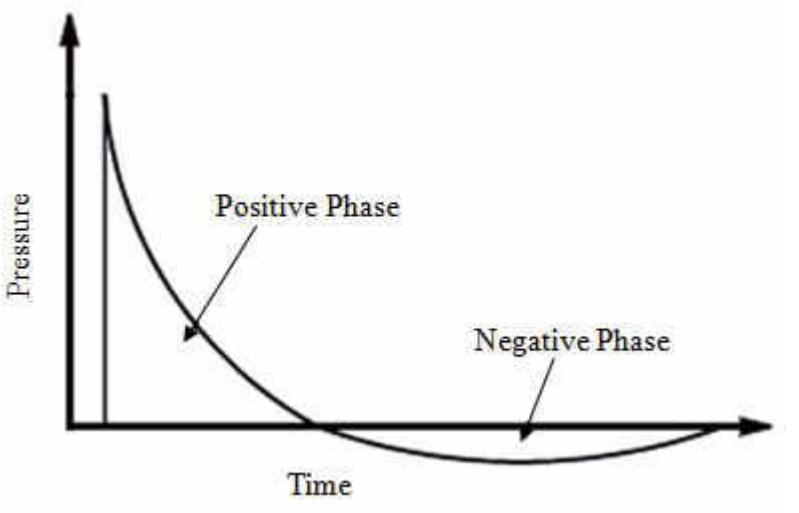


Figure 1. Blast phenomenon [4].

BEHAVIOUR OF THE REINFORCED CONCRETE UNDER BLAST LOADING

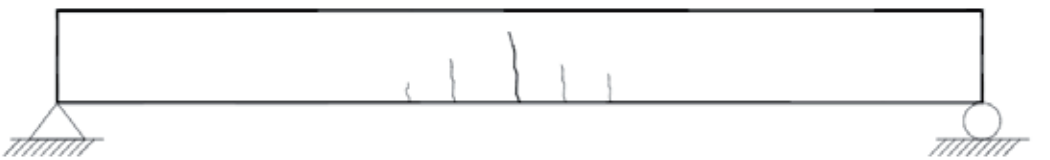
Reinforced concrete is the most widely used construction material for building and structures. However, due to low tensile strength capacity and brittle behaviour of the materials, it can be vulnerable to attack. Reinforced concrete slabs can fail in three major ways when it is subjected to blast loading. These modes of failure on concrete structures are either flexural, flexural shear or breaching failure, which depends on the distance between the source of the explosion and the target, and also the ductility of the structural elements [5].

The flexural failure mode is characterised by initial cracking of the concrete, subsequent yielding of the tensile reinforcement and ultimately, compression failure of the concrete. The nature of flexural failure is normally ductile and energy absorbing.

The shear failure mode, on the other hand, is abrupt and brittle in nature, which severely limits the capacity of the element. The flexural shear mode is characterised by initial flexural cracks that develop where the maximum bending moment is obtained and then, ultimately, the formation of an inclined diagonal tension crack close to one or both supports. This failure mode is primarily associated with transient short duration dynamic loads that result from blast effects and it is depends mainly on the intensity of the pressure waves. This failure mode is abrupt and brittle in nature, which severely limits the capacity of the element

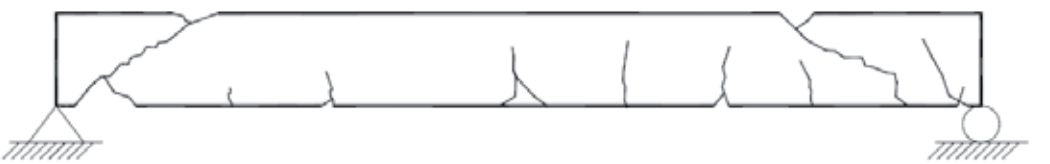
The punching effect is frequently referred as breaching failure which is local failure through the full thickness in component area of the highest blast load. Breaching failures are typically accompanied by spalling and scabbing of the concrete covers as well as fragments and debris. The three failure mode of the concrete is as shown in the Figure 2.

Besides this, the post blast damage of the concrete can be classified as light, moderate and also severe. Light damage is referring to the appearance of hair line crack with crack width of less than 1 mm on the exposed surface of the concrete. Moderate damage refers



(a) Flexural failure

(b) Flexural shear failure



(c) Breaching failure

Figure 2. Failure mode of concrete subjected to blast loading [5].

to the situation when the bottom surface of the concrete is having cracks width of up to 1.5 mm and also having a minor spalling. Severe damage refers to the large cracks up to 4 mm wide together with large deflection and also heavy concrete spalling [6].

The effect or damages on the structure due to blast loading can be overcome by several methods. One of the methods to protect the structure from explosion is to provide a sufficient stand-off distance to the building or structure with bollard, fences and walls. However, this method is not practical in urban areas where there is insufficient space available

Another method is by developing a blast resistance concrete material which is very ductile and has large energy absorption capabilities when subjected to blast loading. As the normal concrete has relatively low tensile strength and brittle response to the blast loading, this disadvantage can be overcome by introducing randomly dispersed steel fibres into the mixture that can increase the ductility and the survivability of concrete structures subjected to blast loading .This research area is currently receiving more attention from researchers and building designers in terms of providing the protection of buildings from explosion.

STEEL FIBRE REINFORCED CONCRETE SUBJECTED TO BLAST LOADING

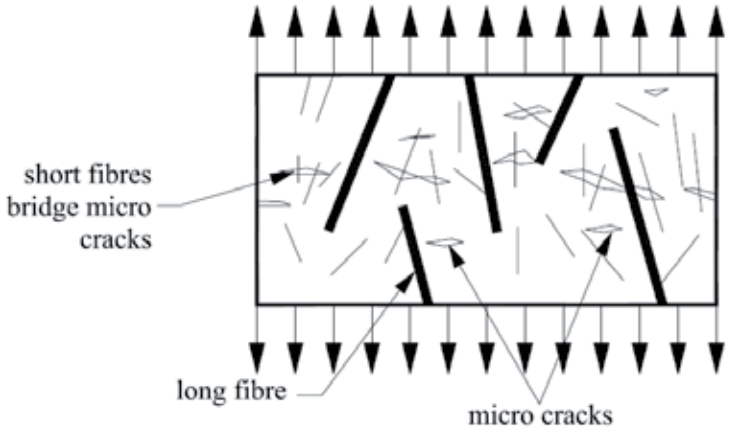
Previous studies on concrete structure subjected to blast load had shown that by incorporating steel fibre, the blast resistance of the concrete can be increased. Alias et al. [7] investigated the behaviour of steel fibre reinforced concrete subjected to air blast loading. They concluded that by incorporating long steel fibre in reinforced concrete, it can increase the blast resistance of the materials. Similarly, Magnusson et al. [8] reported on the benefits of incorporating the steel fibre in the reinforced concrete to resist the blast load. A number of studies have also been performed to examine the suitability of the steel fibres as a blast resistance element in concrete.

Lan et al. [9] performed a series of blast tests on the composite component which include steel fibre reinforced concrete slab, profile sheeting reinforced concrete slab and also conventional reinforced concrete slab. The specimens were tested with a charge weight ranging between 8 and 100 kg of bare explosive at a stand-off distance of 5 m. The test results show that 1.0% of steel fibre volume in the concrete is significant in resisting the blast loading.

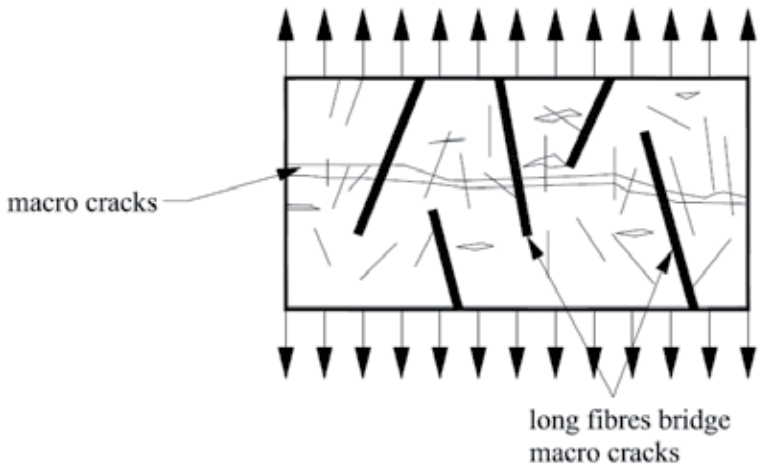
A study carried out by Lok and Pei [10] found that the addition of steel fibres to reinforced concrete can improves resistance to impact and the fibre can delay the propagation of the cracks. The fibres can bridge these cracks and restrain their widening, thus improved the post peak ductility and energy absorption capacity of the concrete. All the stated investigation was focused on single steel fibre only.

