Residual Risk in Hazard Zones

Some shelters already exist in every hazard zone, and hence, the populations not covered by existing shelters are at risk, which can be termed as residual risk. Replacing L by Y in Eq. 6-5, the residual risk, ρ_{hz}, in a hazard zone can be expressed as

$$\rho_{hz} = Y.P(m_c) \qquad (6\text{-}6)$$

where Y is the existing unprotected population in a hazard zone. Unprotected population implies the population not covered by existing shelters.

Residual Risk in the Region

Aggregating residual risk, given by Eq. 6-6, for all hazard zones, residual risk in the region for the existing condition (before construction of shelter) can be obtained as given below:

$$R_B = \sum_{i=1}^{n} P_i Y_i \qquad (6\text{-}7)$$

where R_B is the residual risk in the region before allocation of shelter, P_i the probability of exceeding the flood depth of 1 m in the ith hazard zone, Y_i is the existing unprotected population in the ith hazard zone, and n the total number of zones in the region.

Similarly, the residual risk in the region after construction of shelters is given by

$$R_A = \sum_{i=1}^{n} P_i (Y_i - N_i K) \qquad (6\text{-}8)$$

where R_A is now the residual risk in the region after shelter construction, N_i is the number of shelters allocated to the ith hazard zone, and K, the shelter capacity.

Allocation of Shelters

Equity-Based Weight for the Hazard Zone

Equations 6-7 and 6-8 account for the vulnerability of lives to the flood hazard. From an equity point of view, consideration of socio-economic vulnerability is also important because disadvantaged sections of the society usually live in the coastal areas most vulnerable to storm surge floods. The shelter allocation policy based on minimizing the residual risk in the region, given by Eq. 6-8, would maximize the number of people covered by shelters. However, this approach may lead to inequitable distribution of shelters mainly because the unit cost of shelter increases towards the coast (see Table 6.2) and the poorest people usually live in the most vulnerable areas, which are close to the sea where the depth of storm surge flood is highest. A methodology is needed to incorporate an equity factor in the objective function.

The depth of flood is higher towards the coast. Therefore, the hazard zones with a higher hazard index, *HI*, should be given greater weight in the objective function. For equal hazard magnitude, an area with higher concentration of socially disadvantaged people would be more vulnerable. Therefore, hazard zones having a poor socio-economic condition should also be weighted more heavily in shelter allocation. This can be done using a socio-economic vulnerability index. Density of population, D, is used here as the vulnerability indicator as was by Mott Macdonald et al. (1993) and Sener et al. (1996). Population density is an indication of the socio-economic status of an area (Sener et al.1996).

An equity factor, based on hazard and socio-economic vulnerability indices, is formulated to give weight to the hazard zones in Eqs. 6-7 and 6-8. The formulation is similar to that used for a hazard index by Mott Macdonald et al. (1993). The equity factor whose maximum value will not exceed 1, is defined as given below.

$$E_i = \left(\frac{HI_i}{HI_m}\right)\left(\frac{D_i}{D_m}\right) \qquad (6\text{-}9)$$

where E_i is the equity factor for the ith hazard zone, HI_i the hazard index for the ith hazard zone, and the scale for the HI is given in Table 6.2, HI_m the maximum value of HI_i among the hazard zones, D_i the density of existing unprotected population in the ith hazard zone, and D_m the maximum value of D_i among the hazard zones.

Incorporation of the equity factor in Eq. 6-7, results

$$Z_B = \sum_{i=1}^{n} E_i P_i Y_i \qquad (6\text{-}10)$$

where Z_B is the aggregated value of the weighted residual risk for the existing condition (before allocation of shelter) in the region.

Optimization Model

As explained previously, the shelter allocation is subject to a budget constraint. The reduced residual risk in the region as a result of the allocation of N_i numbers of shelters to the hazard zones is given by Eq. 6-8. The challenge is to find optimum values of N_i for the hazard zones by taking account of equity concerns arising out of socio-economic vulnerability. Incorporating the equity factor in Eq. 6-8, the objective function can be stated as follows:

$$\textit{Minimize} \quad Z_A = \sum_{i=1}^{n} E_i P_i (Y_i - N_i K) \qquad (6\text{-}11a)$$

$$\textit{subject to} \quad \sum_{i=1}^{n} U_i N_i \le T \qquad (6\text{-}11b)$$

where Z_A is now the objective function, U_i is the unit cost of shelters in the ith hazard zone, and T the available budget for the region.

