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Transfer Functions of Monetizing the Intangible Benefits of Flood Control Works

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A B S T R A C T

Flood disasters are ubiquitous and may occur anywhere as long as certain hydrological, hydrometeorological and topographical conditions are met. The impacts of floods may include social, economic and environmental aspects, and therefore the losses due to floods are usually varies with respect to the wide range of its tangibility and intangibility. One of the standards of analysis of a flood control project is economic viability, the elements for this analysis could be either tangible or intangible component of costs and benefits. While the tangible benefit components are usually effortless to quantify, the intangible ones are, in contrary, complicated and challenging. This study attempts to quantify the intangible benefits of the flood control works in monetary terms, as an effort to develop transfer functions to translate intangible benefits to the quantifiable ones. The study was undertaken by reviewing extensive numbers of sources of concepts and best practices all over the world.

Keywords: intangible benefits, tangible benefits, socio-economic viability, transfer functions.

ARTICLE HIGHLIGHTS

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1 Introduction

It is quite certain that, among natural disasters, flood may occur more frequent than any other disasters caused by natural phenomenon, for example, in comparison to earthquake or volcanic eruption. While the frequency of earthquake, which causes severe disastrous devastations, is in the range of 20-50 years, the floods may occur every year. The floods may have social, economic and environmental consequences to individual, communities and countries. The impacts may vary, for example, from priceless loss of life to just insignificant crop-harvest failures, from immediate effects to long-term impacts, from intangible to tangible aspects (Daniel et al., 2016). The immediate effect includes loss of life and property losses, the long-term impact, for instance, the development of leptospirosis due to the spread of rat's urine mixed with flood water particularly in densely populated urban slum areas, which will take months to progress with the symptoms. The magnitude of the severity and loss of the flood impacts may vary depending on the variables such as location i.e. urban v. rural; timing of floods and inundations; velocity of flood waters. The impacts associated with floods and possible methods to quantify the impacts as shown ted in the Table 1.

Table 1: Intangible and Tangible Flood Losses

Aspect of Losses	Types of Impacts	Possible Methods of Quantification
Intangible, Social aspect	Loss of life	Hedonic price method. Although this method may not be accurate, but still this method is the best method to approximate the priceless loss of life.
	Absence from works due to traffic disruptions	Market price stems from daily or hourly wage.
	School disruption that causes the absence of teaching and learning process	Market price originated from teacher's salary (from teaching side), plus part of future losses of young generation (from learning side). The later may be approximated by valuation method i.e. willingness to pay.
	Long term sickness	Market price based on the costs of hospital visits and medicinal costs.
Intangible, environmental aspect	Damage on natural environment	Depending on the environmental devastation, it can be approximated by market price or willingness-to-pay method.
	Post disaster indoor pollution, i.e. unhealthy indoor condition after the floods	Market price based on cost of rehabilitation, plus valuation method when the conditions are not fully repairable.
	Water sources pollution	Market price based on cost of water supply.
	Ground water contamination	Market price based on cost of minimum standard of bulk water.
	Aesthetic damage	Market price based on cost of rehabilitation of the damage.
Tangible, economic aspect	Property losses	Market price based on the price of property per unit area multiplied by flood depth and inundation time.
	Industrial/commercial disruptions	Market price based on industrial and commercial production per unit area multiplied by inundation time.
	Recreational/tourism disruptions	Market price based on number of tourists/visitors and approximate visitor's spending and admission fee.
	Damage on value object e.g. flushed or submerged cars	Market price based on the cost of repairs.
	Utility services disruptions	Market price based on alternate costs of water supply or electricity. If the disruption is on internet, the alternate cost of internet disruption on case-by-case basis.
	Injuries	Market price based on medical services cost.

