

SYSTEM AND METHOD FOR ECONOMIC ANALYSIS OF BUILDING PROTECTION MEASURE

FIELD OF INVENTION

This invention relates to an economic analysis method for building protection
5 measure.

BACKGROUND OF INVENTION

Building owners in prominent cities are advised to enhance the security and
safety of their buildings along with the global campaign against terrorism. Various
security measures may be adopted. In order to make a sound decision in choosing
10 appropriate measures, building owners need to understand and assess the economic
benefits of each measure. The lack of a systematic approach to this analysis may
cause them to either spend more than necessary or suffer big losses should their
buildings be attacked. This disclosure outlines a systematic framework to analyze this
issue.

15 The present value of economic losses (L) due to a terrorism attack can be
represented mathematically as follows:

$$L=C*I(T)*v^T$$

Where C represents the value of loss caused by the attack, T represents the time
(in days) from present to when the attack occurs, I(T) is the indicator function that
20 equals one at time T and zero otherwise (i.e. if time = T, I(T) = 1, or if time $\neq$ T, I(T) =
0), V^T represents the discount factor for time T and is tabulated based on historical
data at hand. C, an economic value, is calculated from an assessment by field experts.

Since there is uncertainty associated with C, T, and v, the loss L itself is a random
variable. The random nature of the loss L makes it difficult for building owners to
25 assess its significance. Hence, they may underestimate the financial impact of an
attack and spend less on enhancing security of their buildings.

Protective measures suggested by some government agencies affect both C and
T. A protective measure can reduce the damage to the building and thus lower the
amount of loss C. At the same time, the existence of a protective measure can deter
30 terrorists from taking an action against the building, which lowers the probability of an
attack at time T. T represents the time (in days). For example, increasing stand-off
distance not only lowers the loss L due to the attack of a roadside car bomb, but also
reduces the probability of having such an attack. Therefore, to evaluate the economic

benefits of a protective measure, we need to analyze its total impact on the loss L . The best protective measure is the one that leads to the lowest value of the loss L .

A successful analysis of the loss L hinges on our ability to quantify the uncertainties associated with C , T , and vT . Construction engineers are the experts who can assess the distribution of the value loss C should an attack occur. They can also assess the extent to which a protective measure can alter the distribution of C . Terrorism security experts can provide an assessment on the probability that a particular building will be the target of an attack, depending on the social, economic, and environmental factors, etc. Financial experts are capable of providing inputs on the discount factor V^T based on current market conditions and also long-term economic outlook.

The distribution of loss L can be ascertained by combining the distributions of C , T , and v . Decisions can be made by examining the characteristics of the distribution of L . For example, the mean of the distribution gives an estimate of the expected loss due to an attack. The distribution can also be used to compute the risk that reflects the worst-case scenario of an attack.

Due to the complicity of the problem, computer software system is necessary to integrate the inputs from these experts and carry out required computation. The system should be robust and flexible to meet the demands from building owners of various types, be it large or small, domestic or foreign, military or civil, etc.

For a global and high-density city, the risk of terrorism is credible as the probability cannot be ruled out. Such consequences are potentially devastating in terms of not just property damage, human toll but also a loss in investors' confidence. For this reason, building owners have been urged to enhance security and the general public was urged to be mentally prepared and ready for a quick recovery should an incident take place. One of these terrorism attack risks is that of an improvised explosive device going off, whether borne by a vehicle, in a left package or through a suicide bomber.

In the countries where land is vast and less densely built-up, the planning guideline of a 30m stand-off distance for buildings away from the roadside, where a vehicle-borne improvised explosive device (VBIED) can be detonated, is possible. However, the same requirement is impractical or costly in high building density places, e.g. Singapore, where land is scarce and high building density is needed for economic reasons.

INVENTION DISCLOSURE

The objective of this invention is to provide an economic analysis method for building protection measure.

