Malta's risk minimisation to earthquake, volcanic and tsunami damage

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Keywords

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Abstract

The paper defines Malta's disaster risks parameter. Various data are given on Malta's earthquake-related hazards. By referring to mean damage ratios and death rates, earthquake losses are equated as a percentage of the gross domestic product, and the number of casualties and homeless estimated. Being a small island, the need for foreign help in the aftermath of a large disaster is analysed. Because of the present large number of vacant premises available, the amount of material foreign help required is minimized, as households could be evacuated to other regions of the Island. The above risks could further be minimized if Malta adopts strategic preparedness and mitigation management. Retrofitting of the present building stock is necessary, as is actively encouraging the purchase of disaster insurance, together with preparation of planning tools and strategic choices.

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Introduction

Malta, situated in the Sicily Channel, forms part of the relatively stable northernmost platform of the African continent. The 1989 Newcastle earthquake, MM8 situated in New South Wales, Australia, occurred in a low frequency area. Australia is situated well within a continental shelf, not on the edge, where the most frequent activity is associated. It is known that infrequent but occasionally severe earthquakes can occur within continental plates (Melchers and Page, 1992).

This fact should not make Malta complacent to above damage. Malta cannot run the risk of being unprepared for the effects of a medium sized earthquake. With the economy concentrated in a small region, with a high dependency on real estate due to the high price of land, the situation is even worse than in other localities, as help from other parts of the country cannot remedy the situation. The current rebuilding cost under normal conditions of only the residential property market, works out at twice the GDP.

Defining disaster risks

There are a number of different measures, which can be used to express estimated risk. These include individual mortality rates, societal mortality rates, fatalities per million, loss of life expectancy and death per unit measure of activity (Royal Society, 1992).

The setting of tolerability thresholds requires a baseline against which comparisons may be made. Engineers rely on guidelines provided by the Health and Safety Executive (1989, p. vi). Maximum tolerable individual risk is deemed to be 1 in 1,000 for workers, for voluntary activities involving economic benefits or other profits a higher risk may be considered as acceptable. For somebody subjected to an involuntary or unnatural risk, from which he has no benefits at all, the target is substantially lower at 1 in 10,000 for the public, classified as "very low" risk. Then for those living close to a nuclear plant or near a transport route of dangerous materials, having no profit whatsoever the target is set at 1 in 100,000. These limits for individual risks are defined as just tolerable and a minimal level below which further action to reduce risks may not be required. Between these

Disaster Prevention and Management
Volume 12 · Number 1 · 2003 · 37-47

levels, it depends on how much safety society really needs and what it is prepared to pay for that level, if society insists (Vrouwenvelden *et al.*, 2001).

Table I gives the fatal accident rate (FAR) (Kletz), which is a comparison between the level of risk associated in participating in different activities. It is defined as the risk of death per 100 million hours of exposure to the activity. It is approximately the same as the probable number of fatalities from 1,000 people working lives, each taken at about 100,000 hours (Hambly and Hambly, 1994).

A disaster is defined as a sudden low probability event, which when it happens, has such severe consequences in terms of loss, human, material and financial, for a given community that it causes tensions in the social fabric of this community (Denis, 1995). A disaster is defined if one or more of the following consequences result from one event over a relatively short period of time:

- 10 or more fatalities;
- damage costs exceeds $1 million;
- 50 or more people evacuated.

Table I Relative risks of death in UK by activity – updated for earthquake effects to the Maltese Islands

	Activity	Risk of death $\times 10^{-8H}$: FAR	Classification of unlikely risks
1	Plague in London in 1665	15,000	High
2	Rock climbing, while on rock face	4,000	
3	Fireman in London air-raids 1940	1,000	
4	Travel by helicopter	500	
5	Travel by motorcycle and moped	300	
6	Police officer in Northern Ireland, average	70	
7	Workers in high-rise building industry	70	
8	"Tolerable" limit 1 in 1000/yr at work	50	Tolerable
9	Smoking	40	
10	Walking beside a road	20	
11	Offshore oil and gas extraction	20	
12	Travel by air	15	
13	Travel by car	15	
14	Coal mines	8	
15	Average man in 30s from accidents	8	
16	Average man in 30s from diseases	8	
17	Travel by train	5	
18	Constructions, average	5	
19	Metal manufacturing	4	
20	"Tolerable" limit 1 in 10,000/yr near major hazard	1	Very low
21	Travel by bus	1	
22	Accident at home, able-bodies	1	
23	Radon gas natural radiation "action level"	5	
24	"Tolerable" limit 1 in 100,000/year near nuclear plant (Frosdick, 1997)	0.1	Minimal
25	Radon gas natural radiation, UK average	0.1	
26	Terrorist bomb in London Street	0.1	
27	1 in 1,000,000/year annual risk of death from fire in a home (Strutt, 1993)	0.01	Negligible
28	Malta earthquake MM – VII	0.0077	
29	Building falling down	0.002	
30	1 in 100,000,000 annual risk of death from a contaminated land fill (Wood and Grant, 2000)	0.0001	Insignificant
31	Malta earthquake MM -VIII	0.00073	