Floods may occur due to either natural or man-made causes. The combination of both can rectify one another towards the severity of the impacts. One widely known the cause of flood is global warming that eventually leads the rise of global sea level (Fritgerald et al., 2008; Rodolfo & Siringan, 2006; Cazenave & Cozannet, 2014). The rise of sea level may increase the vulnerability of low-lying lands and coastal areas to flooding. As most urban development takes place in coastal areas and estuaries, and coupling this to ever more rapid urbanization, more and more humans will be exposed to greater risks and threats of flooding in urban areas. There are flood variables e.g. depths and velocity that dictate the losses due to flood as schematically depicted in the Figure 1.

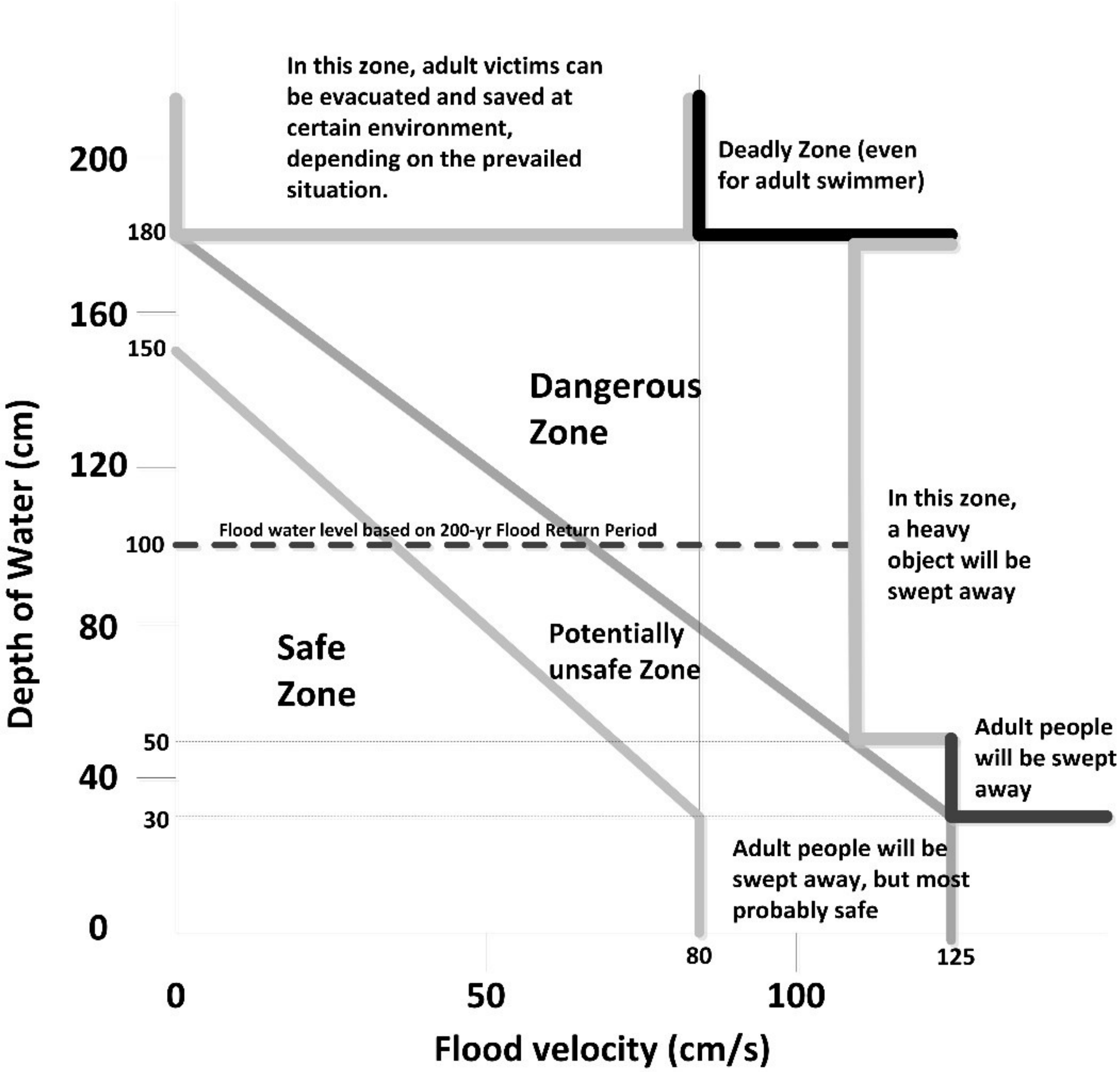

Figure 1: The Correlation between Flood Variables and Possible Impacts

2 Objective and Methodology

As the tangible costs and benefits of flood control works are entirely easy to quantify, the intangible ones, in the meantime, are completely intricate. The main objective of the study is therefore to elucidate the process of monetizing the intangible benefits of flood prevention works by providing sets of transfer functions that translate the undistinguishable variables into more measurable ones. A rational approach in developing the transfer functions were employed. This rational method in a sense that avoiding the unreasonable steps, for example with respect to the correctness in dimension. As the empirical and theoretical references are abundantly available despite lacks practical and quantitative applications, the study was undertaken by exploring those existing associated references and critically review and adopt them for the clarity of the issues. This study discusses only the intangible benefits of preventing losses to occur as they are difficult and complicated to determine while the other parts are relatively easier.

3 The Development of Transfer Functions

The transfer functions in this study are mathematical functions that model the input-process-output system, see for example, the studies by Jury (1982), Disney & Towill (2002). The functions received raw or half-done input variables of the intangible quantities and deliver the tangible outputs. A simple example of this process in flood prevention works is injured due to flood. Injury is actually a loss, but this incident could be prevented by eliminating flood occurrence, and thus this loss could transfer to the