Long Term Effects Evaluation of a National Typhoon/Flooding Protection Program.

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Introduction

This paper summarizes an original analysis developed by the same authors in the book "Improving Sustainability through Reasonable Risk and Crisis Management" (F. Oboni, C. Oboni, 2007, www.riskope.com) which discusses the need to integrate potential risks in a transparent and quantitative way in any decision and human endeavor. Integrating risks in decisions also means to be able to measure and evaluate the effects of a long term mitigation program in order to understand if it actually represents a wise social investment for a country, an organization, a community.

As a case study the Japanese Typhoon mitigation program is brought forward. This program started in the 50s and is still active. It aims to protect the population of the country from the floods generated by typhoons and other high intensity meteorological phenomena. Any program for any natural or man-made hazard could be evaluated using the same methodological developments. As examples of other hazards we will cite: tsunamis, draught, sea-level rise, earthquakes, explosive remnants of war icluding land mines, terrorism etc.

In this study the evaluation of the efficiency of the mitigation program is carried out by determining the "investment" necessary to "save a life".

The data used in this study were all derived by publicly available information sources spanning more than half a century (from 1951 to 2005), mainly the http://agora.ex.nii.ac.jp/digital-typhoon/. When data were missing or were unavailable assumptions and hypotheses were made to bridge the informational gap and still allow to bring forward the discussion.

The study follows the general steps of a Quantitative Risk Assessment, insofar it:

- Defines the system to be studied (Japan as one national target of the hazard).
- Identifies the hazards (typhoon) in terms of probability of occurrence and magnitude.
- Evaluates consequences (flooding with its human and infrastructure (houses) damages or losses).
- Evaluates short and medium term risks.

- Examines the effect of the national mitigative policies implemented in 1961 after the infamous Ise-Wan typhoon of 1959 (appx. 5,000 casualties).
- Discusses the Disaster Countermeasures Act in terms of societal benefits vs mitigative investments.

Typhoons Frequency and Probability of Occurrence

Within the considered period from 1951 to 2005, 133 typhoons were recorded in Japan as displayed in Fig.1.
The rich data set available in Japan allows the evaluation of frequencies and probabilities of events of various magnitudes. At this stage however, the generic frequency and probability will be looked at.
The calculation of the frequency is quite simple, i.e. the number of typhoons divided by the period under consideration, thus 133/54=2.46 events/yr. Frequency measures the

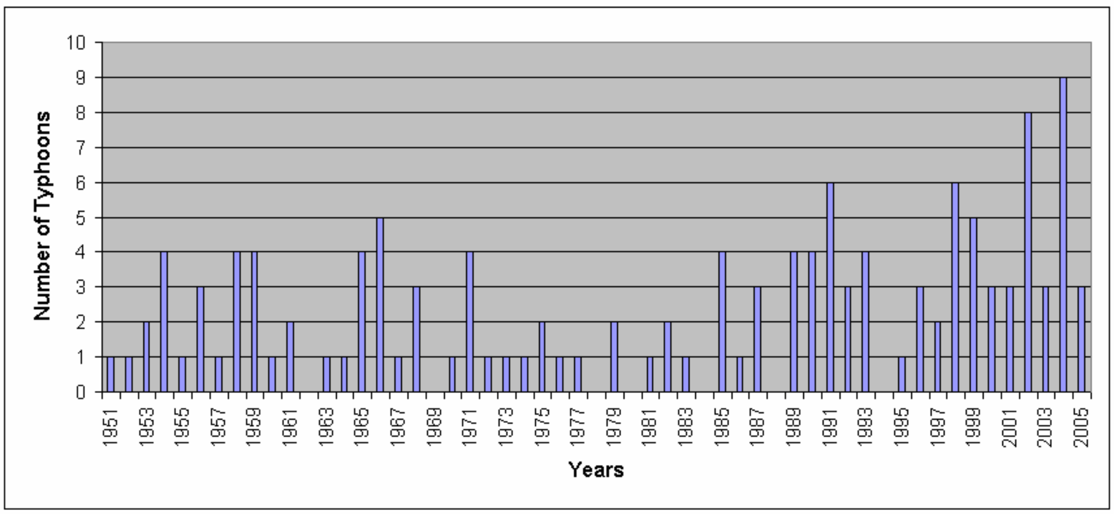


Fig. 1 Number of Typhoons per Year (1951-2005) in Japan

number of occurrences of a given phenomena per unit of time, whereas probability measures the chances a given phenomenon will occur during a certain period. Despite this very critical difference frequency and probability are often confused.