The probability P_i of exceeding the flood depth of 1 m in the ith hazard zone was interpolated using water level profiles for different return periods. The water level profiles were generated using the flood simulation model previously discussed. Details of the method of interpolating flood profiles are provided in Chowdhury and Rahman (1998). The shelter capacity K is 1,750 per shelter (BUET and BIDS 1993); the population data is provided in Chowdhury and Rahman (1998).

Experience shows that long lapses occur between the decision to allocate shelter and the completion of shelter construction as allocated. There will be autonomous change in the population during this period not considered here, which is an interesting additional element to study.

In Eq. 6-11a, $(Y_i - N_iK)$ gives the number of people that would remain unprotected in the ith hazard zone after allocation of shelter while Y_i is the existing unprotected population in the ith hazard zone. Solving Eqs. 6-11a and 6-11b is possible using a linear programming model because the equity factors E_i, which are based on the existing unprotected population in a hazard zone, have constant values. In another formulation of the problem, Chowdhury et al. (1998) used a factor based on the population that would remain unprotected after allocation of shelter to a hazard zone. The solution required a non-linear programming model.

Equity Constraint

The formulation in Eq. 6-11 provides a solution that allocates shelters in hazard zones with high equity factors and large unprotected populations. It may not be acceptable for some hazard zones to receive very few shelters; besides, shelters are also designed for multi-purpose use as schools and community centers. To address this concern, another equity consideration is incorporated in the model by imposing a constraint to ensure a minimum fraction of the total number of shelters required in each thana, thus ensuring a minimum community facility in each. It can be expressed as given below:

$$\frac{N_j}{G_j} \geq \alpha \qquad \text{for } j = 1 \text{ to } k \tag{6-12}$$

where G_j is the total number of shelters needed in the j-th thana, α the desired minimum fraction of the shelters required, and k the total number of thana in the region.

Results and Discussion

The problem defined by Eqs. 6-11 and 6-12 is an integer programming problem. The solution begins by considering the problem as a linear programming problem that considers fractions of shelters and rounds them to the nearest integer value. This algorithm yields solutions that are nearly optimal. The rounding may reduce the total number of allocated shelters and keep the total cost considerably below the budget. This problem is overcome by distributing the number of shelters that can be supported by the remaining funds according to the remaining unprotected populations in the hazard zones. This problem depends on the type of solver used and can be eliminated by using a suitable solver.

A summary of results is given in Figure 6.2. The budget is assumed to remain consistent with the government's funding pattern. As seen from the lowest curve in the figure, for an investment of 150 million Taka, the value of the objective function (Eq. 6-11a) decreases to 64 percent when the equity constraint is not imposed ($\alpha = 0$). Doubling the investment to 300 million Taka reduces the value to 52 percent. The incremental decrease in the objective function value is 12 percent, which is much lower than the proportional value.

The two upper most curves in Figure 6.2 are for the residual risk in the region, which are assessed using Eqs. 6-7 and 6-*8*. With investments of 150 and 300 million Taka, the corresponding residual risk are 87 and 73 percent of the present value, given by Eq. 6-7, when the equity constraint is not imposed ($\alpha = 0$). This indicates that the decrease in the residual risk in the region is nearly proportionate with the increase in the investment.