benefit. However, not all the process could be done in very simple and smooth ways by using a straightforward transfer functions, some of the processes require external tools to get input variables, for example, perceptions and willingness to pay on something immeasurable but imaginable events (Hanemann, 1991; Borchers et al., 2007). By referring to Table 1, this issue is discussed in the subsequent subsections.

3.1 The Benefits from avoiding Loss of Life

This type of loss is the most difficult to quantify as a somebody's life is invaluable for whatever reasons. However, along with the other quantified losses, there must be a way to approximate the losses in monetary term. By employing the economic logic in which every single man is a profit taker and always try to take advantage to meet his/her hedonic life (Commons, 1935; Livne, 2000; Alba & Williams, 2013), the loss of life could be approximate by using the comparison of his/her desired salary against the life and death of working environment. A straightforward example, the willingness to work in Afghanistan (rank 163/163 in Global Peace Index, the most hostile country in the world) with salary X against working in Iceland (rank 1/163 in GPI, the most peaceful country in the world) with salary Y, in which X is multiple times of Y. It is then reasonable to measure the loss of life from this simple perception as the respondent fully understood and aware of the situations including the risk of life.

The benefits, B_l, from avoiding loss life of one person during flood event can be expressed in the following transfer function:

$B_l = (A_l - A_p)n_1 \times S_{ann}$ for age of victim younger than productive age [1]

$B_l = (A_l - A_v)n_2 \times S_{ann}$ for age of victim older than or same as productive age [2]

Where:

A_l: national life expectancy [year]
A_p: national productive age [year]
A_v: age of victim at the time of loss of life happen due to flood event [year]
n_1: number of victims of the younger-than-productive-age group [person]
n_2: number of victims of the older-than-or-same-as-productive-age group [person]
S_{ann}: average national annual salary [currency unit/person/year]

Alternately, whichever is higher, it can also be approximated by using the life insurance claims for the death multiplied by a factor (k) determined by the assessor, multiplied by number of victims (n):

$B_l = k \times n \times Insurance\ claims$ [3]

Assessor may determine and adjust the k-factor based on current and local situation at the time of flood events.