For the sake of this study the initial 54 years period was split into 3 periods of equal duration (18 years) as follows: Period I: 1951-1969, Period II: 1970-1987, and Period III: 1988-2005.

It can be noted that Period I has a total of 40 typhoons while the two other periods have respectively 26 and 67 typhoons. By using simple mathematical rules (Poisson, 1838) that allow converting a frequency in a probability, it can be calculated that the probability of seeing no typhoons “next year” (End of Period III, 2006) is 0.02 while it was 0.1 at the end of Period I (1970), respectively 0.23 at the end Period II (1988).

Also, the probability of at least one typhoon "next year" was appx. 1- 0.1=0.9 in 1970, 0.77 in 1988 and a staggering 0.98 for 2006!

Now let's consider the magnitude of typhoons. There are lots of data needed to compare the strength of these phenomena, i.e.:

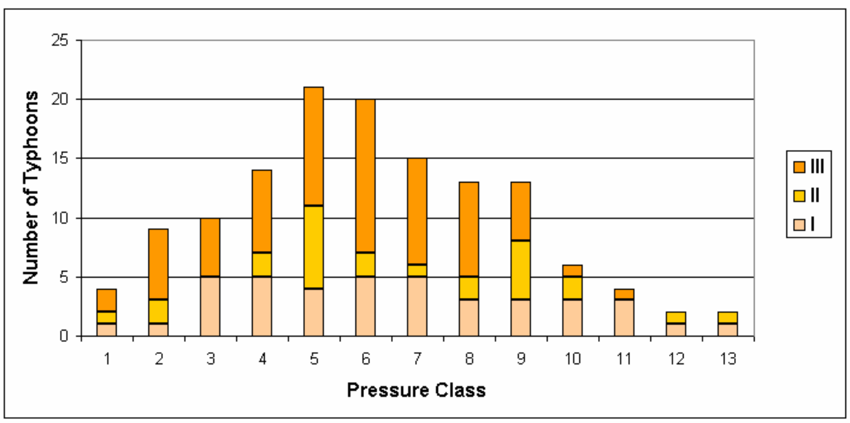
- the size (diameter in kilometers: the bigger the stronger)
- the maximum sustained wind (the fastest the stronger)
- the pressure at the eye (the lower the stronger)

Because of historic and monitoring reasons not all the records present all of the data, thus it was necessary to use as a typhoon categorization parameter the only data available for the full set of typhoons, i.e. the pressure at the eye.

Pressure data can be used to generate typhoon magnitude categories useful for this study (official typhoons categories cannot be applied because of lack of data for the older events), i.e. over the three 18 years long periods. Thirteen categories were defined on the basis of the pressure at the eye.

By looking at Fig.2 which depicts stacked number of occurrence of typhoons of each class in the three considered periods, we can say that the more we advance in time the more we get high pressure's eye typhoons, i.e. more frequent, but less powerful phenomena.

Fig.2 Number of Typhoons per Pressure Clas in each Period



As we saw above, other factors far outweigh this data interpretation, so we cannot claim to be in the position to establish a strength-time relationship. Thus the assumption that the destructive strength of a typhoon is not a function of the year of occurrence will be made in this study.

Typhoons Cost of Consequences

From the entire period of observation we can derive a fair amount of data about victims (dead or missing people) from each typhoon.

The evaluation of human life losses due to natural hazards in the world varies from single injured to multiple fatalities up to the order of 100'000 to 500'000 in case of large historic earthquakes (Shansi, Japan, earthquake, 1556) (Lee, 2004). However, both terms "death" (or casualty, or fatality) and "injured" cover a wide spectrum of adverse consequences.

For example "injured" can include costs involved in the:

- rescue,
- scale,
- recovery, and the
- extent to which full recovery can be expected, as well as
- long term loss of function.

Moreover no international definition standards exist, leading to great uncertainties when statistics and old records are used in a study.