The objective of this research therefore is to investigate and develope a blast resistance concrete containing hybrid steel fibre which is capable to provide adequate resistance against the blast loading. Hybrid is referring to two or more types of fibres that are rationally combined in a common matrix to produce a composite that derives benefits from each of the individual fibres and exhibits a synergetic response [11].

Benthur and Mindess [12] reported on the advantages of hybrid fibre systems in concrete. By providing hybrid reinforcement in which, one type of the fibre is smaller, it can bridge the micro cracks of which the crack growth can be control. This leads to a higher tensile strength of the composite. The second type of fibre is larger, so that it arrests the propagating of macro cracks and can substantially improve the toughness and ductility of the composite. This is as illustrated in the Figure 3.



(a) Short steel fibre control the micro cracks



(b) Long steel fibres control the macro crack

Figure 3. The benefits of hybrid steel fibres in controlling cracks [12].

In addition to this, smaller fibre improves the pull out response of larger fibre, thus increasing the flexural strength and toughness of the composite [13]. The improvement of mechanical properties such as compressive strength, flexural strength and tensile strength of the hybrid concrete had also been reported by Mohammadi et al. [14].

EXPERIMENTAL PROGRAM

The concrete panels to be used for the experimental programme was Normal Reinforced Concrete (NRC) and Hybrid Steel Fiber Reinforced Concrete (HSFRC) as shown in Figure 4. The samples were reinforced on both tension and compression face with 10 mm diameter steel reinforcement at 200 mm centre-to-centre in both ways. The entire specimen was measuring 600 mm × 600 mm at a thickness of 150 mm with 20 mm cover.

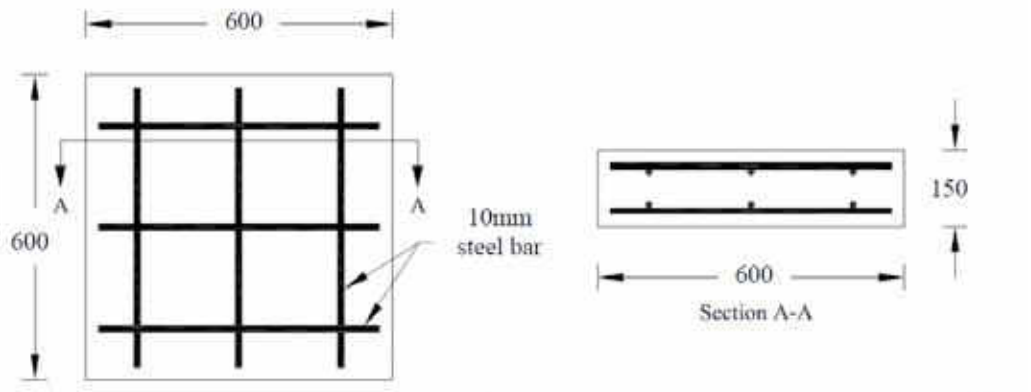


Figure 4. The size and steel reinforcement arrangement of in the NRC and HSFRC panels.

The size, thickness for both the NRC and HSFRC panels were the same. The only difference was that the HSFRC panel was incorporated with two different lengths of hooked-end steel fibres, namely short fibre (30 mm) and long fibre (60 mm) as shown in the Figure 5.

(a) Long Steel Fiber **(b) Short Steel Fiber**

Figure 5. Hooked-end steel fibre for Hybrid Steel Fibre Reinforced Concrete (HSFRC) panel.

The proportion of the long steel fibre (60 mm) to short steel fibre (30 mm) was 7:3 with a volume fraction of 1.5%. The tensile strength for both of the fibres is 1100 MPa. Ordinary Portland cement, crushed coarse aggregates with maximum size of 10 mm and river sand were used to cast the samples. The concrete mix proportion for the NRC and HSFRC panels was as shown in the Table 1.

Table 1. Concrete mix proportion for NRC and HSFRC panels.

Item	Ratio and Fibre Volume	
	NRC	HSFRC
Water/cement	0.45	0.45
Sand/cement	1.5	1.5
Coarse aggregate/cement	2.8	2.8
Volume of Fibre, V_f (%)	0.0	1.5

The conventional procedure for preparing the NRC was carried out as usual in the laboratory. The freshly mixed NRC was poured into standard cubes of 150 mm × 150 mm × 150 mm, standard cylinders of 150 mm × 300 mm and standard beams of 100 mm ×100 mm × 500 mm for compressive strength tests, split tensile strength tests and flexural strength tests respectively. All the specimens were left 24 hours for consolidation before they were cured in water for a period of 28 days.

Meanwhile, in mixing of the HSFRC, the sand and aggregates were initially dry mixed for 2 minutes. Then, ordinary Portland cement was added follow by water and mixed for a period of approximately 5 minutes. After this, fibres were added in small amount into the wet mix to avoid fibre balling. The mixture was then mix for another 10 minutes to ensure all the fibres were disperse randomly throughout the concrete and having a good workability.

The freshly mixed HSFRC was also placed into the mould of standard cubes of 150 mm × 150 mm × 150 mm, standard cylinders of 150 mm × 300 mm and standard beams of 100 mm ×100 mm × 500 mm for compressive strength tests, split tensile strength tests and flexural strength tests respectively. However, there are poured in two equal layers into the mould. Each layer was consolidated by using a vibrating table. At the end of 24 hours after the consolidation, the specimens were removed from the mould and cured in water for 28 days.

Finally the NRC and HSFRC were poured separately into the panel mould of 600 mm × 600 mm × 150 mm. The NRC and HSFRC panels were later removed from the mould after consolidation and cured with wet gunny sacks for 28 days before the field blast test. Table 2 shows the results of the average compressive strength tests, flexural strength tests and split tensile strength tests for both the NRC and HSFRC specimens.

Table 2. Test Results for NRC and HSFRC at 28 Days.

Average Strength, MPa	NRC	HSFRC
Compressive Test	32	41
Flexural Test	3.5	7.5
Split Tensile Test	3.0	5.0

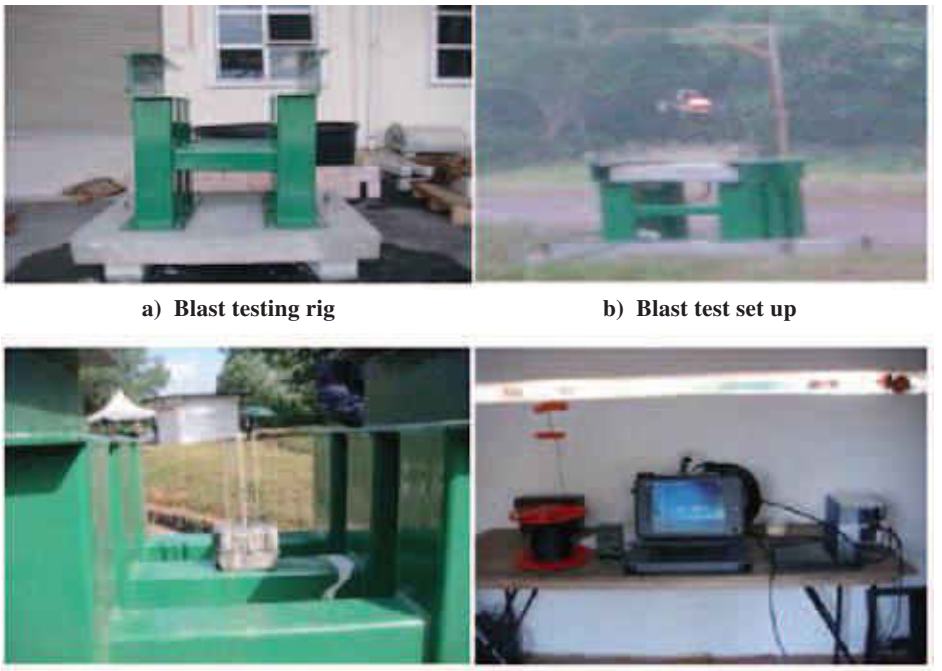
FIELD BLAST TEST PROGRAM

Due to the limitation of cost and also possible blast charge weight to be used for the test, the dimension of the test specimen were set to 20% from the actual size of the slab, however the reinforcement and also the thickness of the slab remain the same as shown in Figure 4. In addition to this, the charge weight was also limited to a maximum of 1 kg of explosive.