An economic analysis method for building protection measure is disclosed, comprising:

Using the first prediction model to determine the function between the first estimated cost and stand-off distance;

Using the second prediction model to determine the function between the second estimated cost and stand-off distance;

Determining the function between the combined estimated cost and stand-off distance based on at least the first estimated cost and the second estimated cost;

Based on a predetermined requirement, retrieving at least one of the pluralities of combined cost estimates for use in an economic decision.

The first prediction model is the function between the land space cost and stand-off distance. The second prediction model is the function between the protective system cost and stand-off distance

The first prediction model is: $Y_1 = K_1 D$, Where Y_1 is the land space cost, D (stand-off) is the stand-off distance; the value of K_1 is proportional to land costs.

The second prediction model is: $Y_2 = K_2 / D$, Where Y_2 is the protective system cost, D (stand-off) is the stand-off distance; the value of K_2 depends on factors including the level of protection system, as well as the construction and maintenance costs.

Combining the above functions produces a third curve which illustrates that the total cost is related to the stand-off distance. Based on a predetermined requirement (e.g. the limitation on stand off distance, the requirement of protection level and budget etc.), we can retrieve one of the pluralities of combined cost estimates for use in an economic decision.

The function between the above mentioned combined cost estimates and the stand-off distance is obtained by adding the first cost estimate function and the second cost estimate function together.

Retrieving one of the pluralities of combined cost estimates, as mentioned above, is to use the function between the combined cost estimates and stand-off distance, to locate the point where the combined cost estimates will be at the minimum and determine the corresponding stand-off distance. The minimum value of combined cost estimates and corresponding stand-off distance can be obtained, if K_1 and K_2 are

determined. If the stand-off distance is determined, the combined cost estimates is depending on the value of K_2 . The value of K_2 is basically depending on the level of protection system during certain period, as the protective system cost normally remains the same during this period. Therefore, the combined cost estimates is related to the protective system and the optimal stand-off distance and protective system can be determined using the above mentioned method, based on the requirement of protection level and budget.

The system developed for the economic analysis of protection measures can be used as an effective tool to find out the optimal stand-off distance and protection system to be used, and to determine land use and space planning during the research phase of development and implementation. Apart from being a tool for effective decision making, it also possesses the following benefits::

As a macro Planning tool for the relevant authorities to assist in decision making and cost planning.

As a cost planning tool for developers to establish the development budget.

As a Value engineering tool to assist planners in master-planning of the land usage and assist designers in design solution.

A tool for carrying out Life Cycle Costing analysis.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a hypothetical site plan of this invention

Figure 2 illustrates the relationship between the stand-off distance and the corresponding land cost it has incurred

Figure 3 illustrates the relationship between the protection reinforcement cost and the stand-off distance

Figure 4 illustrates the relationship between the combined cost of protection (land cost + reinforcement cost) and the stand-off distance

BEST MODE

Example 1. Case study on economic analysis for building protection measure in the development of a typical high-rise building in a high-density city

1. Economic analysis for building protection measure in the development of a typical high-rise building in a high-density city

For this study, a typical high-rise development in an urban context is assumed

(See Figure 1 for the hypothetical site plan). It is chosen as it is likely to be a more costly development and without much stand-off. As a result there is greater likelihood for it to need protective features.

Typically, enhanced security and protection against blasts is needed where there are critical assets to be protected, vulnerabilities in the building design or when the consequences of a terrorist attack are significant. Critical assets need not be just thought of as valuables, but could also be important data, key operational capability in a team of officers, VIPs, the venue for a large gathering of people and/or important international events, etc.

(1) Analysis for building protection technologies in the development of a typical high-rise building in a high-density city

Various protective features may be employed to enhance the security of a building. For a start, an owner would want to consider perimeter defense as the first line of protection. However in an urban context, it is unlikely that fences will be allowed. Hence landscaping incorporating barriers like planter boxes and anti-ram bollards with softer things like thorny plants are likely solutions.

Perimeter protection would include access control at entry control points. At these entry control points, systems like automatic retractable bollards and in some cases guard houses with greater protection (e.g. blast or ballistic protection) would have to be complemented by under-vehicle scanners and relative operational procedures. In fact guardhouses which need to be located further away from the complex proper will require more land, and incur an additional cost.