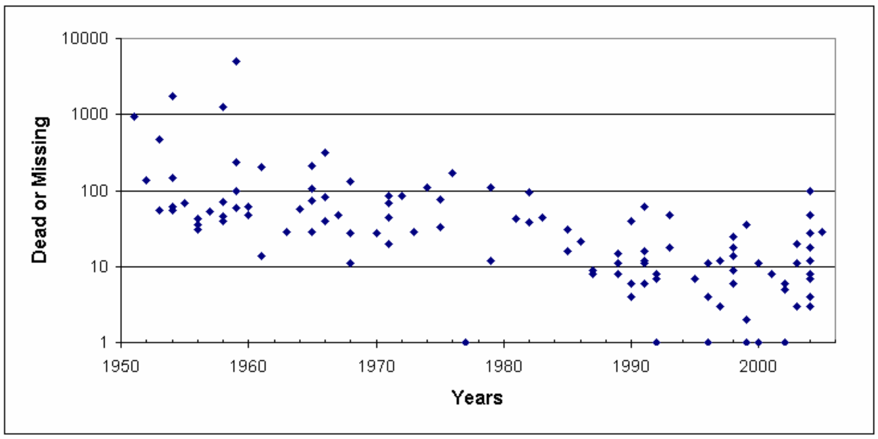


Fig. 3 Victims vs. years

Thus, the average cost of an injured person can only be estimated, and it is of paramount importance to clearly state which components of the cost are taken into account or excluded from the analysis. Statistics on deaths can also be considered uncertain as the time of death should be carefully recorded, but generally is not (are we looking strictly to deaths on site, during the event, or deaths occurred as a delayed consequence, in the aftermath of an event, etc.). These considerations lead to accept the available data as approximate at best only.

Fig.3 displays the general downwards trend with time. If we want to get a realistic image of the human impact of typhoons over the 54 years period, one could calculate the average number of deaths per typhoon, i.e. 14659/133=110, a number that seems too high with respect to the large majority of typhoons bearing little or no victims, as the average is raised by a few typhoons occurred before 1960. Thus it is suggested that the median will be used in this study (i.e. the value that divides the sample in exactly two halves), i.e. 20 victims per event, as the most realistic parameter to quantify the central tendency of human impact of the whole set of data, or of a group of typhoons.

Considering median, minimum and maximum casualties' count for the three 18 years periods the following table can be derived:

Period	Casualties per Year			Casualties per event		
	Min	Median	Max	Min	Median	Max
I	0	135	5492	0	61	5098
II	0	44	217	1	32	169
III	0	23	225	0	8	99

As it can be observed in the table, the median values clearly decrease with time and are generally shifted towards the minimum because only a few typhoons generate high casualties' counts.

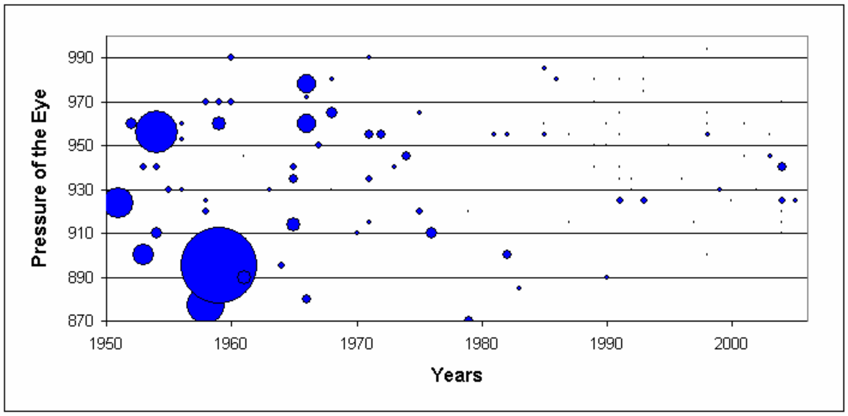


Fig. 4 Casualties vs. pressure at the eye vs. years

In Fig.4 which links pressure at the eye, year of occurrence and casualties count, the size (diameter) of the bubbles represents the number of death per event. We can see that low pressure at the eye is not the only predictive indicator of typhoon's strength and resulting casualties count, especially when considering the simultaneous and opposite effects of mitigative measures implemented in Japan and demographic growth.

The prior points lead to the conclusion that a study like this one (Japanese national scale) can only look at macroscopic relationships, generalized to the entire country, because of the complexity of the environment in which the hazards hits, complicated by human interferences, demographic growth, and the completely stochastic behavior of the hazard (typhoons) in terms of their paths, intensity, etc. (Fig. 5).

Should the study be concerned with a detailed area, then the record would become insufficient as 54 years of monitoring cannot offer a statistical basis for each area of Japan. This is where experience and a lot of thinking have to de developed by a Risk Assessment Team which has to complete the often irrelevant and censored statistics with proper probabilities estimates including dynamically evolving systems (climate changes, etc.). The limit where incomplete statistics and probabilities estimates merge is the day to day area of work of risk management experts.