The panels were place on site at a proper steel frame testing rig like table which was fabricate at the Fabrication Laboratory of the Engineering Faculty of Engineering Universiti Pertahanan Nasional Malaysia. The size of the blast testing rig in plan is 700 mm face turned towards the blast. The height of the test frame is 1000 mm, including a 150 mm thick concrete base. The testing rig provides support along two side of the specimen. The setup on the tests panels were acting as a two-way slabs with a span of 600 mm. A wooden timber supporting the explosive was erected to hold the charge.

The vertical distance at the centre of the explosive and the panel were set to 300 mm based on the prediction provided using conventional weapon software known as ConWep [16].ConWeps perform air blast calculations, compute the breaching and fragment penetration, determine standoff distance, type of burst and also pressure resulted from the explosive used in the experiment.

Placticine displacement gauges, high speed camera and also high speed data acquisition instrumentation were used in the experiment. Plasticine with steel rod displacement gauges were specially fabricate at the testing site to measure the maximum deflection of the specimen. When the blast load displaces the concrete panel, the steel rod will pushed into the placticine. The maximum displacement was determined by measuring the difference between the slab and also the rod. High speed video of the explosion was recorded by using a speed video camera recording 3,000 frames per second (fps). The field blast test set up , measuring tools and also the sequence of explosion event is shown in Figures 6 and 7.



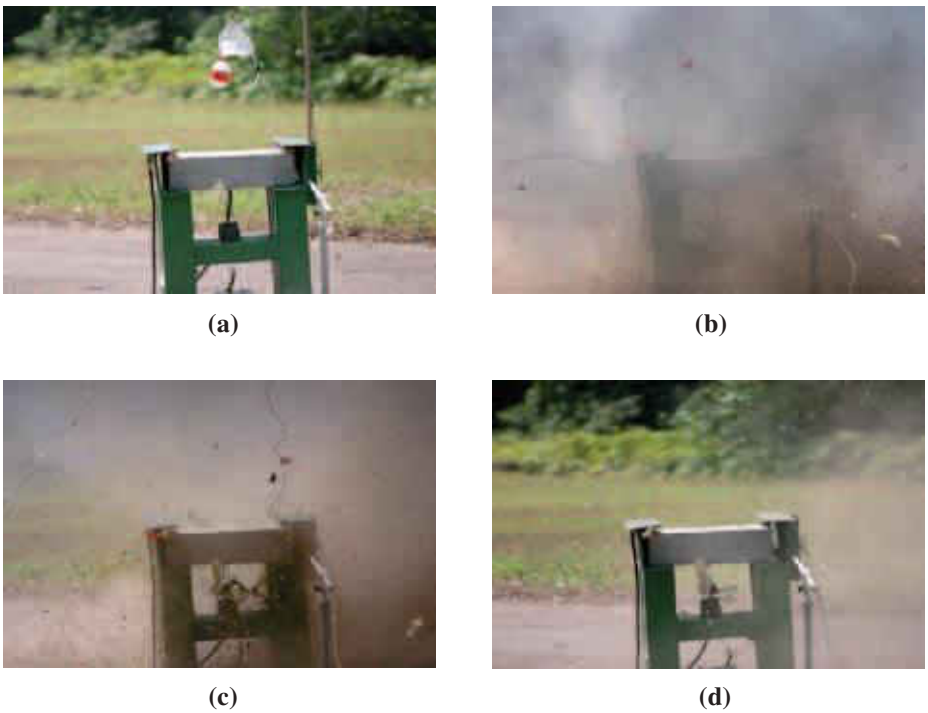
a) Blast testing rig

b) Blast test set up

c) Plasticine displacement gauge

d) High speed data acquisation system

Figure 6. Test set up and measuring tools at blast testing site.



(a) **(b)**

(c) **(d)**

Figure 7. Sequence of explosion events captured using high speed camera.

TEST RESULT AND DISCUSSIONS

At the end of each blast test, the failure patterns of each specimen were recorded. A set of photographs of the specimens is presented to illustrate the damage pattern of the specimens is shown in Figures 8 and 9.

(a) **(b)**

Figure 8. Damage pattern of the NRC panel.

The NRC panel act as a control specimen had failed in shear and flexural mode. It has cracks at the back and rear face. Besides, the NRC panel had a full depth inverted shear cracks greater than 4 mm at the support and the concrete at this area has crush. Concrete breaching was also observed at the back face. A number of smaller cracks were observed on both the front and rear side. No displacement measurement gauge was placed for this panel therefore the deflection history of this panel was not recorded. However from the visual inspection and measurement of crack width, severe damaged and breach failure was observed in the panel. Overall, the experiment has shown that the NRC panel could not absorb the energy resulted from the explosive detonation and failed in brittle condition. In addition, the low flexural strength of the NRC panel has also contributed to the failure of the test specimens.

(a) **(b)**

Figure 9. Damage pattern of the HSFRC panel.

There were only fine vertical crack widths of less than 1 mm was observed at the mid span of the HSFRC panel. No permanent deflection was observed. The maximum deflection was measured as 4 mm. From the visual inspection and also deflection measurement of the HSFRC panel, it was found that the blast effects only caused minor damages to the panel. The hybrid fibres in the HSFRC panel had improved the mechanical properties of the test specimen. The short fibres have bridged the micro cracks and leads to a higher tensile strength of the concrete. Besides the long fibres arrests further the propagating of macro cracks and improve the toughness and ductility of the composite. The synergy effect between the two types of fibres has improved of the blast resistance of the concrete panel. Detailed observations on both the NRC and HSFRC specimens were summarised in Table 3.

Table 3. Observation on the NRC and HSFRC panels after the blast tests.

Items	NRC Panel	HSFRC Panel
Volume of Fibre, V_f (%)	0.0	1.5
Main Observation	Shear failure, concrete breach	Minor cracks
Damage Classification	Severe	Light
Maximum Deflection, mm	-	4

CONCLUSION

The results from the air blast test shows that the concrete panel without steel fiber (NRC) failed in shear and breaching mode, whereas concrete panel with addition of hybrid steel fibers (HSFRC) survived the blast test. Therefore the experimental results confirm the substantial ability of HSFRC for resisting the blast load.

ACKNOWLEDGEMENT

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DEVELOPMENT OF ARSENIC DETECTION TEST KIT FOR MILITARY FIELD DRINKING WATER

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ABSTRACT

Water quality is crucial in military field drinking water as consumption of contaminated field drinking water by a toxic substance such as arsenic, could cause acute adverse health effects or performance-degrading effects. Detection of contaminants in field drinking water is important as it can help protect military personnel from drinking contaminated water. Extensive arsenic contamination of drinking water has been reported in many parts of the world. Arsenic is a toxic element and exposure to it can cause cancers. A simple and low cost test kit was developed to detect arsenic (III) in military field drinking water in this study. The test kit was developed based on colorimetric method. In this method, generation of arsine gas was obtained by reduction of arsenic trioxide using zinc powder and sulfamic acid, then arsine gas produced forms a grey to brown or dark brown spot on silver nitrate paper strip which form a standard colour chart. The intensity of colour developed on the paper strip is based on concentration of arsine gas produced from the reaction. The test kit can detect arsenic ranging from 0, 10, 100, 300 and 500 ppb. The concentration of arsenic in water sample can be quantified by visual comparison with arsenic standard colour chart. Validation of the arsenic test kit with inductively couple plasma-mass spectrometer was performed. The correlation coefficient of 0.999 was obtained for arsenic over a range from 0 to 500 ppb indicated that results obtained by arsenic test kit has a good agreement with results obtained by inductively coupled plasma-mass spectrometer (ICP-MS). Statistical analysis by t-test shows that there was no significant difference between both results. This indicated that the results obtained by arsenic test kit were comparable with laboratory instrument. The test kit is reliable as it has high sensitivity for detection of arsenic.

INTRODUCTION

Water quality is crucial in military field drinking water as the consumption of contaminated field drinking water by a toxic substance such as arsenic, could cause acute adverse health effects or performance-degrading effects. Detection of contaminants in field drinking water is important as it can help to protect military personnel from drinking contaminated field drinking water. Extensive arsenic contamination of drinking water has been reported in many parts of the world [1]. Arsenic is a toxic element and exposure to it can cause various types of cancers [2]. The provisional guideline value for arsenic

in drinking water by the World Health Organization (WHO) is 10 µg/L [3]. For a normal human adult, the lethal range of inorganic arsenic is estimated at a dose of 1–3 mg As/kg [4]. Arsenic can be found naturally in surface and ground waters [5], and as a result of human activity such as in industrial applications such as leather and wood treatments, and pesticides. The two most common species of arsenic found in the environment are the arsenic (III) and arsenic (V) oxyacids [2], where arsenic (III), is more toxic than arsenic (V) [1].