The intention of perimeter protection is to prevent vehicles which have the potential to carry significant amount of explosives from entering the building complex. This may often be supplemented by a trusted vendor system to control incoming goods vehicles which are hard to check except by either expensive scanners or decanting content which is impractical.

However, not all buildings can exclude vehicles within their complex. Quite often car parks are built in the basements or lower floors of a building, even though this is undesirable from a protection point of view. Even if car parks or inspections can exclude the risks of improvised explosive device (IED), it may not be feasible to completely eliminate smaller sized IEDs which can be more easily concealed, e.g. in the seats of vehicles, haversacks, etc, except by more intrusive and thorough inspections.

Hence, there is a need to protect buildings and occupants against the effects of blasts. The first concern would be to prevent the damage and loss of primary structural elements which actually magnifies the consequences of the initial blast and can cause progressive collapse of the building. Things like column jacketing, closer spacing of links in column reinforcement and other structural protection measures are needed.

The next protective measure may be directed at flying debris from walls, windows and glazing elements resulting from a blast. For windows and glazing, systems such as protective film with anchoring system, window fabric catcher or cable catcher systems are available in the market to give some blast protection. For walls, there is available technology to provide a polymer membrane or thin sheet metal system to help catch or hold the debris. Other openings in walls would also need protection, e.g. M&E louvered vents and doors as they would otherwise be the weak link in the chain of protection.

Other protective measures include a blast protected mail room to contain or mitigate against the blast effects of a parcel or letter bomb.

(2). Cost analysis of the protective system

Having gained an understanding of the protective technologies and the need for putting them in place, building owners are naturally interested in the cost of such measures. Whether it is for a new development or for an existing facility, a realistic provision in the budget is a key prerequisite for implementing protective measures. Without funding, protective measures can be left out in the project implementation process even though the needs are recognized.

The cost of protective works may be divided into design and construction cost (Cost D&C) and, long-term maintenance and upgrading cost (Cost M&U).

a) Design & Construction Cost (Cost D&C)

As a rule of thumb, protective technologies will increase the total building construction cost from several to more than ten percent. However, this is subjected to actual environmental conditions and hence may vary. The value and importance of the assets that need to be protected and their vulnerability determine the protection level required which in turn influence the cost of the protection measures.

The degree of integration of protective measures with the architectural and interior design can have a significant impact on the overall cost. While bunker-like walls and barriers may give cost-effective protection, these will not be acceptable in

public or commercial venues where glass is prevalent for the transparency and openness is required to create the ambience. Protective solutions that blend in with the architecture and interior design would be a necessity if the solutions are to be acceptable aesthetically; and these tend to be more expensive too.

5 Building services/systems such as mechanical ventilation, air conditioning, lighting, etc, may be affected or modified with the introduction of the protection measures. The cost involved in modification and design of the services/systems will need to be factored into the overall cost equation.

10 Protective design costs are naturally higher than conventional building design as it is a specialized field often involving highly sophisticated computation efforts and creativity. Additional design efforts are also required of the conventional building consultants (namely, architects, structural engineers, M&E engineers, etc) to interface the building elements and systems with the protective works.

15 In the costing for the provision of protective measures in a building project, one will need to consider, besides the construction cost of the protection works, the associated incremental cost of various building, renovation and M&E services. Additionally, the design costs of protection works and also the extra associated incremental design cost of the other consultants in the project should also be considered.

20 As an illustration, fixed K-rated anti-ram bollards would require at least a four digit sum per set to construct; whereas automatic retractable ones would cost a few thousand dollars per set. The total Implementation costs for bollards range from several thousands to tens of thousands of dollars.

25 Construction costs for column jacketing and window protective systems, on the other hand, are tabulated based on surface area. Total implementation costs approximate a few thousand dollars each. Similarly computed according to size, a blast protected mail room costs at least a six-digit sum to execute.

b) Long-term Maintenance and Upgrading Costs (Cost M&U)

30 It is generally accepted by the Industry that the Life Cycle of a building is assumed to be 60 years, or more. The building's major components generally have a product life cycle of 5 to 10 years, or more.