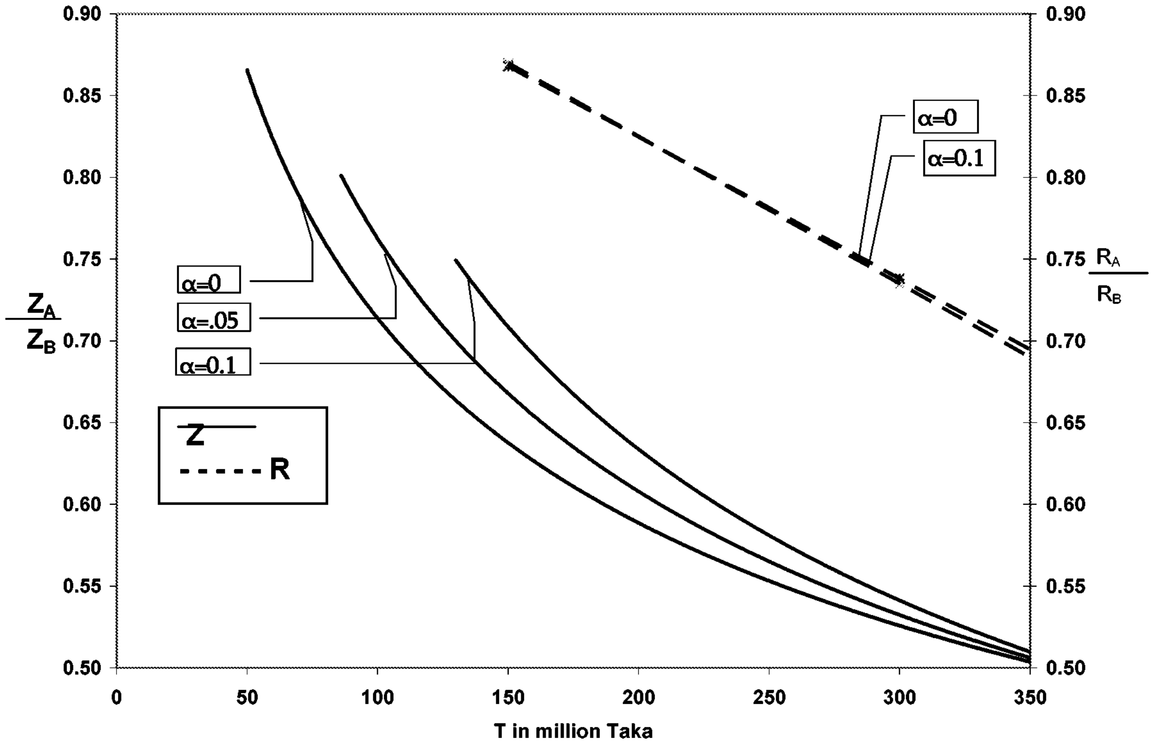

Fig. 6.2. Objective function value and residual risk in the region as fraction of their initial values for different budgets and equity constraints

Comparison between the curves for the objective function value for α = 0 and α = 0.05 or 0.10 in Figure 6.2 indicates a major change in the distribution of shelters is required to meet the equity constraint at a low investment level. For instance, the objective function value is 64 percent for an investment of 150 million Taka when equity constraint is not imposed (α = 0), while with the same investment, the value is 72 percent for α = 0.10. To reach same value of 64 percent with a retaining equity constraint at α = 0.10, a higher investment of nearly 200 million Taka is required. At an investment level of 350 million Taka and greater, there is no significant impact of the equity constraint. However, there is a budget level below which equity constraints cannot be met. The equity constraints of α = 0.05 and 0.10 cannot be met with investments lower than 60 and 120 million Taka.

The residual risk in the region are 87 and 74 percent of the present value for investments of 150 and 300 million Taka respectively for α = 0.10, and the curve for α = 0 is very close to the curve for α = 0.10 in Figure 2. This shows that, although the equity constraint brings significant change in the distribution of residual risks in the hazard zones, the resultant global residual risk in the region remains approximately the same.

Table 6.3. Disbursement of Fund to the Administrative Units Based on Allocation of Shelters to the Hazard Zones for Given Budgets for the Region

Thana	Hazard Zone no. i	Disbursement of fund for different budgets, T in million Taka, and equity constraint α			
		$T = 150$		$T = 300$	
		$\alpha = 0$	$\alpha = 0.1$	$\alpha = 0$	$\alpha = 0.1$
Patharghata	1, 2	3.44	20.91	10.41	34.67
Barguna	3, 4	141.85	55.31	203.77	165.93
Amtali	5, 6, 7	3.44	21.06	10.65	21.06
Kalapara	8, 9, 10	0	27.61	60.32	50.56
Galachipa	11, 12	0	24.08	14.42	27.85

Table 6.4. Allocation of Shelters to Hazard Zones in the Region for Given Budgets