The preferred laboratory methods for the measurement of arsenic involve pretreatment, either with acidic extraction or acidic oxidation digestion of the sample. This will be followed by using any one of several accepted analytical methods, such as graphite furnace atomic absorption (GFAA), atomic fluorescence spectroscopy (AFS), hydride generation atomic absorption spectroscopy (HGAAS), inductively coupled plasma-atomic emission spectrometry (ICP-AES), and inductively coupled plasma-mass spectrometry (ICP-MS) to measure concentration of arsenic. However, these instruments are expensive to operate and maintain, bulky, and require well trained personnel to maintain and operate the instruments [2]. On the other hand, field measurement can give results on the site where the sample is taken [5]. The field method can also produce a large number of screening results in a short period of time, and are relatively inexpensive [2].

Most of the field test kits for arsenic available in the market are developed based on the Gutzeit method [6] and most of the colorimetric methods for measuring arsenic are also based on this method [7]. The Gutzeit method is a name of method given referring to its original inventor who begins with the generation of arsine gas by reduction of arsenic using zinc and hydrochloric acid. Silver nitrate crystals were used as the detector in this method, which was later replaced by a more practical paper strip impregnated with mercuric chloride, and subsequently with mercuric bromide. However, a weakness of this approach is the use of concentrated hydrochloric acid, often 6 N HCl, which is highly corrosive. Consequently it causes problems during the transportation of the acid, and it is also dangerous to be handled by technicians without formal chemistry training. Then this strong acid was replaced with solid sulfamic acid, NH2SO3H [6].

Apart from that, the detection of the contaminant in military field drinking water should be performed on site by a field test kit instead of transporting the water sample to a laboratory for analysis which is time consuming. Hence, development of field test kit is crucial to detect the contaminant in field drinking water. The objectives of this study are: (1) to develop a test kit to detect arsenic (III) in drinking water by visual colorimetric method, whereby concentrated hydrochloric acid will be replaced by solid sulfamic acid; (2) to validate the arsenic field test kit with instrumental analysis.

METHODOLOGY

Materials and Reagents

All reagents used in this study were analytical reagent grade. Analytical grade arsenic trioxide (Sigma Aldrich, USA) was used to prepare arsenic (III) stock solution. Other materials used were zinc powder, silver nitrate, sodium hydroxide and sulfamic acid were obtained from Merck (Germany). High purity water (18 MΩ) from Sratorius Arium 611 water purification system was used to prepare all solutions.

Preparation of Arsenic Stock Solution

Arsenic (III) stock solution containing 1.00 mg As (III)/mL was prepared by dissolving 1.320 g of arsenic trioxide (Sigma, Aldrich) (USA) in 10 mL high purity water (18 MΩ) containing 4.0 g sodium hydroxide and made up to 1000 mL with the high purity water.

Preparation of Arsenic Working Solutions

Arsenic (III) solution with concentration of 100 ppm was prepared from dilution of arsenic stock solution. Then various concentrations of arsenic working solutions ranging from 0, 10, 100, 300 and 500 ppb were prepared daily by a serial dilution of 100 ppm arsenic standard solution with high purity water. The concentration of each arsenic standard solution was verified twice to obtain the average value of the concentration by using ICP-MS (Perkin Elmer) (Model: ELAN 6000).

Preparation of Silver Nitrate Paper Strip

A paper strip of 1.5 cm x 6.5 cm was prepared from Whatman filter paper. Then, a drop of 5% (w/w) silver nitrate was added to the paper strip. The paper strip was left to dry for an hour prior to use.

Preparation of Arsenic Standard Colour Chart

A reaction bottle was filled with 50 mL arsenic standard solution followed by addition of 2.0 g of sulfamic acid (Merck). The bottle was swirled and then 1.0 g zinc powder (Merck) was added. Then the bottle was closed and swirled again to homogenize the mixture. A silver nitrate paper strip was then inserted into a groove through the bottle cap to detect arsine gas formed. The development of colour on paper strip was observed in the period of 30 minutes where the intensity of colour developed on the paper strip is based on concentration of arsine gas produced from the reaction.

Validation of Arsenic Test Kit by Laboratory Instrument and Data Analysis

Another series of arsenic solutions ranging from 0 to 500 ppb was prepared and tested using the arsenic test kit and the results was validated by ICP-MS (Perkin Elmer) (Model: ELAN 6000). The analysis was performed duplicate by ICP-MS to obtain average value of concentration. Correlation between results obtained using the arsenic test kit and the results obtained using ICP-MS was evaluated. The results obtained using the arsenic test kit and ICP-MS were also statistically analysed to determine the significance of difference between both results.

RESULTS AND DISCUSSION

Generation of Arsine Gas

Arsine gas is produced from the reaction between arsenic trioxide and zinc powder under acidic condition as follow:

(1)

$$As_2O_3 + Zn + H^+ \longrightarrow AsH_3 + Zn^{2+} + H_2O$$

arsenic trioxide → arsine

The arsine gas then reacts with silver nitrate on paper strip to form a colour compound, which is silver arsenide:

(2)

$$As_2H_3 + 3Ag^+ \longrightarrow Ag_3As + 3H^+$$

arsine silver ion silver arsenide

The arsine gas reacts with silver nitrate on paper strip to produce a grey to brown to dark brown spot on the paper strip which form a standard colour chart (Figure 1). The concentration of arsenic present in water sample can be quantified by visual comparison with arsenic standard colour chart. It was determined through the test that the test kit is capable to measure arsenic concentration in water as low as 10 ppb which follows the WHO guideline value for arsenic in drinking water.

The test kit is simple to be used even by unskilled staff as it only requires two chemicals to perform the test. The test kit is also easy to be handled and transported as all chemicals used are in solid form.

Figure 1: Arsenic standard colour chart in ppb.

Validation of Arsenic Test Kit with Laboratory Instrument and Data Analysis

In order to validate the data obtained through the usage of the developed arsenic test kit, the data was compared with results obtained by a laboratory instrument: ICP-MS. Figure 2 shows the correlation between arsenic concentrations obtained by arsenic test kit and ICP-MS. The correlation coefficient of 0.999 was obtained as shown in Figure 2 which suggests that the results obtained using arsenic test kit have a good agreement with results obtained using ICP-MS. Furthermore, statistical analysis by t-test strongly shows that there was no significant difference between both results (Table 1). This indicated that the results obtained by arsenic test kit were comparable with laboratory instrument. Hence, it was determined that the test kit is reliable as it has a high sensitivity for detection of arsenic in water.

Table 1: Comparison of results obtained by arsenic test kit with ICP-MS.

Concentration of Arsenic Detected by Arsine Test Kit (ppb)	Concentration of Arsenic Detected by ICP-MS (ppb)
0	0.00
10	9.88
100	97.25
300	294.50
500	509.50

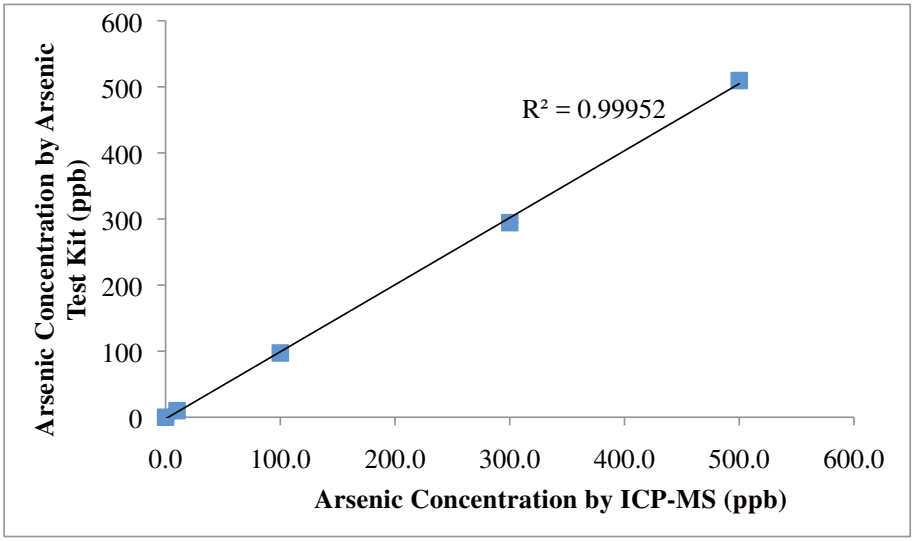

Figure 2: Comparison of arsenic analysis with arsenic test kit and laboratory analysis by ICP-MS.