Source: Hambly & Hambly (1994)

Disaster Prevention and Management
Volume 12 · Number 1 · 2003 · 37-47

In addition to adopting the above threshold for disasters, the Bradford disaster scale (BDS) was also formulated. When faced with numbers of lives lost or losses in terms of money in a disaster, the human mind has difficulty in visualizing the scale or magnitude in comparing one disaster with another. The scale, inasmuch as it is logarithmic, has much in common with other scales such as the Richter earthquake scale (Keller and Al-madhari, 1996).

As an example, the Los Angeles earthquake, resulting in over 70 fatalities and $30 billion damage, has BDS magnitudes of 1.86 and 4.48 respectively. The Armenia earthquake with 24,000 fatalities has a BDS of magnitude 4.38. A storm in France of $22.7 million damage has a BDS of magnitude 1.36.

The Health and Safety Executive (1989), find that it is not possible to place an upper limit on the tolerability of hazardous events causing multiple fatalities. This is because "we commonly take large numbers of individual accidental death far less seriously than we do a single event killing a similarly large number of people. Any large scale accident raises questions of responsibility for safety and public accountability in a way that accidents to individuals do not".

The social acceptance of risk to human life is often presented as a *F*-*n*-curve. Figure 1 indicates the border between "acceptable" and "unacceptable", where probabilities "*P*" are plotted on one axis and the number of casualties "*n*" on the other. N_d is the number of people killed in one year in one accident.

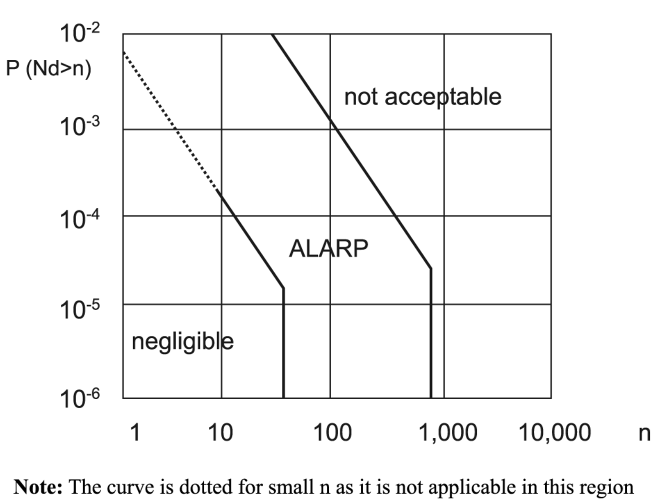
In Figure 1, two levels of acceptance are plotted. In the upper level the risk is considered as being not acceptable and below the lower level the risk is considered as being negligible. In the area in between, risk reducing measures should be considered and judged on an economical basis, considered as the "as low as reasonably practicable" principle (ALARP). For the individually based risk criterion, such as the car accident, limits here indicate a point far above the line given, hence it is only considered valid for $n > 10$, explaining the broken line in Figure 1.

The upper limits may be inspired by the ethical maximum acceptable risk of individual persons or by the risk aversion of society to large disasters. Figure 2 with examples from chosen target reliabilities included, is based on a mathematical expression in the case of a straight *F*-*n*-curve (log-log-scale) presented as

$$F(n) = P(N_d > n) < An^{-k}$$

For an individual risk, A assumed at 0.1, with k taken at 1, for a societal risk, A assumed at 0.01, with k taken at 2. However, the socially acceptable level should start on a national level, reflecting the national safety policy, with large countries having larger A values than smaller countries for reasons of consistency. High values of k express the social aversion to large disasters (Vrouwenvelden *et al.*, 2001).