Thana	Hazard zone no. i	Parameters of Eq. 11a			No. of shelters allotted for different budgets, T in million Taka, and equity constraint α			
		Y_i (thousand)	E_i	P_i	$T = 150$		$T = 300$	
					$\alpha = 0$	$\alpha = .1$	$\alpha = 0$	$\alpha = .1$
Patharghata	1	61.5	.31	.065	1	3	2	7
	2	26.1	.34	.08	0	3	1	3
Barguna	3	113.8	.50	.07	32	13	50	39
	4	23.5	.41	.10	9	3	9	9
Amtali	5	54.3	.24	.07	1	4	2	4
	6	18.1	.20	.10	0	1	0	1
	7	3.8	.08	.11	0	1	1	1
Kalapara	8	44.1	.24	.08	0	7	0	8
	9	35.3	.25	.10	0	1	0	1
	10	52.3	.33	.11	0	0	16	5
Galachipa	11	48.8	.26	.07	0	7	2	7
	12	60.2	.25	.11	0	0	2	1

Based on allocation of shelters to hazard zones, disbursement of funds to the thanas is shown in Table 6.3 to indicate the impact of the equity constraint. For a given budget $T = 150$ million Taka, most of the budget is received by Burguna Thana when equity constraint is not imposed ($\alpha = 0$). Patharghata and Amtali receive a nominal amount of funds, while Kalapara and Galachipa get none. When an equity constraint of $\alpha = 0.1$ is imposed, the change in the distribution of funds among the thanas is quite substantial, and the disparity is reduced considerably. At a higher investment level $T = 300$ million Taka, the change in the distribution of funds is not that dramatic.

Total number of shelters at budget $T = 150$ million Taka is 43 (which is 14 percent of the requirement) for both $\alpha = 0$ and 0.1; at $T = 300$ million Taka, the number of shelters are 85 and 86 for $\alpha = 0$ and 0.1, respectively. Shelter allocation to the hazard zones is shown in Table 6.4 to indicate the role of equity constraint. Hazard zone 3, which has the highest equity factor and the largest unprotected population, gets bulk of the shelters while other zones, except zone 10, get none or a small number of shelters when the equity constraint is not imposed. The disparity is reduced considerably when equity constraint is imposed. Allocation of shelters to the hazard zones in Kalapara and Galachipa Thanas is controlled by shelter construction cost. Hazard zone-based equity constraint would be better for these areas than thana-based constraint.

In summary, the incremental decrease in the objective function value is much lower compared to the proportional increase in the budget. The equity constraint has a significant controlling effect on the allocation of shelters among hazard zones at low budget levels, and the effect decreases with budget increases. Thus, the influence of equity consideration becomes less prominent with larger budgets. The residual risk in the region after shelter allocation decreases almost proportionately with the increase in the budget. The equity constraint has very little influence on the global residual risk. In other words the total number of people in the region that would be covered by the new shelters is not altered significantly by equity considerations. These results indicate the importance of equity consideration in shelter allocation when the available budget is low, which is the likely scenario in Bangladesh.

Studies are needed to develop improved representation of the equity factor, expressed by Eq. 6-9, based on socio-economic considerations. Better indicators than population density are needed to represent the socio-economic condition. The effectiveness of an indicator depends on how well it represents the socio-economic vulnerability of a hazard zone. Consideration should also be given to the percentages of children, women, elderly people, and seasonal migrant workers present in the unprotected population. A human development index, such as those used in development studies, can be utilized to represent equity concerns. The shelter allocation process should also take account of the higher risk for island populations and the changed risk for poldered areas.

Another similar issue is how to allocate the fund among the regions in the coastal area. On political grounds, the government may split the available budget among different regions proportional to the unprotected population in each. Distribution within the region can then follow the methodology discussed in this paper. Other methods of allocating the fund for shelter construction among the regions can also be investigated.

Possible sea level rise due to climate change and geologic subsidence has long-term implications for the management of storm surge hazard in the coastal areas of Bangladesh. The flood depth and the extent of flooded area are likely to increase. The constructed shelters may then become inadequate to protect against 100-year flooding. Shelters would be needed in additional areas because of the upland progression of the 1-m critical depth. Shelter planning should keep the provision so that adaptation to these changes in the storm surge risk is possible. This aspect needs adequate consideration in updating the NWMP.

Conclusion

Shelter planning should take socio-economic vulnerability into consideration to ensure social justice in the allocation of shelters among competing areas in the storm surge prone coastal region of Bangladesh. This paper illustrates how risk to life and equity criteria can be incorporated in the decision-making process for allocation of multipurpose shelters. Further study is needed to devise better socio-economic indicators to represent equity concerns.