Cost Estimation of Arsenic Test by Developed Arsenic Test Kit.

Apart from the validity and reliability, the developed test kit must be cost effective so it can be mass produced. As being projected in Figure 3, the test kit will only involved an estimated RM 4.30 per test and the cost is much lower compared to a laboratory analysis.

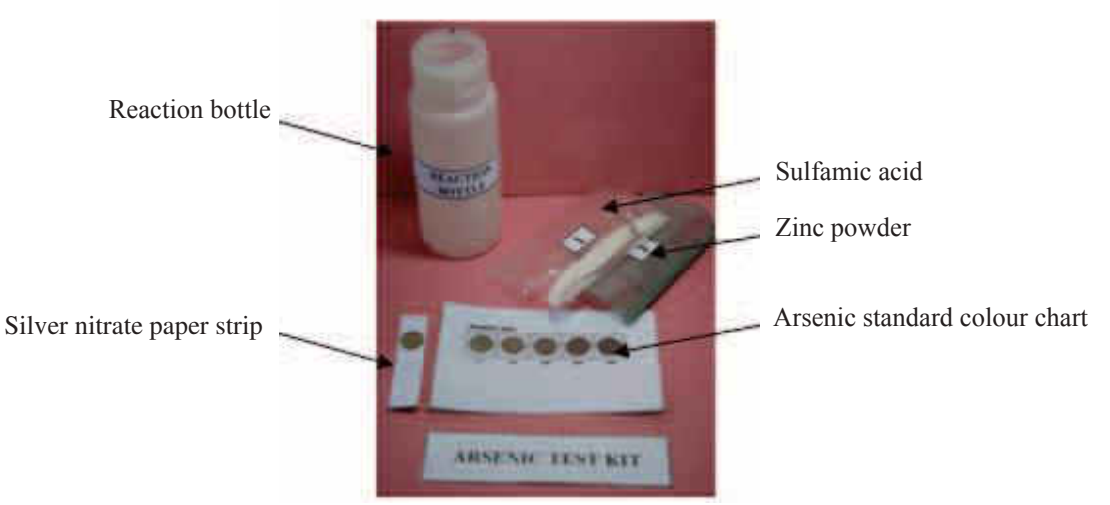

Figure 3: Arsenic test kit.

Table 2: Cost estimation of for arsenic in water samples by developed arsenic test kit.

Chemical/Apparatus Used	Cost/Test (RM)
Silver nitrate, $AgNO_3$	0.0023
Sulfamic acid	3.35
Zinc powder	0.39
Whatman filter paper	0.45
Reaction bottle	0.10
Total Cost/Test (RM)	**4.30**

CONCLUSION

This research has successfully developed a simple and low cost arsine test kit that can detect the presence of arsenic in water at a concentration as low as 10 ppb arsenic, which conforms the WHO guidelines. Validation of the arsenic test kit with ICP-MS was performed. The high correlation coefficient indicated that results obtained using arsenic test kit has a good agreement with results obtained using ICP-MS. Statistical analysis by

t-test shows that there was no significant difference between both results. These show that the results obtained using the arsenic test kits were comparable with the laboratory instrument. The test kit is reliable as it has high sensitivity for detection of arsenic. It will be useful for testing arsenic in water in a large number of samples as the test kit is simple and cost effective.

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AN EVALUATION OF INDOOR AIR QUALITY (IAQ) IN A MACHINERY ROOM OF A FLOATING VESSEL

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ABSTRACT

Deterioration of air quality in working environments has now become an increasing and widespread concern in both developed and developing countries. The potential risks and problems related to indoor air pollution has been recognised, and there is a need to measure and establish air quality standards for those working in any confined environments. For health and safety reasons, the indoor air quality (IAQ) in a machinery room, where a few people are working in it, was investigated. This study attempts to provide more information about the present IAQ status in the room. The air pollutants measured in this study includes carbon dioxide (CO_2), respirable suspended particulate matter (PM_{10}), carbon monoxide (CO), oxygen (O_2), ammonia (NH_3), volatile organic compounds (VOCs) and airborne bacteria. The results shows that the 5-h average concentrations of investigated CO, CO_2 and PM_{10} were higher than those recommended by the Department of Occupational, Safety and Health (DOSH), Malaysia. This was due to inefficient diesel engine burning process, system leakage and inadequate ventilation. The indoor air pollution caused by PM_{10} and CO was more serious and kept increasing as the operation time of the engines continued. The temperature and relative humidity in the room were also influenced by the heat from the combustion sources. The air in the room had average concentration of airborne bacteria of much less than 300 cpu/ml, and the impact from VOCs, NH3 and O_2 was not so critical.

INTRODUCTION

Indoor air quality has become an important occupational health and safety concern in the workplace. It is widely accepted that the indoor environment is important for public health and that a high level of protection against adverse health effects due to inadequate quality of the indoor environment should be assured. This is incorporated in the human rights to a healthy indoor environment as formulated in the WHO Constitution [1]. The human rights to a healthy indoor environment includes the right to breathe clean air, the right to thermal comfort, and the right to visual health and comfort [2]. Many studies have already shown that people can be exposed to much higher pollutant concentrations in confined spaces as compared to ambient atmospheres [3-6]. In Malaysia, indoor air quality (IAQ) has been recognised by the Department of Occupational Safety and Health

(DOSH) as a critical issue [7]. In order to ensure that all workers are protected from indoor air pollutants, the department has set forth a code of practice entitled "Code of Practice on Indoor Quality" [8].

The quality of the air is the result of a complex interaction of many factors that involve the chemistry and motions of the atmosphere, as well as the emissions of a variety of pollutants from sources that are both natural and anthropogenic. Air pollution occurs because of anthropogenic activities such as fossil fuel combustion, i.e., natural gas, coal and oil to power industrial processes and motor vehicles. Combustion puts harmful chemical constituents into the atmosphere, such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxides (SO_x), and small solid particles and liquid droplets [9-12]. Large numbers of peoples are exposed on a daily basis to harmful emissions and other health risks from unhealthy air, which typically takes place in low efficiency, or inadequate ventilation [13, 14]. The majority of individuals exposed to enhanced concentrations of pollutants are workers or individuals who are normally responsible for operating and maintaining machineries during their routine jobs.

They spend the majority of their working time indoors and, therefore, must be aware of the harmful effects of indoor air pollution. When indoor ventilation is limited, pollution can accumulate inside, sometimes reaching higher concentrations than what is found outside. During the past several decades, indoor air pollution has become a public health concern. Hundreds of outbreaks of illness among occupants of new or recently remodelled offices, schools, and other public access buildings have been reported [15-19]. The indoor air quality of any confined space is therefore directly influenced by internal activities carried out inside, such as smoking, cooking, generating electricity, biological & chemical pollutants, and so on [20-24]. The air pollutants emitted by these types of activities are not easily dispersed in highly confined areas and can easily accumulate to levels that can pose adverse health effects to people living or working inside [25].

Another important aspect of air quality is the presence of fine particles, or "particulate matter" (PM). Fine particles can be either directly emitted ("primary") pollutants or they can be formed within the atmosphere. For example, particles that are directly emitted into the atmosphere include soot particles from burning vegetation (which can be both a natural and a human-caused source), sea-salt spray, blowing dust, and volcanic ash. Other particles can be generated within the atmosphere, such as those arising from chemical conversion of the nitrogen oxides, volatile organic compounds or sulfur-containing gases emitted from fuel burning, volcanic eruptions or other sources. Many studies have found that the concentrations of suspended particulate matter were higher indoors than outdoors when there were sources of indoor particulates in domestic homes [26-28]. One of the contributing factors affecting indoor concentrations of airborne bacteria is the hygienic quality of a residence. Jaffal et al. found that houses with low hygienic standards had higher bacteria counts [29]. The age of a residential building, the frequency of housekeeping and ventilation were predominant factors associated with the concentrations of airborne bacteria within a domestic home [30].

Volatile organic compounds (VOCs) are an important group of air pollutants to study because they play an important role in the chemistry of the troposphere and are among the greatest concerns to health [31-33]. Formaldehyde is the chief concern among the VOCs as it is very widely used. Its effects normally show up in the itching of the eyes, ears and throat, but it is more seriously implicated as a carcinogen [35, 36]. Furthermore, some of the VOCs – such as benzene and toluene – have been shown to be harmful to human health, ecosystems and the atmosphere [2, 37]. Large amounts of VOCs are emitted from mobile and stationary sources, mainly owing to processes of combustion, solvent and fuel evaporation, and tank leakage [38]. Motor vehicles can be the most important source of VOC, especially in areas with few industrial sources, since they can account for 35% of total VOC emissions [39].