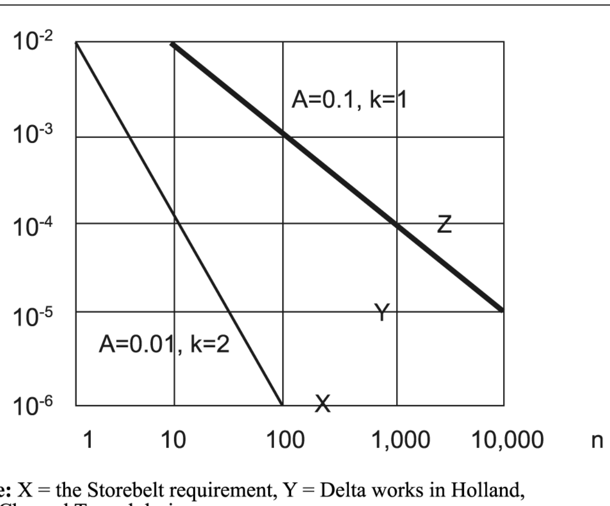
Figure 1 F-n-curves, where $F(n) = P(N_d > n$ in one year), and the ALARP region



Note: The curve is dotted for small n as it is not applicable in this region

Source: Vrouwenvelden *et al.* (2001)

Figure 2 The $F(n) = P(N_d > n) < A\ n^{-k}$ requirement for one year (see ISO 2394)



Note: X = the Storebelt requirement, Y = Delta works in Holland, Z = Channel Tunnel design

Source: Vrouwenvelden *et al.* (2001)

The above *F*-*n*-curve method does not take into account the economic consequences. In a market economy it is not the concern of the state or of the law to maximise the benefit of the single actors. Everybody is responsible for him/herself. Therefore the law does not care about damages which are suffered by the risk owner himself, but it wants to prevent damages caused by the risk owner to someone else. Therefore, only the externalised damages are relevant for the law. The internalised damages are in principle not a legal problem.

Risks are acceptable if the cost of further risk reduction measures would be higher than the monetarized risk reduced by these measures. The following figures in million Euros per life saved were applied in a "risk based regulation" project (Seiler and Beinz, 2001):

- Category 1: voluntary risk exposition, e.g. dangerous sports – no compensation/life saved.
- Category 2: direct individual benefit, e.g. car driving – 2.75 Euros/life saved.
- Category 3: individual benefit, e.g. working conditions – 6.70 Euros/life saved.
- Category 4: involuntary no direct benefit, e.g. vicinity to dangerous installation – 13.5 Euros/life saved.

The above values are to be treated with caution, as it is claimed to be difficult, unethical and even impossible to make a valuation of human lives. The value of life appears to be assessed differently according to geography and the social development. The integration of economic losses and human safety needs further attention with the quality of life index (QLI) approach seeming to be promising.

Technological disasters call the credibility of the expert and science into question. The fact is that scientists and engineers can only deal with probabilities, when decision makers expect certainties. There is often a discrepancy between objective (scientific) evaluation and subjective (public) perception of the level of risk. The complexity of society means that the number of decisions an individual has to make in the course of daily life precludes the carrying out of an objective evaluation in most cases. The conclusion is that even though a person is intellectually and academically able to evaluate a situation objectively, practicality dictates that in most cases subjective conclusions must be reached using short cuts. Subjective decisions are based on rule of thumb guidelines, which experience indicates are adequate to avoid danger (Kirkwood, 1994).

The process is thus summarized (Parker, 1990). A rule of thumb, is a shot in the dark tempered by experience, judgement and raw ingenuity – and it is as good as any other rule we live by. A rule of thumb works four out of five times. This has interesting implications, in that any scientific or objective assessment method must have an accuracy significantly in excess of 80 percent to be considered any better than a subjective educated guess.

Malta's earthquake-related hazards data

A seismic risk analysis has not yet been drawn up for the Maltese islands, but from the limited data available, the return periods are approximately estimated as per Table II.

The above subjective educated guess for above return periods, together with the death rates specified in Table IV, classifies an MMVII earthquake as negligible risk and an MMVIII earthquake as an insignificant risk on the FAR scale values shown in Table I.

Table III defines the building types classified for earthquake intensity-related effects. In Malta a few buildings are classified as type B. These would be restricted to old rural deteriorated dwellings exceeding 150 years in age or old deteriorated buildings in Valletta, which due to little maintenance, stability has been impaired due to ingress of water. Type A are limited to deteriorated old agricultural sheds found in fields. Most masonry buildings and most buildings in concrete frames would be classified as conforming to type C. The more rigid buildings, satisfying stiffness regularity and

Table II Return periods for earthquake intensity

MM-earthquake intensity	Return period (years)	% g
VI	333	2-5
VII	1,800	5-10
VIII	100,000	10-20

Disaster Prevention and Management
Volume 12 · Number 1 · 2003 · 37-47

Table III Classification of building according to anticipated earthquake intensity damage

Type	Description	Base shear design % of gravity
A	Building of fieldstones, rubble masonry, adobe and clay. Buildings with vulnerable walls because of decay, bad mortar, bad state of repair, thin cavity brick walls, etc.	0.5
B	Ordinary unreinforced brick buildings, buildings of concrete blocks, simple stone masonry and such buildings incorporating structural members of wood	0.7
C	Buildings with structural members of low-quality concrete and simple reinforcements with no allowance for earthquake forces, and wooden buildings, the strength of which has been noticeably affected by deterioration	0.9
D_1	Buildings with a frame (structural members) of reinforced concrete	2-3
D_2	Buildings with a frame (structural members) of reinforced concrete	3-4
D_3	Buildings with a frame (structural members) of reinforced concrete	6
D_4	Buildings with a frame (structural members) of reinforced concrete	12
D_5	Buildings with a frame (structural members) of reinforced concrete	20

Source: Swiss Re Zurich (1992)

symmetry in plan/elevation layout, are classified as D^1.