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Chapter 7: Shelters—More Than a Safe Haven

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Introduction

Bangladesh is exposed to many natural and human-induced events including cyclones, flood, drought, tidal surge, earthquake, riverbank erosion, tsunami, and water-logging. It is not that more of these events occur in Bangladesh than in other countries; however, with a population density of approximately 1,000 persons per sq. km, Bangladesh is more vulnerable than most countries to such events. Since 1970 more than one million people have lost their lives with the cyclones of 1970 and 1991 claiming in excess of 900,000 lives. Financial costs (see Appendix 7.1) do not realistically reflect the total cost of these disasters when the broader impacts on the many millions that survived but lost everything are considered.

Assessing the Shelter Needs

In 1996 the government adopted a policy to construct 2,500 multipurpose shelters in high-risk areas to provide safe havens to both the humans and animals. This is in addition to the pucca buildings—schools, health centers, and killas schools—which can also be used as safe havens. To date 2,023 cyclone and 200 flood shelters have been constructed There is still a requirement to construct an additional 1,338 shelters to serve the 3.56 million people residing along the high-risk coasts (Fig. 7.1). In cyclone shelter planning, saving lives is the only criteria in contrast to flood control and drainage projects where protection against agricultural damage is the main consideration.

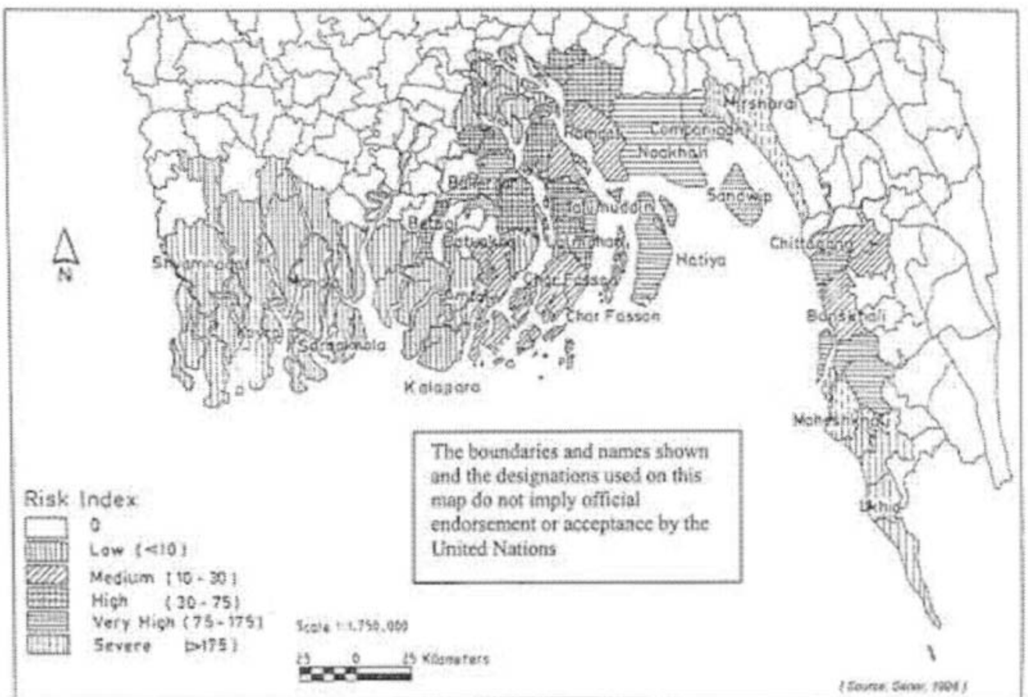

Fig. 7.1. Thana classified by risk index

Major Considerations in Shelter Construction

Building shelters is part of the government's broader strategy to protect people in high-risk areas. In general, the level of vulnerability to specific hazards, population at risk, availability of public and privately-owned buildings within the commanding area and availability of donor funds are the major considerations applied in shelter construction.

The assumptions are that shelters are built in low-risk areas and are highly accessible to the most vulnerable groups including women and children, the elderly, handicapped, and other groups that may be considered to be socially disadvantaged. In other words, they will provide a high level of safety during emergency periods.