However, limited data on specific environments is available on the general understanding about the present status of air quality standards in the workplace. Therefore, the objectives of this study are to identify air pollutants in a machinery room during engine operation and to determine the concentration of the contaminants in the air. This study is conducted not only to investigate the effects of indoor machinery operations on the concentration and composition of air pollutants, but also to provide useful information about the 'real' exposure levels for the staff working in the room.

MATERIALS & METHODS

A case study is chosen to investigate the effect of air pollution in confined areas. The premise studied is a single storey medium sized machinery room located in a suburban tropics environment. The floor plan of the room is presented in Fig. 1. The room was selected due to the presence of carbonaceous particulate matter, or black carbon sticks, on the room's wall as shown in Figure 2. The sampling instruments were placed on a bench, 1 m above the floor and approximately 2 m from the diesel engines. Extensive measurements were performed before starting the diesel engines in order to identify the possible indoor sources that might affect the initial mass and particle number concentrations in the room. No significant changes in indoor concentrations were recorded, when the door and windows of the room were kept closed.

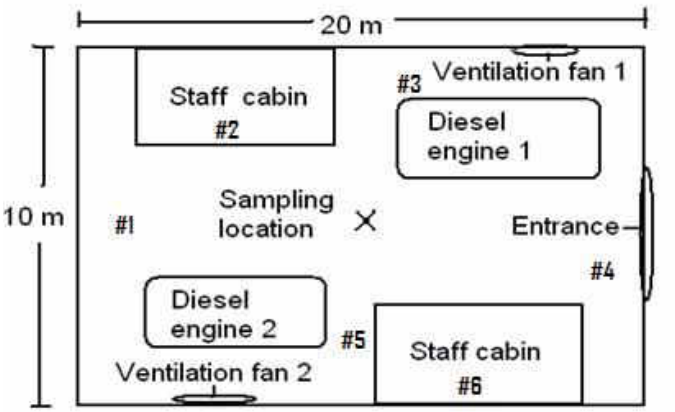

Figure 1. Floor plan showing the location of the measurement point (x = air, # airborne bacteria).

The ventilation system of the room was operated throughout the measurement period in order to maintain the indoor temperature and relative humidity constant throughout each specific experiment. A few persons responsible for the duty were present in the room during the experiments. After the end of each experiment, the room was kept completely empty until the mass and particle number concentrations reached the values observed before the initiation of the source. The diesel engines were in operation throughout measurement period, and no one was allowed to enter the room, with the exception of the personal assigned to inspect the engines' performances.

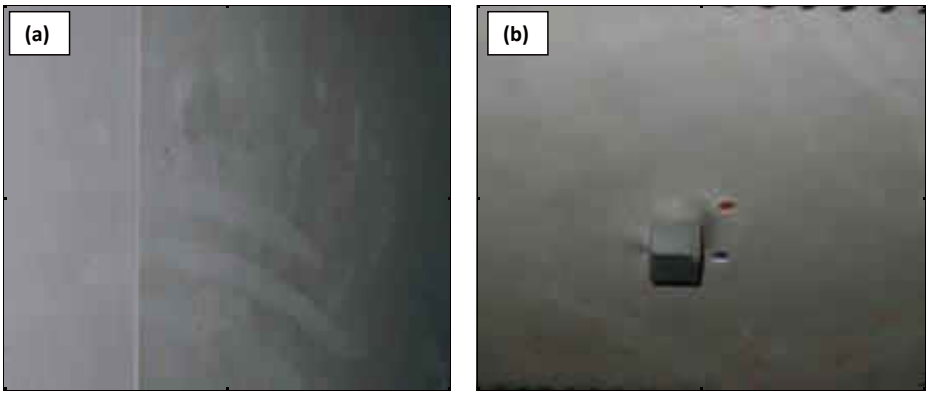

Figure 2. Contaminated wall inside the machinery room (a) 3 m from diesel engine (b) 5 m from diesel engine.

Air pollutants investigated in this study included: carbon dioxide (CO_2), VOCs, carbon monoxide (CO), ammonia (NH_3), oxygen (O_2), temperature and relative humidity (RH), total bacteria count (TBC), and respirable suspended particulate matter (PM_{10}, aerodynamic diameter less than 10 μm). A portable multiple gas monitor (model PGM50-5P, Ray System Inc.) was used to monitor the indoor CO, VOC, O_2, NH_3 and CO_2 concentrations. Before the 5-h sampling, the multiple gas monitor was calibrated with a standard gas at a known concentration. A Dust-Trak air monitor (model 8520, TSI Inc.) was used to measure PM10 concentrations in indoor air. The Dust monitor measured PM_{10} at 1 min intervals at a flow rate of 1.7 l/min. It has a resolution of ± 0.1% of the reading and a stability of ± 0.001 mg/m3 over 24 h. The built-in data logger has a storage capacity of more than 31,000 data points (storage for 21 days, if logging is done every minute), and the logging interval can be adjusted between 1 s and 1 h. The data was analysed using the TrakProTM V3.41 software.

Temperature and RH were continuously monitored and recorded using RHTemp2000 data loggers. The temperature measurement accuracy of the sensor is ± 0.5 °C for a range of −5 °C to + 55 °C with linearity better than 0.1 °C. The RH measurement accuracy for the sensor is ± 3% over the range of 0–95% and has temperature dependence between (10–60 °C) for a variation of RH less than 0.5%. The results of the measurements of the

selected air quality parameters were compared with the ceiling limits set by DOSH (Table 1). The concentration of airborne bacteria was measured at the six different locations (# mark) in the room. An agar plate was used to sample the airborne bacteria. Plate count agar was used as the nutrient media. The bacteria samples were taken from a volume of 500 ml of air for 5 min. The bacteria samples were incubated at 35 °C for 2 days in an oven. The colonies of bacteria were counted under a light microscope.

Table 1. Ceiling limits for the selected air quality parameters.

No.	Parameter	DOSH (8-TWA)
1.	CO_2	1,000 ppm
2.	CO	10 ppm
4.	VOC	3 ppm
3.	NH_3	25 ppm*
5.	Aerosol	0.15 mg/m^3
8.	O_2	19-21 %
9.	Temperature	20-26 ºC
10.	Relative humidity	40-60 %

* Based on *American Conference of Governmental Industrial Hygienist* (ACGIH, 1996).
8-TWA: *8-h time weighted average*

RESULTS AND DISCUSSION

Temperature and Humidity

Temperature and humidity cannot be overlooked because thermal comfort concerns underlie many of the complaints regarding "the status of air quality." Furthermore, temperature and humidity are among the key factors that affect indoor contaminant levels. Figure 3 showed the average temperature and RH obtained in the room for 6 h of measurement while the diesel engines were in operation. The diesel engines' combustion process caused significant variation on the temperature and RH during the measurement period. The generated heat caused an increase in temperature from 28 to 46 °C, with an average of 45 °C, while the emitted air pollutants caused the RH to decrease from 73.5 to 28.3 %, with an average of 36.9 %. The temperature in the room exceeded the ceiling limits in Table 1. The RH values were initially above the ceiling limit, but then,

during the measurement period, reduced to below the floor level. The temperature and RH were both unacceptable for human comfort, and did not meet the criteria set by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) [40]. Low RH or "dry air" has been associated with poor IAQ and sub-standard indoor environments since the 1980s [41]. Low RH can increase the risk of dry eye syndrome and cause the alteration of precorneal tear film [42].

Carbon Dioxide (CO_2)

Figure 4 illustrates the indoor levels of CO_2 obtained in the machinery room for approximately 5 h of measurement while the diesel engines were running. The CO_2 concentrations in the room ranged from 1,100 to 1,620 ppm, with an average of 1,300 ppm, exceeding the DOSH standard of 1,000 ppm, as shown in Table 1 [8]. Almost the entire monitored machinery room had higher indoor concentrations of CO_2 as compared with the value set by ASHRAE for indoor spaces [43]. During the period of air sampling, the room was ventilated by exhaust fans with closed windows. The results show that the elevated CO_2 levels observed in this room was related to insufficient ventilation and fresh air supply [44-48]. Therefore, the inefficient ventilation system enhanced the effect of the emissions from engine combustion sources in the room, resulting in higher concentrations of CO_2 being found in the room as compared to outside. The ASHRAE standard recommends a minimum of 15 cubic feet per minute (CFM) of outdoor air per person for offices (reception areas) and 20 CFM per person for general office space with a moderate amount of smoking. A minimum of 60 CFM per person is recommended for smoking lounges with local mechanical exhaust ventilation and no air recirculation [49, 50].