From Table IV, note that the mean damage ratio (MDR) for present type B buildings varies from 2 percent for MM5 up to 45 percent for MM8. The death rate at MM8 would approximate to 1 percent. If Malta's wall construction is modified to include an outer skin of masonry, with the inner skin constructed in hollow concrete blockwork, infilled with concrete and reinforced at corners to tie in with the overlying concrete floor slabs, this tied building would then be classified as a type C. The MDR would then decrease to 25 percent at MM8, whilst death rate also decreases to 0.4 percent. Table IV also shows the saving in re-building costs, by retrofitting of existing buildings, or improving existing methods of construction. It is noted that a premium would have to be paid for the repairs to be carried out – the premium increasing with the increase in MDR; as the supply of materials and labour would dwindle, foreign help would have to be obtained. At one point a decision would have to be taken whether to repair or whether to construct anew. To be noted that for a type B building, non-structural damage would amount to 50 percent of MDR, whilst increasing to 70 percent for a type C building. As the quality of building goes up, with the contribution of non-structural damage increasing, the death rate reduces, but a higher number of injuries occurs (Swiss Re, 1992).

From Table IV, the number of deaths and damage solely to residential premises has been calculated as shown in Table V, with the total direct losses tending towards double the amount below, and the cost of business

Table IV Mean damage ratio (MDR) and death rates for building types B and C

	Building type					
	B			C		
Earthquake intensity MM	MDR (%)	Death rate (%)	Mean damage costs as % of rebuilding costs	MDR (%)	Death rate (%)	Mean damage costs as % of rebuilding costs
5	2	–	2.5	–	–	–
6	4	–	6	1	–	1.25
7	20	0.03	40	10	–	15
8	45	1	135	25	0.4	62.5

Source: Camilleri (1999)

Disaster Prevention and Management
Volume 12 · Number 1 · 2003 · 37-47

Table V Quantification of losses for earthquake intensity

Earthquake intensity	Loss to residential premises only (Lm)	Total losses (% GDP)	No. of casualties (persons)
MMV	4,500,000	1	0
MMVI	35,000,000	6	0
MMVII	400,000,000	70	45
MMVIII	1,600,000,000	300	2,370

Note: GDP (Malta, 1999) Lm1,500,000,000 1Lm = 2.5Euro

interruption being at least as much as the direct losses (EEFIT, 1995).

The above fatalities and staggering financial losses classify the event as a disaster on the Bradford disaster scale (BDS), outlined previously. It should be noted that losses amounting to 2 percent of GDP, for large modern economies are crippling.

The economic consequences and loss of life for an earthquake may be aggregated into an overall risk component, which for Malta works out at:

$$\begin{aligned}&\text{Lm}4,500,000/333\text{yr}\\&+(\text{Lm}400,000,000\\&+45\text{ persons}*\text{Lm}1,750,000)/1,800\text{yr}\\&+(\text{Lm}1,600,000,000\\&+2,370\text{ persons}*\text{Lm}1,750,000)/100,000\text{yr}\\&=_{Lm}428,550_{pa.}\end{aligned}$$

The economic figure for a loss of life has been obtained by assuming Malta's GDP/capita at one third of that of the advanced countries in the EU.

This overall risk equates to Lm1/2 million pa, which should be sought as a basis on whether seismic retrofitting of buildings should be undertaken or not.

The author had subdivided the Maltese Islands into four regions for earthquake hazard (Camilleri, 1999), dependent on the geological formations. Table VII outlines various data for the various regions, including percentage of buildings built after 1960, percentage of substandard and unsound buildings, populations densities, percentage of population living below poverty line, together with characteristics of the large amount of vacant dwellings.