3.2 Absence from works due to traffic disruptions

Flood events, to some extent, may disrupt the traffic and further prevent citizen's activities of studying, working, and other business activities. This disruption certainly causes economic losses, in terms of the length of interruption of the activities. The economic losses or the benefits of preventing and evading such a loss, can be computed by the following transfer function. Elmasry et al. (2018) also asserted about similar direction in estimating the losses due to traffic disruptions.

$$B_w = V_T \times 5 \times W_{day} \times N \qquad [4]$$

Where:
B_w: economic benefits of preventing traffic disruption by flood control works [currency unit]
V_T: daily traffic volume at particular disrupted road by flood in equivalent passenger car unit [unit]
W_{day}: daily wage of the worker [currency unit/day]
N: number of days of disrupted traffic, integer [day]

If the disruption rather occurred at work places, in which the workers were able to come to the work places, but the work place itself could not operate because of submerged by flood waters or inundated, the benefits from avoiding this distractor by flood work prevention could be approximated by the following function.

$$B_p = \left(\frac{N}{365} \times Annual\ Benefit\ of\ the\ Company\right) + \left(n \times N \times W_{day}\right) \qquad [5]$$

The transfer functions [5] can also be applied to industrial and commercial activities interrupted by flood events.

3.3 School disruption by flood

School disruption by flood events may void the teaching and learning activities. The disruption may hamper the advancement of the students toward their future to whatever the level or scale. The losses of the school disruptions or the benefits of preventing school disruptions by flood control works can be computed by in two perspectives (1) from the teaching viewpoint, and (2) from the learning viewpoint. From the teaching viewpoint, the benefit of evading school disturbance from flood events can be seen from the losses suffered by the teacher, which is the losses of the teachers when he/she is absence from the teaching activities, or the benefits gained if such losses can be avoided. From this perspective, the transfer function of losing equivalent earning can be expressed by the following.

$$B_t = n_e \times N \times W_t \qquad [6]$$

Where:
W_t: equivalent daily wage of teacher
n_e: number of teachers and supporting staff of the schools

In the perspective of learning process, the transfer function is formulated according to the duration of education up to undergraduate level, which is 6-year primary education plus 6-year secondary education plus 4-year university education is equal to 16 years of education or equivalent to 5,844 days of educational duration. The transfer function from the learning viewpoint, B_e, is therefore expressed by the following.

$$B_e = \frac{N}{5844} \times \left(A_l - A_p\right) n \times S_{ann} \qquad [7]$$

Where:
N: number of disrupted learning activities [day]
n: number of students impeded by flood events [person]
A_l: national life expectancy [year]

A_p: national productive age [year]
S_{ann}: average national annual salary [currency unit/person/year]

The physical losses of school's buildings, facilities, equipment, furniture, books, etc. must be calculated separately in tangible economic losses, which is out of scope of this study.

3.4 Long term sickness

If the flood generates the long-term sickness that causes a person is disable to sustain his/her own life, then the transfer function is equal to the loss of life plus the medical cost of the person until she/he recovers. The function is expressed by the following equation.

$B_s = \left(A_l - A_p\right)n_1 \times S_{ann} + C_{med}$ for age of victim younger than productive age [8]
$B_s = (A_l - A_v)n_2 \times S_{ann} + C_{med}$ for age of victim older than or same as productive age [9]

Where:
B_s: Benefit of avoiding long-term sickness due to flood of one victim [currency unit]
A_l: national life expectancy [year]
A_p: national productive age [year]
A_v: age of victim at the time of loss of life happen due to flood event [year]
n_1: number of victims of the younger-than-productive-age group [person]
n_2: number of victims of the older-than-or-same-as-productive-age group [person]
S_{ann}: average national annual salary [currency unit/person/year]
C_{med}: total medical cost until recovery [currency unit]

In the event that the long-term sickness does not generate the lifelong disability of the victims, the benefits of preventing long-term sickness is expressed by the following transfer function.