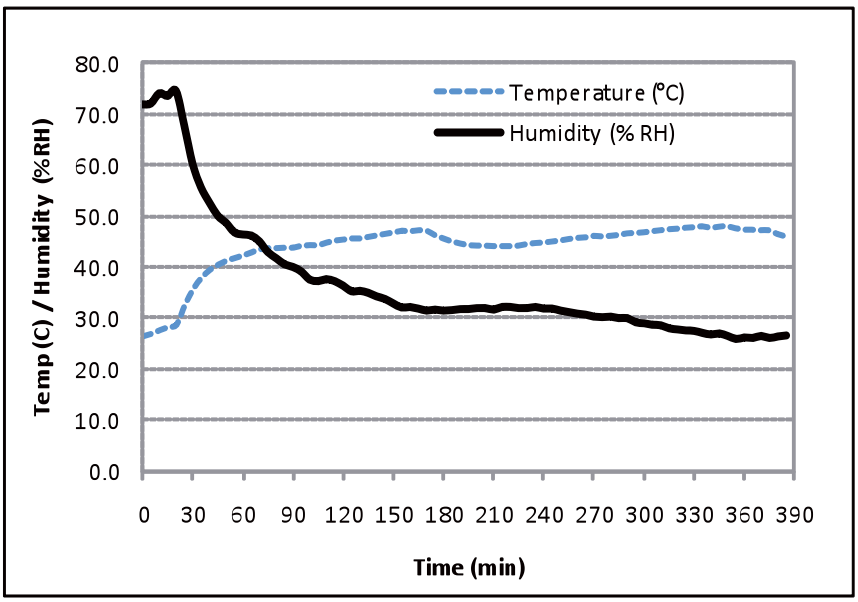

Figure 3: Temperature and relative humity (RH) in the machinery room.

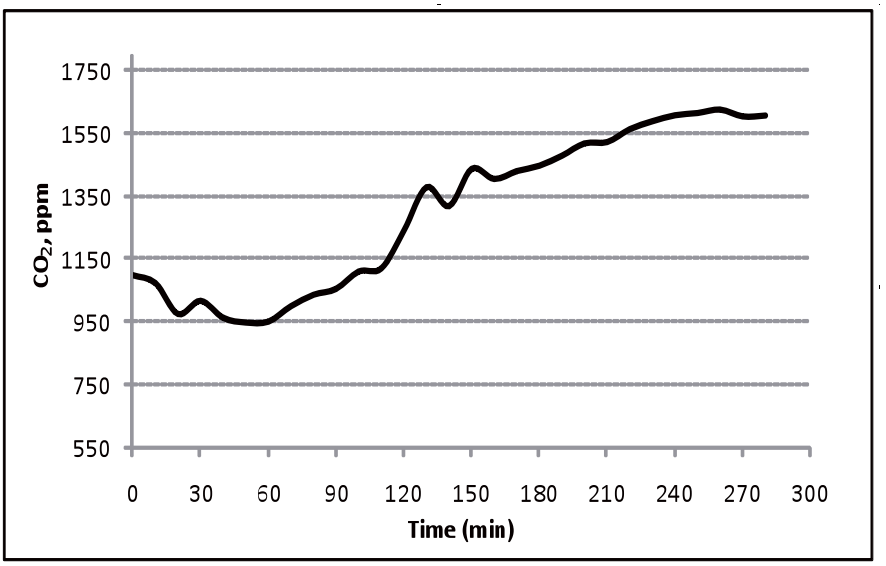

Figure 4. Indoor concentrations of carbon dioxide (CO_2) in the machinery room.

Respirable Suspended Particulate Matter (PM_{10})

It is observed in Figure 5 that the concentrations of PM_{10} recorded in the room were higher than the DOSH standard of 0.15 mg/m^3. The average indoor level of PM_{10} was 0.84 mg/m^3, exceeding the DOSH standard by 460%. The peak indoor concentration was measured to be as high as 1.6 mg/m^3. The increased concentrations of PM_{10} were probably associated with the leakage of the exhaust piping system from the diesel engines. The combustion of fossil fuel produced from the diesel engines polluted the room environment through the exhaust emissions of PM, and it is strongly believed that other pollutants, such as unburned hydrocarbons, oxides of nitrogen, carbon dioxides and oxides of sulphur, were also emitted. Diesel emissions contain hundreds of chemical compounds, partitioned in the gaseous and particulate phase. For these reasons, diesel exhaust was classified by the International Agency for Research on Cancer (IARC) as 'probably carcinogenic to humans' (group 2A) [54]. Moreover, fine particles (with mean aerodynamic diameter less than 2.5 μm) have a high probability of deposition deep in the respiratory tract, and are likely to initiate lung tumors and cause respiratory diseases [55, 56]. Other factors such as load, fuel type, engine type, engine maintenance, individual operator, emission control device, and lubricant oil composition can also influence the pollutant emissions from diesel engines [57-61].

Another factor causing the increase of PM_{10} concentration with time could be related to the room condition, whereby the windows of the room were kept close during the air sampling. The effect of outdoor air intake or flow into the room could have lead to an

increase in indoor concentrations of PM_{10} in room. The room was comparatively poorly ventilated as indicated by the higher indoor concentrations of CO_2 found in indoor environments [51]. Inadequate ventilation could increase the levels of suspended PM in enclosed environments [52, 53].

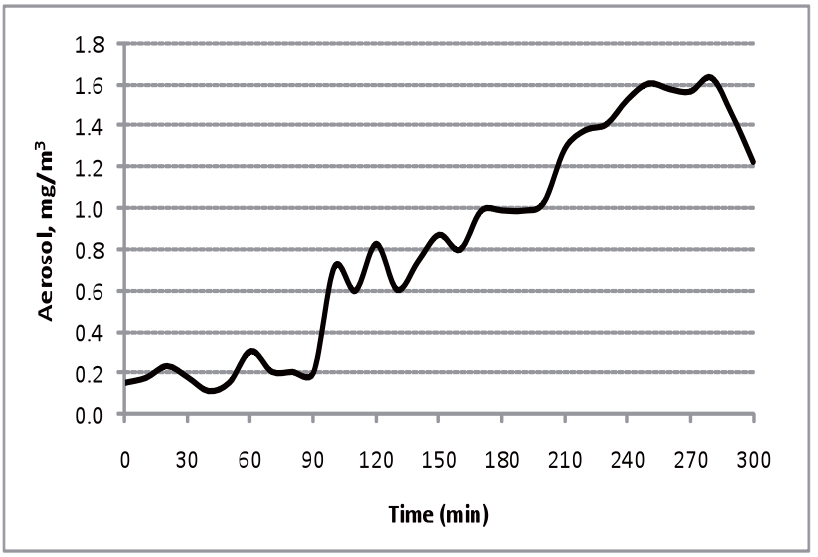

Figure 5. Indoor concentrations of respirable suspended particulate matters (PM_{10}) in the machinery room.

Particular focus is given to PM emissions, because of their significant impact on both health and the environment [62-64]. A number of epidemiologic studies reviewed by the California Air Resources Board (CARB) confirm an association between ambient PM and adverse health outcomes, including mortality rates, respiratory related hospital admissions, asthma attacks, and aggravation of chronic diseases [65]. Additionally, animal studies showed that prolonged exposure of rats to high concentrations of diesel PM (2–10 mgm^{-3}) initiated a dose-dependent progression of cellular changes that eventually led towards the development of benign and malicious lung tumours [66]. With respect to environmental effects, PM is characterised as an absorbing aerosol [67]. Absorbing aerosols heat the air, alter regional atmospheric stability and vertical motions, and affect the large-scale circulation and the hydrologic cycle with significant regional climate effects.

Airborne Bacteria

The indoor airborne bacteria exposure level is a good indicator of the cleanliness of air and is a useful parameter for IAQ assessments. The concentrations of airborne bacteria measured at the six locations in the room are given in Table 2. There was a large variation in indoor concentration of airborne bacteria between the six locations. The average levels of total bacteria counts recorded in locations 2 and 6 were greater than the rest of the locations, being double the mean concentration measured for the whole room. The results shows that indoor concentrations of airborne bacteria ranged from 1 to 135 cpu/ml. The low colony of airborne bacteria obtained in the room, which did not exceed the American Conference of Government Industrial Hygienists (ACGIH) and World Health Organization (WHO) standards [68, 69], was due to the small number of occupants working in it and adequate household cleaning. This is a good indicator of excellent hygienic aspects of the room and its occupants.