Of the recorded Mediterranean tsunami, 20 percent have been damaging (Swiss Re Zurich, 1992). Recorded tsunami height exceeding 20m have reportedly been reached in the Eastern Mediterranean and the Messina earthquake (M7.5, 1908) caused waves of 8.5m on the Sicilian and more than 10m on the Calabrian Coast, with the maximum height of 11.7m at S. Alessio washing up 200m inland. The Messina Straits and the eastern coastline of Sicily, especially around Catania, have an average of up to 10 tsunamis per 1,000 years. The last tsunami recorded in this region was 1954 and a high probability exists for another tsunami disaster. A 20m high tsunami wave on the Greek coastline in 1956 is a reminder that large and destructive tsunami can effect the Mediterranean tourist packed beaches (Dominey-Howes, 1998).

In the more exposed parts of the Mediterranean, for long coastlines, the return period for approximate run-up height of tsunami wave has been given at (Swiss Re Zurich, 1992): 100 years = 1.5m high; 500 years = 4.0m high; and 1,000 years = 7.0m high.

There are 13 active volcanoes in the Central Mediterranean (see Table VI) with a chain density of 68km. The general rate of activity is related to the chain density. This varies as 37km for Central America, 42km for Japan, and 88km in the northern island of New Zealand.

Mount Etna, situated 220km due north of Malta, is the largest active volcano in Europe that erupts fairly regularly. It does not seem to have exceeded VEI 3 over the last 3,500 years, but its two calderas and its rather viscous lava are a warning that this is not an absolute rule. Its extensive magna chamber amounts to approximately 550km^2 with a volume estimated at 1,600km^3 on an ellipsoid structure extending horizontally 22 by 31km and vertically 4km. Etnean eruptions tend to be less explosive and therefore produce less fine-grained fragmental debris and ash. Etna erupted a total of 37 times during the eighteenth and nineteenth centuries and has erupted six times so far during the twentieth century.

Other volcanic areas include Pantelleria and Limosa roughly in line with Malta. Further

Table VI The return periods in years for various volcanic explosive index (VEI) for the Central Mediterranean

VEI	2	3	4	5	6	7	8
R (yrs)	80	750	5,000	45,000	650,000	16.10^6	8.10^{10}

Source: Swiss Re Zurich (1992)

Disaster Prevention and Management
Volume 12 · Number 1 · 2003 · 37-47

north are Ustica, the Aeolian Islands 340km away together with Vesuvius 570km away, further up. In 1906, the height of column reached by steam ejected from Vesuvius reached 13km. During AD 79 the volume ejected of solid material from Vesuvius during an explosive eruption estimated at $4km^3$ (max recorded $1,000km^3$). Vesuvius has a span of 5.27 years between each eruption, with a standard deviation of 4.8 years. The last eruption dates back to 1944, which could be a sign that a relatively violent event is probable now. The span of time is longer than the 38 years of repose separating eruptions of 1906 and 1944, both VEI 3.

In 1930, the distance reached from a 30t projectile from Stromboli reached 3km. The greatest distance measured in 1883 was 80km for pumice stores from Krakatou. Stromboli tsunami in 1930 by a VEI 3 eruption produced a 2.2m tsunami generated by the shaking of the flanks of Stromboli, which extend far out under the sea. It has erupted on average every 3.25 years, but somewhat irregularly, as shown by the standard deviation of 5.35 years.

The damage caused by a volcanic eruption depends primarily on the type and magnitude of the eruption, on the distance between the risk and the source, and on the wind direction and meteorological conditions. The damage that may affect the Maltese Islands appears to be limited to those which, in turn could be the cause of a reduction in visibility, temperature, ash fall, build-up of corrosive and noxious gases, together with effects of pressure disturbance in the air and electrical phenomena.

The worst earthquake-related peril to have hit Malta is recorded as at 1693. In John Shower's Book (Ventura *et al.*, 1994), written five days after the earthquake, it is mentioned that the roof of the Church of Our Lady Tal-Pilar was thrown down, with part of that of St Lawrence. The church and College of the Jesuits also suffered very much, but the Cathedral and St Paul's Church in Rabat received the greatest damage and are so ruined that they can hardly be repaired. Most of the houses are extremely shattered and deserted by the inhabitants who now live in Grotto's and under tents in the fields. He also mentions that the Grand Master was hunting, presumably in the Buskett-Girgenti area and was in great danger by the falling of a mountain near him. Agius de Soldanis in his manuscript *Gozo Antico & Moderno*, recounts how the sea at Xlendi rolled out to about one mile and swept back a little later "con grande impeto and mormorio" in the earthquake of 1693.

Considering the above damage, in addition to rock falls, together with a tsunami, it appears that intensity of the 1693 earthquake works out at MMVII.