$B_s = C_{med}$ [10]

3.5 Damage on Natural Environment

Flood may create devastation on natural environment. This intangible loss could be transferred to intangible benefits of preventing this loss due to flood control works. There are several components of benefits of preventing natural environment damage: (1) aesthetical component (2) loss of habitat (3) cost of rehabilitation. The aesthetical component and loss of habitat could not be estimated straightforward, rather through valuation process by exercising the willingness to pay of the citizens. The cost of rehabilitation of the natural environment damage could either be combined with components (1) and (2) becomes one complete package of valuation survey, or as a separate element as this component is as tangible component. To get maximum benefit, in the valuation survey, the willingness to pay of aesthetical component, and loss of habitat can be separated in a separate survey with different respondents. The transfer function of the combination of all components as a result of willingness to pay of the citizens in the valuation survey, the benefit of avoiding this damage, B_n, is expressed by:

$B_n = N_a \times W_{tp}$ [11]

Where:
N_a: number of populations in the city and surroundings those aware the issues [person]
W_{tp}: Willingness to pay of the citizens of one person [currency unit/person]

In case the valuation survey separates the tangible component, the transfer function of the benefits can be computed according to the following equation.

$$B_n = \left(N_a \times W_{tp}\right) + C_{rehab} \quad [12]$$

Where:
C_{rehab}: rehabilitation cost of the environmental damage [currency unit]

3.6 Post Disaster Indoor Pollution

After the flood occur, particularly when the inundation takes a long time, the indoor high humidity may generate indoor air pollution, for example due to fungus that generate bad odor in the room. In this case, the benefit of preventing this pollution from taken place can be approximated by the following equation.

$$B_i = C_{med} + C_{rehab} + (N \times C_d) \quad [13]$$

Where:
B_i: benefit from preventing indoor air pollution [currency unit]
C_{med}: medical cost due to indoor pollution i.e. hospital visit and cost of medicines [currency unit]
C_{rehab}: rehabilitation cost of the building for eliminating the pollution [currency unit]
N: number of days of the incidence of indoor pollution [day]
C_d: daily cost of grievance due to indoor air pollution [currency unit/day]

3.7 Water Sources Pollution

In some cases, the flood waters pollute the other water sources, for example, dug-well of the individuals or communities. Groundwater pollution due to flood water is rarely taking place because of the soil itself may act as the groundwater filter, unless the flood water carries hazardous pollutant that may not be able to be screened by the soil. This issue will be discussed separately. In case of flood water contaminates the water sources, which are usually used by the people as domestic water use, the benefits of the water sources pollution prevention as a result of flood control works, can be expressed in the following transfer function.

$$B_{ws} = n(N \times C_{al}) + C_{rehab} \quad [14]$$

Where:
B_{ws}: benefit of preventing water source pollution by flood prevention works [currency unit]
n: number of people affected [person]
N: number of days of one people spend money for alternate domestic water [day]
C_{cal}: cost of buying alternate domestic water [currency unit/person/day]
C_{rehab}: rehabilitation cost of the water source to return to normal function [currency unit]

3.8 Ground water contamination

Flood waters can also contaminate the groundwater, particularly when the flood waters carry hazardous contaminant. When the situation is reversible then the benefits of preventing such a groundwater contamination is equal to the cost of rehabilitation plus the alternate cost during the contamination (if the groundwater is also source of domestic water). When the situation is irreversible, then the benefit is equal to the alternate replacement plus bequest and existence costs. The bequest and existence costs are approximated from the valuation survey. The transfer function of the reversible condition is given by:

$$B_{gw} = C_{rehab} + (N \times C_a) \qquad [15]$$

Where:
B_{gw}: benefit of preventing groundwater contamination [currency unit]
C_{rehab}: rehabilitation cost to return the groundwater to original function [currency unit]
N: number of days of the duration of contamination [day]
C_a: alternate cost during the contamination [currency unit/day]