In reality, location and accessibility are often determined by local politics. Shelters are typically designed and built to withstand specific rather than multiple hazards, with minimal consideration given to the social, gender, and cultural needs of vulnerable groups or to the broader multi-purpose use of shelters. Furthermore, without clear policy direction, these shelters are likely to become homeless entities that are neither properly maintained nor kept at a state of operational readiness. In the absence of such considerations, the poor and other disadvantaged groups are often forced to revert to alternate, less effective shelter options. Such shelters do not provide a sufficient level of protection for families or their livelihoods and as a consequence leave them extremely vulnerable to the risks associated with natural hazards.

The following are the key considerations for constructing a shelter:

- Shelters should be constructed in low-risk areas within 1.5 km of the community.
- Shelters should be built in well communicated and undisputed land to ensure accessibility by all.
- Shelters should construct with proper ventilation and heat control options.
- Shelters should have provisions for safe drinking water, lighting, and separate toilet facilities for men and women.
- Each shelter should have a workable plan for normal time use and shelter maintenance.

Use of Shelters

Seventy percent of shelters are currently used for education purposes, mostly as primary schools and madrasas in normal (nonemergency) times. About 1 percent are used for health centers, 3 percent for office uses, 2 percent for community purposes such as cultural/ceremonial events, and 5 percent for other use. The available statistics provide contradictory information about the use of shelters during emergency periods. Although there are different government statistics claiming the very high use of shelters during disasters, the recent CEGIS field study indicate that only 6 percent in 1991, 28 percent in 1997, 18 percent in 1998, and 5 percent in 2001 took shelter in safe havens during severe events.

Women, children, the elderly, and the disabled are the most vulnerable during major events such as flooding and cyclones. The disability study conducted by Handicap International (July 2005) illustrated that 60 percent of the country's 7.5 million disabled population are physically or visually impaired. The CEGIS survey found no provisions for this group to access shelter facilities during emergencies. Provisions of separate rooms and safe water and sanitation facilities for males and females are longstanding requirements.

Major Reasons People are Reluctant to Use Shelters

Among the primary reasons people are reluctant to use shelters are the following:

- Because of frequent false warnings, the accuracy and timing of the warning messages is not trusted.
- The warning messages are not in user friendly language.
- The distance to and from the shelters was too great. Most the shelters are located beyond the prescribed reachable area.
- Not all shelters are built on socially undisputed land and with a good communication system.
- Access by the community to existing shelters, *pucca* public buildings, and private houses is difficult.
- Shelters are not always gender friendly, lacking separate sanitation facilities for males and females. The recent CEGIS survey on 1,705 cyclone shelters and killas from 10 districts found that only 25 percent of the shelters have available water supply in the high-risk zone, 14 percent have storage facilities for vulnerable things, 26 percent have separate space for women, and only 36 percent have separate toilet facilities for women. There is almost no access for people with disabilities.
- Shelters being used for mosques and madrasas during normal times are not gender neutral; therefore, women believe they do not have sanctioned access and do not enter.
- Insufficient shelter space for livestock and for preserving foods are additional considerations for the poor, especially for the women responsible for the overall management of kitchen and tending poultry and livestock. According to the CEGIS study, only 21 percent of the shelters in high-risk zones have a place for cattle, 72 percent of their ground floor is open, 39 percent restricted, and 13 percent is too vulnerable to be used.
- Almost 13 percent of all the shelters are unusable due to lack of budget provisions for regular/routine maintenance (about 91 percent of cases) and also lack community participation (only 3 percent have community participation) in the maintenance program.

Shelters as a Safe Haven: Issues for Future Considerations

Shelters as a Viable Risk Reduction Strategy

Whether designed for large communities or for fewer households, shelters play an important multi-purpose role in rural areas where the poor and most disadvantaged people live. Shelters must, therefore, be built to provide a sustained benefit during normal day-to-day life as well as during emergencies.

Shelters should be designed as an integral element of the development, such that providing a safe haven is just one element of broader multipurpose function. Government should establish policy governing the design, location, and use of shelters and enforce rigid adherence. Awareness training, particularly for woman and the elderly should counter the stigma that currently prevents or deters women from using the shelters. Empowering women is critical yet often difficult, if not dangerous, in today's environment.

The risk environment is also changing due to the effects of climate change and unplanned human interventions. Shelters must consider the full risk environment and be designed and constructed to provide a safe haven to the people and their livelihoods in any threatening situation. This all-