Proposed risk minimization procedures

The above data should not make Malta complacent to the above risks. Malta cannot run the risk of being unprepared for the effects of a medium sized earthquake. With the economy concentrated in a small region, with a high dependency on real estate due to the high price of land, the situation is even worse than in other localities, as help from other parts of the country cannot remedy the situation. The appropriate level of outside relief should be determined by assessing the community's remaining capacity to provide for its own population. Total collapse of the community system is to be considered rare and usually, the support and reinforcement required is for the community to get back on their feet, not for replacement or massive influx of misplaced, well intentioned help, with long term recovery hindered instead of promoted. It has been noted, that when casualties exceed two-thirds of 1 percent, systems were sufficiently damaged to require outside help. The percentage of those killed to total casualties totalled 11 percent. For a community with a casualty rate approaching 5 percent, it was found to have crossed the threshold of system destruction or collapse, with 33 percent of the total casualties killed. With the casualty rate down to 0.00072 percent, of which only 1 percent were killed, the community system remained largely intact (Granot, 1995). The above emphasises the need for proper risk disaster management of the Maltese Islands, for losses to be mitigated during the possible eventual strike of one of the above perils, at MMVII, the number of casualties was estimated at 0.125 percent of the population, and at 3 percent for an MMVIII. The infrequency of experiencing crisis events leads to a reduction in preparation and planning. Lack of experience

Disaster Prevention and Management
Volume 12 · Number 1 · 2003 · 37-47

is likely to produce lower non-routine decision-making and with less skills, less ability to adapt to the situation.

Earthquake damage, considering high population densities (Table VII), in areas of closely built, older residential dwellings would affect mostly the building infrastructure, with people made homeless. The high number of vacant dwellings at 23 percent (Central Office of Statistics, 1995) would help towards relocating the evacuated population, possibly to return to one's original home site, or else to stay with relatives. From Table V it appears that a massive evacuation would occur from the most stable geological region A. This being mostly from the Inner Harbour area, as it is the most densely populated and having a higher proportion of older and substandard buildings towards region C and Gozo, with the greatest number of vacant premises in a relatively good condition. This is possible as the present Maltese population is housed at 0.65 persons per room, well below the overcrowding statistic of four persons per room (Granot, 1995).

In Table VIII, households made homeless are classed as such when the MDR exceeds 50 percent. The present housing stock is assumed to consist of 40 percent classified as type B (Table II) and 50 percent as type C. For an earthquake of intensity MMVII, the households made homeless calculated at 14,500, whilst for intensity VIII, calculated at 30,000. The vacant dwellings are made up of 25 percent as type B and 75 percent as type C. An earthquake of intensity MMVII would cause 2,850 vacant dwellings to become uninhabitable and 7,000 for MMVIII. The number of stable vacant dwellings would then be reduced to 32,873 and 28,723 respectively. These numbers are sufficient to cater for the homeless at earthquakes of intensity MMVII, but slightly below for MMVIII.

During the tourist season the increased density, from an additional 5 percent of population in December increasing to 15 percent over the peak month of August, overpressures lifelines – utilities, communications, power supply, sanitation and health services, to their limit. Simple rules of good maintenance and providing redundant sources of lifelines would help avoid breaks and ruptures. A volcanic eruption due to the infiltration of ash dust would effect the agricultural sector together with the increase in cleaning industries, replacing previously more robust industries. For an assumed 25cm ashfall thickness, the damage to buildings was estimated at 10 percent (Held and Rossi, 1999). There is a probability that Malta International Airport would have to be closed for three to five days, further complicating the arrival of foreign help. The tourist industry would also be affected. Tsunami damage would cause losses to the infrastructural services and warehousing facilities located close to the low-lying coastal areas, defined as less than 3-5m above sea level or 7-10m for a more hazardous event. The vulnerability of Mediterranean coastal settlements to tsunami flooding has increased exponentially with time due to the intense coastal urban

Table VII Characteristics of the sub-divided regions of the Maltese Islands

Region (km^2)	Population density person/km*	Age structure of dwellings – % built after 1960	% substandard and inadequate occupied dwellings**	% of poor households earning < Lm2,500 p.a.***	% of vacant dwellings (% bad condition)
A (158.7)	2126	56	6.4	24	17.17 (8.11)
Inner Harbour* (16.9)	5258	28	11.3	36	19.55 (11.73)
Outer Harbour* (33.3)	3389	66	5.7	20	13.8 (6.5)
B (33.0)	476	56	6.1	24	11.6 (19.4)
C (54.6)	298	76	3.6	22	61 (1.6)
Gozo (68.7)	422	60	5.9	33	39.3 (5.86)

Source: Census of Population and Households (Malta) 1995
Notes: * the highest population density occurs in Senglea in the Inner Harbour region at 22,744 persons/km; ** Zammit and Miljanic Brinkwork (1997); *** gross under-declaration of income exists

Table VIII Damage probability matrix for buildings (DPM)