When the contamination is irreversible, then the transfer function is approximated by the following transfer functions.

$$B_{gw} = C_r + C_{bequest} + C_{existence} \qquad [16]$$

$$C_{bequest} = N_a \times W_{tpb} \qquad [17]$$
$$C_{existence} = N_a \times W_{tpe} \qquad [18]$$

Where:
C_r: replacement/alternate cost [currency unit]
$C_{bequest}$:cost of the lost heritage resulting from the valuation survey [currency unit]
$C_{existence}$:cost of the environment as a result of the inexistence of environment, which previously exist
N_a: number of populations in the city and surroundings those aware the issues [person]
W_{tpb}: willingness to pay for the bequest value of environment
W_{tpe}: willingness to pay for the existence value of environment

3.9 Aesthetic Damage

Damage on the aesthetics of the environment can be measured by using perceptions if the aesthetics are irreplaceable because of something abstract. If the aesthetic damage is repairable or replaceable, then the benefit of preventing aesthetic damage is equal to the substitute cost of the damage. In case the aesthetic is irreplaceable, the method to value this intangible benefit can be done through environmental valuation, and the benefits can be approximated by the following transfer function.

$$B_{ae} = N_a \times W_{tpa} \qquad [19]$$

Where:
B_{ae}: benefit from preventing aesthetic damage [currency unit]
N_a: number of populations in the city and surroundings those aware the issues [person]
W_{tpa}: Willingness to pay of the citizens of one person from valuation survey of aesthetic damage [currency unit/person]

If the aesthetic is replaceable or repairable by the assessment of the expert, then the benefits from avoiding aesthetic damage come from flood prevention works can be directly approximated by the following transfer function.

$$B_{ae} = C_r \qquad [20]$$

Where C_r is replacement cost to return the aesthetics to original function.

3.10 Total Intangible Benefits

The total intangible benefits due to flood prevention works are equal the sum of all intangible benefits as discussed above, and mathematically expressed in the following equation.

$$B_{int} = \sum_{i=1}^{n} B_i \qquad [21]$$

Where:
B_{int}: total intangible benefits of preventing losses by flood control works [currency unit]
B_i: individual benefits as per above discussion [currency unit]

The intangible benefits are, in monetary terms, more complex to approximate in comparison to the direct tangible damages. The intangible benefits approximation sometimes needs perceptions to estimate through willingness to pay of the citizens, which is largely based on perceptions. However, this study has attempted to present the rational transfer functions, which translate the complicated states into reasonable and simple inputs of the transfer functions to obtain the approximation monetary values of the benefits. By understanding the overall benefits and costs of the flood control works, a more reasonable results of economic analysis of the flood control works can be obtained.

5 Conclusions

The conventional flood prevention activities comprise of structural and non-structural measures, in which structural measures are definitely measurable with respect to monetary terms. The non-structural measures cannot be easily translated into monetary terms. In similar manner, the benefits of the flood prevention works may vary from monetary measurable to non-measurable. The losses due to flood occurrences can be transferred into the benefits for their inexistence as consequences of flood prevention works. Therefore, the benefits of flood prevention work may come from the diminishing negative effects and the other indirect positive impacts of flood preventions. The diminishing negative impacts of the flood events are mostly intangible features, hence becoming the focus of the development of transfer functions. The transfer functions should be effective and simple with uncomplicated inputs to the systems. The efforts to develop transfer functions, which are expected to be able to translate the intangible costs or benefits into quantifiable ones have been done by using rational method. The rational method would show that the results would be in a uniform and consistent monetary unit. This work will be continued to improve for more accurate approximation of the intangible benefits. This improvement is particularly directed to the part where additional or external tools are used, for example, the valuation methods. The proposed transfer functions may need external tools for example valuation and willingness to pay survey to give the input variables to the transfer functions.

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