During the Life Cycle of a building, the building would be subjected to transformation due to the reasons of adapting to the demand and dynamics of the building occupiers, responding to economic changes and the trend of such changes.

Similarly, for the Protective Works installed in a building, one also needs to consider how these works can adapt as the building is being transformed during its Life Cycle. Generally the reasons for change in the Protective Works are as follows:

A) Change in the risk scenario

5 B) Wear and tear of product as it reaches the end of the product Life Cycle

C) Product been abused or vandalized

D) Inadequate maintenance

E) Building been renovated

10 What constitutes long-term maintenance and upgrading costs (Cost M&U) are questions often asked as one considers the life-cycle costing. For most of the protective systems, maintenance cost is no higher than that for normal building systems and materials. The life-span is also similar to normal building materials, e.g. normal steel is used for column jacketing and normal cables for cable catcher system for windows. Another example is protective film which has a similar life span of about
15 10 years, or more, similar to that for solar control film. There will be some cost for building maintenance personnel to maintain the systems in an informed way, so that the performance of the systems is not compromised by lack of knowledge. For example, during renovations, protective systems may be unknowingly altered, rendering them less effective.

20 The actual life-span of the protective systems will depend on exposure, usage and the maintenance regime. Of course, vandalism, extreme exposure and lack of maintenance can abbreviate or reduce the useful duration.

For instance, anti-ram bollards and column jacketing have life spans of more than 10 years and 10 to 20 years, or more, respectively. A recommended upgrade period
25 would rotate around each 5 year period. Upgrade costs for the above range from a four to six digit sum, or more.

For protective cost, we may also look into current land and future land prices.

(3). Economic analysis for building protection measure

30 Instead of making a subjective judgment on the optimal combination of protection based on stand-off distance and protective technologies, one can adopt a systematic informed approach by looking at the relationships of the cost of land and the cost of protective features vs. stand-off distances, before identifying the optimal combination.

Computer-aided economic analysis can be used in implementing a systematic approach to assist in making an economic decision. For this purpose, the method of

analysis includes using the first prediction model to determine the function between the first estimated cost and stand-off distance; Using the second prediction model to determine the function between the second estimated cost and stand-off distance; Ascertaining the function between the combined estimated cost and stand-off distance based on the first estimated cost and the second estimated cost; And extracting at least one combined estimated cost for economic decision based on predetermined requirements. The above method will be described in greater detail in the following paragraphs..

a) Ascertaining a plurality of first cost estimates as a function of stand-off distance using a first predictive model

For example, starting at a close range and increasing the stand-off distance, the cost of protection through stand-off alone increases with each incremental metre of land that is "wasted" (for the purpose of simplicity and clear description, the stand-off distance used for other purpose, such as landscaping, etc., is not considered). In this regard, cost increment is in direct proportion to stand-off distance. (See Figure 2) Figure 2 may be represented by the following equation:

$$Y1=K_1D \text{ (equation I) ;}$$

Where Y1 is the land space cost, D (stand-off) is the stand-off distance between an infrastructure, e.g. building, and a public access area, e.g., public road (See Figure 1). K_1 is a variable constant whose value is unique to each infrastructure or building. The value of K_1 would be proportional to land costs which may be varied by factors including, but not limited to, location, type of land use, built-up density in the area.

b) Ascertaining a plurality of second cost estimates as a function of stand-off distance using a second predictive model

In order to enhance the protection, protective features on the building for reinforcement purposes, e.g. structural protection like column jacketing or façade protective systems, are employed. With increasing stand-off distance, the corresponding cost for the protective measures will decrease as the effect of the blast on the building structure is weakened. Therefore, the resultant relationship between cost and stand-off distance is a decreasing one (See Figure 3). This may be represented by the following equation:

$$Y2=K_2/D \text{ (equation II) ;}$$

Where Y2 is the protective system cost, D (stand-off) is the stand-off distance between an infrastructure, e.g. building, and a public access area, e.g., public road