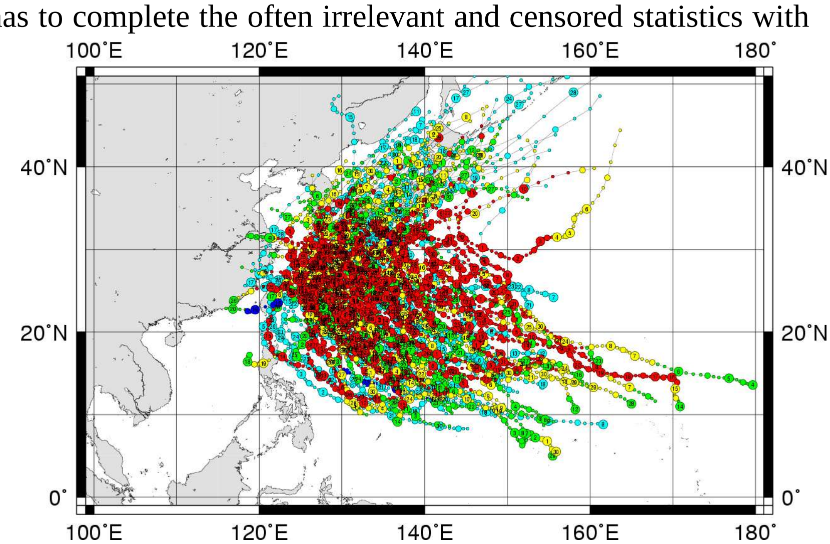


Fig. 5 Path of the 133 recorded typhoons over Japan

In addition to all the points developed above, over the last 54 years a significant change in population density and lay out has occurred, leading to believe that, in absence of any mitigation, the same strength typhoon having the same trajectory would result in a lot more victims now than it did 50 years ago.(Tatano, 2005).

Based on publicly available data the population of Japan has increased from approximately 83M in 1950 to 127M in 2007, i.e. an increase of 53% which cannot be ignored when evaluating comparative risks or discussing societal benefits vs. mitigative investments.

Risk Assessment

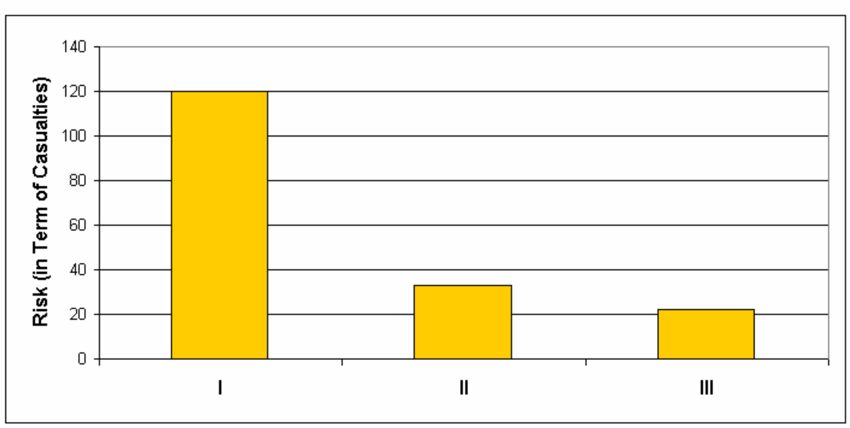
Armed with historic probabilities and cost of consequences defined in terms of casualties it is possible to evaluate the evolution of risks generated by typhoons in Japan over the three considered periods. For each period we can evaluate the median risk for "next year", i.e. using the probability of "1 or more typhoons next year" and the period median casualty count. It is also possible to evaluate for example the risk linked to "next year" first typhoon, using the probability of exactly one typhoon and the "per event" casualty count. Because typhoons in Japan have such a high probability of occurrence it is the first alternative which is more interesting: in other cases the choice of the time horizon used in the risk evaluation is of paramount importance. Indeed, if one considers very long time horizons, even small probabilities per annum will lead to high overall probabilities possibly dramatically changing the risk profile of an operation, organization or a country.

The risk results (probability x consequence) are condensed in the table below and Fig.6:

Period	Risk (in term of Casualties)
I	120
II	33
III	22

If other hazards were considered (for example earthquake, volcanoes, climate change etc.) in a more general study, then the risk figures would allow a comparison, ranking, and rational investment allocation.