Damage class % of value		Mean damage ratio (%) (MDR) 1.5	3	5	10	25	37.5	50	60	70	85
0-1.5	(A)	83	73	60	36	9	2				
1.5-3	(B)	17	25	26	23	9	3				
3-6	(C)		2	10	18	11	5	2			
6-12.5	(D)			3	12	18	12	6	2	1	
12.5-25	(E)			1	8	24	24	15	7	3	
25-50	(F)				3	19	28	29	23	18	10
50-100	(G)				1	10	29	48	68	78	90

Source: Swiss Re Zurich (1992)

development (Dominey-Howes, 1998).
For the above material and business interruption, adopting pre-event strategic preparedness management may mitigate losses. Pre-event developments of capabilities to respond realistically to the impact of an event would reduce the cumulative impact of crisis and problems. In crisis and disaster response management, time is too limited for consensus and slow response times or time lags may have a number of causes. The costs in human life and suffering and in overall loss of structures and community resources will be diminished by the application of pre-event strategic preparedness and strategic management.

The above perils may cause destruction, mortality and casualties without warning and the emergency creates immediate medical and surgical needs. These needs vary: for an earthquake, casualties for an MMVII are estimated at 450 persons, whilst for an MMVIII the estimate is 11,000 persons. Owing to the entrapment under debris and collapsing buildings, the most prevalent injuries are fractures, cuts and entrapment, requiring surgeons and orthopaedists with splints and plaster of Paris, rather than antidiarrhoeals and antibiotics, which are more geared for tsunami flooding problems. In a volcanic eruption, skin diseases necessitate medical treatment. Access to the hospital is crucial, so the hospital must not only be tremor resistant, but also its access routes must be debris-free for patients to be delivered immediately. Roads with debris from landslides extending for more than 60cm on a lane should have delays accounted for. Improvement of the access systems, together with retrofitting of traffic junctions may be necessary. If doctors arrive at the disaster areas with police or firemen, the slightly injured can be dealt with immediately, reducing greatly the congestion of both the roads and health-care facilities. Here again, foreknowledge and preparedness to such major disasters is essential if response is to be more efficient and effective (Gunn, 1995).

The rescue of entrapped personnel depends on the type of buildings. The Maltese masonry building would tend to collapse into a mould of rubble, generating large quantities of dust which can asphyxiate the victims. On the other hand, such loose rubble can be removed quite easily with hand tools by survivors. This help initially comes from people in the same locality and inhabitants of the same building. Moreover, rescuers using hands, shovels, axe, ladder account for the largest number of rescued victims: 96.8 percent, as opposed to those rescued by heavier sophisticated means, 3.2 percent (Gunn, 1995). Removal of the dead would need to be undertaken promptly for health, psychological and sociological reasons. Critical decisions need to be taken: who is to be attended first and who therefore is last (Heath, 1995)? The above underlines the importance of public education and the crucial role played by the community in responding to its own disasters (Gunn, 1995).

A major impediment to planning and preparedness is the constant assault on the limited community resources. The present social problems garner more of the community's attention and resources. When a disaster *does* occur, it then becomes apparent whether planning has been effective. The recent earthquakes in Turkey and Greece are to be a reminder that disasters are not forgiving of poor building details. The losses incurred in North America and Japan for similar earthquake intensities were of a lower level.

Since the 1960s, the philosophy has changed from attempting to control the ravages of nature to mitigation activity, with governments playing a critical role. They have the authority to regulate land use and building design (Fischer III *et al.*, 1996). A building inventory, whether public or highly fragmented among small landlords, has been recognised as an important factor during emergency operations, when the question of where to put temporary shelters may arise. Data stored in parishes and historic archives should be used to obtain a probabilistic map of future disaster events. The percentage of houses owned privately, presently standing at around 70 percent for Malta, together with people's average income, which Table VII tells us which has the lowest in the most densely populated Inner Harbour area also having the worst building stock condition, are important data for assessing the possibility of retrofitting existing buildings before an event, (Menoni and Pergalani, 1996). This prior retrofitting also helps in rebuilding to a higher standard in the aftermath of a disaster. Higher educational standards help increase risk awareness. Furthermore, actively encouraging residents to purchase disaster insurance is to be encouraged; the smaller the amount of direct loss passed on to insurance companies, the more the government and affected people would have to bear more of these losses.

Another option is preparing planning tools and strategic choices for reconstruction before a disaster (Menoni and Pergalani, 1996). Anticipating many important choices will ease the return to normality and in a more efficient and organized way than would happen in the aftermath of a disaster, when planners are under pressure.