(See Figure 1). K_2 is a variable constant whose value is unique to each infrastructure or building. The value of K_2 would depend on factors including, but not limited to, the level of protection system, design and construction costs, and maintenance and upgrading costs, etc. Examples of these costs have already been described in the previous section, namely Cost analysis of the protective system.

c) Ascertaining a plurality of combined cost estimates as a function of stand-off distance based on at least the plurality of first cost estimates and the plurality of second cost estimates

Combining the above equations produces a third curve which corresponds to the relationship of combined cost of land and protective features vs. stand-off distance (See Figure 4).

This function can be used to help finding out the optimal stand-off distance and protection system to be used, based on a predetermined requirement, we can retrieve one of the pluralities of combined cost estimates. Normally the minimum value of combined cost estimates that satisfying the requirements is chosen and the corresponding stand-off distance is obtained, to assist in economic decision making, i.e. determining land use and space planning, protection level and measures. It should be noted that there is an optimum point, a range between points A to B, for example 4m to 12m respectively, where the combined cost is lowest. This is the point where the combined cost of land space/stand-off and the cost of protective systems will be at the minimum.

In arriving at an economic decision to decide on the amount of stand-off distance and protective systems required, a risk and vulnerability assessment together with a blast mitigation and protection study may further be performed to complement the above-described analysis.

2. The benefits in developing a system for economic analysis of protection measure

This case study provides an instructive outline of the protection measures and cost information. Building owner, developer, professionals and other related organization can take into account when enhancing protection measures during the planning, designing new buildings or renovating existing buildings. It is worth to be noted that the cost provided are illustrative as many costs should be based on each unique situation. In addition, the actual cost is, to a large extent, depending on when to implement the protective system due to the high inflation rate. However, the information provided can be used as a useful guide when considering protection

measures. In certain places, land prices have increased several times over the last few years. In the total development cost, land cost may constitute about 60% to 70% of the total development cost and the construction cost constitutes about 20% to 25% of the total development cost. In any development, effective land usage and space planning is very critical in ensuring the commercial viability of the development.

The system developed for the Economic Analysis of Protection Measures can be used as an effective tool for decision making in terms of land use and space planning during the development feasibility study phase. Apart from being a tool for effective decision making, it also possesses the following benefits:

As a macro Planning tool for the relevant authorities to assist in decision making and cost planning.

As a cost planning tool for developers to establish the development budget.

As a Value engineering tool to assist planners in master-planning of the land usage and assist designers in design solution.

A tool for carrying out Life Cycle Costing analysis

APPLICATION

The system developed for the economic analysis of protection measures can be used as an effective tool for decision making, in terms of determining the optimal stand-off distance, protective system employed, land use and space planning during the development feasibility study phase. Apart from being a tool for effective decision making, it also possesses the following benefits:

As a macro Planning tool for the relevant authorities to assist in decision making and cost planning.

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A tool for carrying out Life Cycle Costing analysis

Claims

What is claimed is:

1. A method for determining optimal stand-off distance and protective system for building protection that comprises the following steps:

ascertaining a plurality of first cost estimates as a function of stand-off distance using a first predictive model, wherein the first prediction model is a function between the land space cost and stand-off distance, wherein the first prediction model is: $Y_1 = K_1 D$, where Y_1 is the land space cost, D (stand-off) is the stand-off distance; the value of K_1 is proportional to land costs;

ascertaining a plurality of second cost estimates as a function of stand-off distance using a second predictive model, wherein the second prediction model is a function between the protective system cost and stand-off distance, wherein the second prediction model is: $Y_2 = K_2/D$, where Y_2 is the protective system cost, D (stand-off) is the stand-off distance; the value of K_2 depends on the level of protection system, and the construction and maintenance costs;

ascertaining a function between a combined cost estimates and the stand-off distance by adding the first prediction model and the second prediction model together; and

based on a predetermined requirement, retrieving at least one of the pluralities of combined cost estimates for use in a determination of optimal stand-off distance and protective system for building protection.