Table 2. Bacteria counts at six different locations in the machinery room.

Locations	Total Bacteria (cpu/ml) at 500 ml of air for 5 min
1	28
2	135
3	44
4	1
5	50
6	120
Average	***63***

Carbon Monoxide (CO)

CO is recognized as one of the most important pollutants that need to be regularly monitored due to its toxicity and implications for human health. CO is a colourless, odourless, tasteless, and toxic gas produced primarily during the incomplete combustion of carbonaceous fuels and substances. The CO levels in the room continuously increased with time during the period of the measurement and can be ascribed to carbon in fuels which was not burned completely. Figure 6 shows the variation of indoor concentrations of CO in the room, with the average concentration being 13 ppm, which was above safety limit set by DOSH (Table 1).

CO is also considered as an indoor pollutant and an occupational hazard in many workplaces where certain subgroups are at increased risk [70-72]. When inhaled, CO binds reversibly with blood hemoglobin to form carboxyhemoglobin, impairing the oxygen-transport of the blood, as well as oxygen release to body tissues, causing severe, and even, fatal asphyxiation. Yang et al. established a positive association between ambient CO concentration and daily hospital admissions for cardiovascular diseases for over a period of six years [73]. They suggested that the decrease in oxygen carrying capacity and the impediment to tissue oxygen unloading imposed by the shift in the oxygen dissociation curve combined to contribute to tissue hypoxia in patients whose compensatory cardiovascular responses may be already limited.

Additionally, Zappulla (2008) suggested that CO inhalation increased hemoglobin-O2 affinity and thus, may induce increases in endogenous CO_2, resulting in erythrocyte dysfunction, systemic inflammation and activation of the hormonal stress response [74]. Several studies on the strong association between CO concentration and adverse cardiac events in patients have also supported this possibility. Control of pollutants is the most effective strategy for maintaining clean indoor air. Ventilation, either natural or mechanical, is the second most effective approach to providing acceptable indoor air. Insufficient or malfunctioning ventilation inside, allows contaminated air to accumulate, and pollutant concentrations to increase. This accumulation of contaminant may cause damages to the employees' health, taking into consideration that exposure to CO covers all their working day. Processes involved in ventilation are the most important in determining the quality of indoor air. It is important to get adequate mixing of inlet air with room air, in order to obtain a uniform fresh air distribution [49, 75-77].

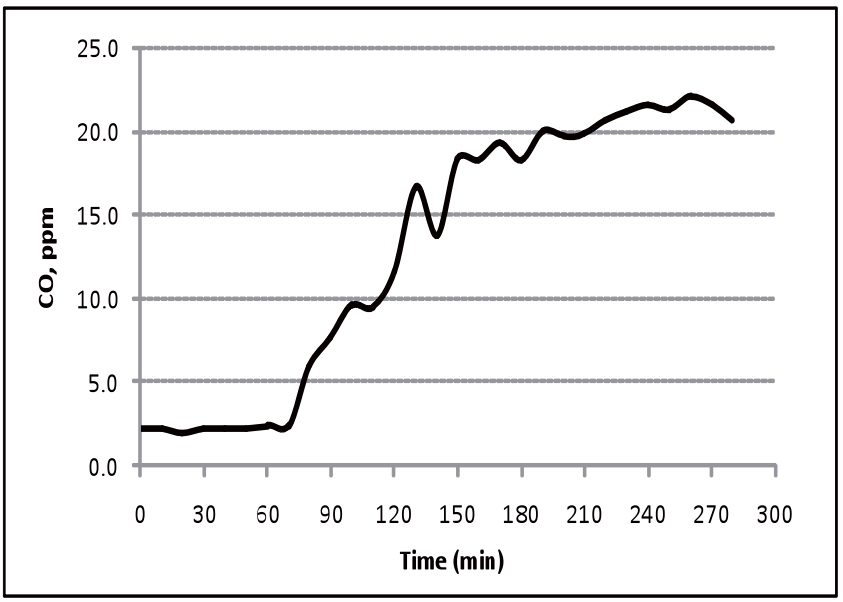

Figure 6. Indoor concentrations of CO in machinery room.

Volatile Organic Compounds (VOCs), Ammonia (NH3) and Oxygen (O2)

Figure 7 shows the 5-h levels of VOCs, NH3 and O2 recorded at the sampling location. In contrast to CO_2 and CO, the concentrations of VOC, NH3 and O_2 appeared unaffected by the time variation. The indoor levels of NH3, VOC and O_2 concentration did not exceed the DOSH and ACGIH standards as shown in Table 1 [8, 69]. However, low concentrations VOCs can still be associated with discomfort, irritation and disease [78]. The low level of VOC concentration found in the room may be from diesel exhaust or products from the diesel engine combustion process [79, 80].

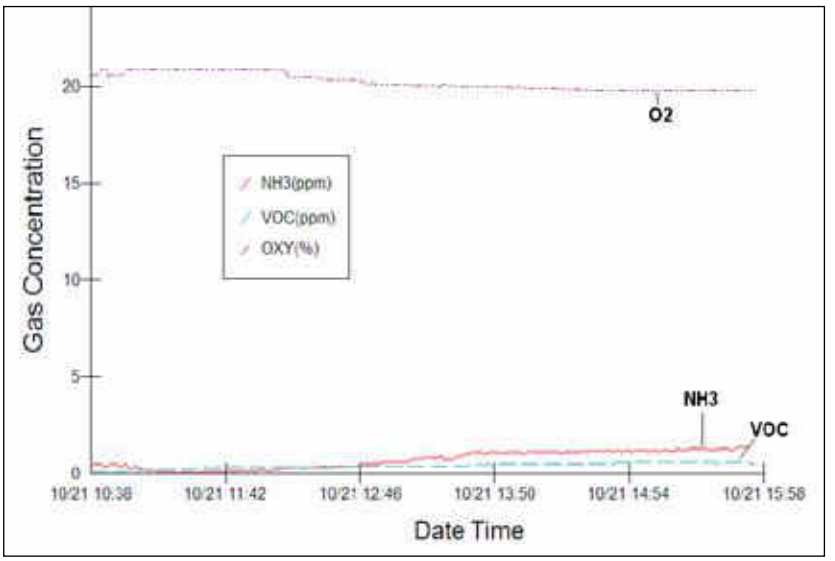

Figure 6. Indoor concentrations of CO in machinery room.

Several studies have correlated exposure to low concentrations of these VOCs with increased risks of cancer, and eye and airways irritations [81-83]. Symptoms such as headache, drowsiness, fatigue and confusion have been recorded in subjects exposed to 22 VOCs at 25 μg m^{-3} [84]. Furthermore, exposure to 1000 μg m^{-3} of formaldehyde causes coughing and eye irritation. In addition, many harmless VOCs can react with oxidants such as the ozone, producing highly reactive compounds that can be more harmful than their precursors, some of which are sensory irritants [85-87]. VOC removal from indoor air is difficult due to very low concentrations (μg m^{-3} range). While biological methods have shown a certain potential for this purpose, it still have a big challenge [88].

CONCLUSION

The indoor air in a selected machinery room has been characterised in order to evaluate its quality. The status of the indoor air showed that the concentration of VOCs, oxygen and ammonia for 5-h measurement fulfil the DOSH requirements. However, the average CO_2 level measured was comparatively higher than the DOSH standard of 1000 ppm. This was probably due to the combined effects of leakage in exhaust emission system and insufficient ventilation. Increasing the rate of ventilation could remove the accumulated CO_2; for example, the use of ceiling and exhaust fans could increase the exchange of indoor and outdoor air. The 5-h average PM^{10} level was measured to be 1.6 mg/m^3, which was 10 times more than the DOSH standard. In addition, the CO concentration in the room was recorded to be more than 20 ppm, and did not comply with most of health safety standards worldwide. In this case, the elevated level of CO associated with inadequate ventilation and exhaust emission from the diesel engines may adversely impact the employees' health, taking into consideration that exposure to CO thought out their working day. In addition, low indoor bacteria levels found in the room were probably due to low occupancy loading, good hygienic conditions of the occupant, and adequate cleaning. This case study is useful as an indicator of air quality status in the machinery room, which is very critical in assessing compliance with health and safety regulation in the workplace.

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