While risk can never be fully mitigated and response and recovery planning can never eliminate all problems during the post-impact period of any hazard, increased preparedness will save more lives, properties and protect the economy (Fischer III *et al.*, 1996). The estimation of the maximum possible loss from natural catastrophes can serve as a basis for catastrophe planning. It is recommended that Malta does not wait for a major peril before seriously enhancing strategic preparedness and mitigation management for the above perils.

References

Camilleri, D.H. (1999), "Vulnerability of buildings in Malta to earthquake, volcano and *tsunami* hazard", *The Structural Engineer*, Vol. 77 No. 22, November.

Central Office of Statistics (1995), *Census of Population & Housing – Malta*, Vol. 6, Dwellings, Malta.

Denis, H. (1995), "Scientists and disaster management", *Disaster Prevention and Management*, Vol. 4 No. 2, pp. 14-19.

Dominey-Howes, D.T.M. (1998), "Assessment of *tsunami* magnitude and implications for urban hazard planning in Greece", *Disaster Prevention and Management*, Vol. 7 No. 3, pp. 176-82.

EEFIT (1995), *The Hyogo-Ken Nanbu (Kobe) Earthquake of 17 January 1995 – A Field Report by EEFIT*, The Institution of Structural Engineers, London.

Fischer, H.W. III, Scharnberger, C.K. and Geiger, C.J. (1996), "Reducing seismic vulnerability in low to moderate risk areas", *Disaster Prevention and Management*, Vol. 5 No. 4, pp. 5-18.

Frosdick S. (1997), "The techniques of risk analysis are insufficient in themselves", *Disaster Prevention and Management*, Vol. 6 No. 3, pp. 165-77.

Granot, H. (1995), "Proposed scaling of the communal consequences of disaster", *Disaster Prevention and Management*, Vol. 4 No. 3, pp. 5-13.

Gunn, S.W.A. (1995), "Health effects of earthquakes", *Disaster Prevention and Management*, Vol. 4 No. 5, pp. 6-10.

Hambly, E.C. and Hambly, E.A. (1994), "Risk evaluation and realism", *Proc ICE Civil Engineering*, Vol. 102, May.

Health and Safety Executive (1989), *Quantified Risk Assessment: Its Input to Decision Making*, HMSO, London.

Heath, R. (1995), "The Kobe earthquake: some realities of strategic management of crises and disasters", *Disaster Prevention and Management*, Vol. 4 No. 5, pp. 11-24.

Held, E. and Rossi, M. (1999), *Vesuvuis: the Giant is still Sleeping – Scenario of the Plinian Type Eruption*, Swiss Re Italia S.p.a.

Keller, A.Z. and Al-madhari, A.F. (1996), "Risk management and disasters", *Disaster Prevention and Management*, Vol. 5 No. 5, pp. 19-22.

Kirkwood, A.S. (1994), "Why do we worry when scientists say there is no risk", *Disaster Prevention and Management*, Vol. 3 No. 2, pp. 15-22.

Melchers, R.E. and Page, A.W. (1992), "The Newcastle earthquake", *Proceedings of the Institution of Civil Engineers*, Vol. 94 No. 2, Thomas Telford Services, London.

Menoni, S. and Pergalani, F. (1996), "An attempt to link risk assessment with land use planning: a recent experience in Italy", *Disaster Prevention and Management*, Vol. 5 No. 1, pp. 6-21.

Parker, T. (1990), *Never Trust a Calm Dog and Other Rules of Thumb*, Harper Collins, New York, NY.

Royal Society (1992), "Risk: analysis, perception, and management", Report of a Royal Society Study Group, The Royal Society, London.

Disaster Prevention and Management
Volume 12 · Number 1 · 2003 · 37-47

Seiler, H. and Beinz, A.F. (2001), "Law and technical risks: risk based regulation: practical experience", *Safety, Risk and Reliability – Trends in Engineering*, International Malta Conference.

Strutt, J. (1993), "Risk assessment and management: the engineering approach", unpublished paper, Centre for Industrial Safety and Reliability, Cranfield University, Cranfield.

Swiss Re Zurich (1992), "Earthquake and volcanic eruptions: a handbook on risk assessment", in-house publication, Swiss Re, Zurich.

Ventura, F. *et al.* (1994), *Mdina and the Earthquake of 1693*, Heritage Books, Malta.

Vrouwenvelden, A., Holicy, B.M., Tanner, C.P. and Canisuius, E.G. (2001), "Risk assessment & risk communication in civil engineering", CIB Report 259.

Wood and Grant (2000), "Dealing with contamination: the real issues", *The Structural Engineer*, Vol. 78 No. 14.

Zammit, J. and Miljanic Brinkwork, M. (1997), "Housing situation 1997-2007", unpublished.