Fig. 6 Risk in term of casualties vs. Period



Mitigative Measures

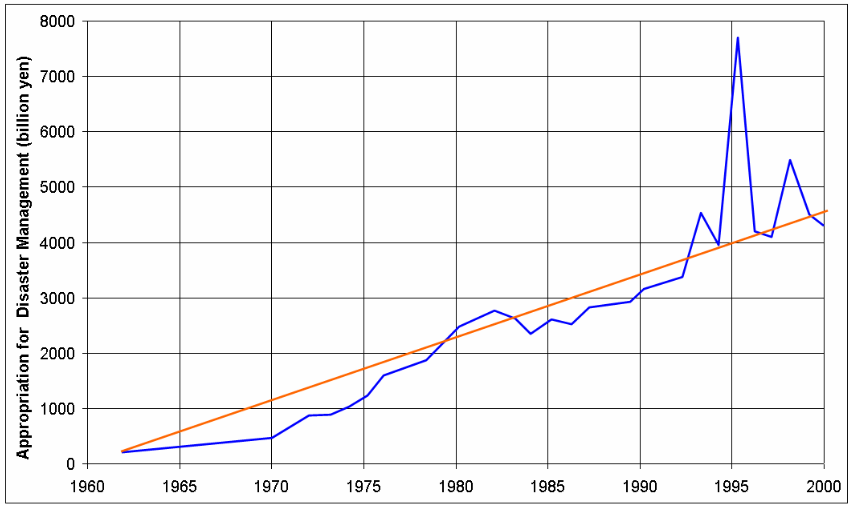


Fig. 7 Amount allocated to the disaster management program between 1961 and 2000 in Japan

The immense damage caused by the Typhoon Ise-wan in 1959 was a turning point for disaster management in Japan, giving rise to a movement to plan and prepare a comprehensive disaster management system. Thus the Disaster Countermeasures Basic Act was enacted in 1961. The Act lead to a three prongs approach including: i) an increase in the overall spending for disasters, ii) the implementation of wide-spread structural flood controls and iii) a passage from a reactive to a proactive policy.

The blue line in Fig. 7 shows the amounts the Japanese government allocated for disaster management not adjusted for inflation. This assumption can be made because the inflation rate has been historically very low in Japan during the 70s and 80s and even presented negative periods from ’93-2002. (Chiodo, Owyang, 2003). As the rate of change with the US$ (the Euro exists only since a few years, thus it cannot be used here) presented large fluctuations from 360 yen per dollar in the era of Bretton-Woods system to 80 yen per dollar, in 1995. (Imai, 2002), for the sake of simplicity, this study is performed in yen.

The orange line is a simplified model which takes into account the fact that disaster relief is also included in the blue line. Moreover, since the blue line also includes other disasters countermeasure for example geared towards tsunami, earthquakes etc. The peak in 1995 is for example the Hanshin-Awaji earthquake and therefore was excluded from the orange line. The orange line equation is (800/7)*(year-1960). Therefore the amount of money spent for the period from 1961 to 2005 is 115’714 billion yen.

The above quoted amount corresponds to an "all disasters" program. If we make the assumption that the percentage allowed to the typhoon compared to the others disasters didn't change over the years we can calculate the amount spent to mitigate typhoons.

Fig. 8 depicts the effects of Structural Flood Controls implemented in Japan during the period going from 1967 and 1995 in terms of inundated area reduction.

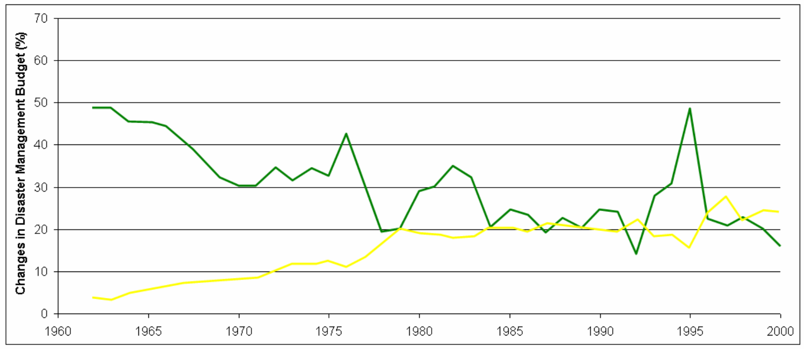


Fig.9 "Disaster Prevention" and "Disaster Recovery construction" relative proportions

The blue plot is the total inundated area during each year. The green plot is the total inundated area of residential and other properties. As it can be easily seen, the two plots feature a downwards trend with time.

Change in the policy from reactive to proactive approach is studied in Fig.9 the green line is the budget percentage devoted to "Disaster Recovery and Reconstruction" while the yellow is the budget percentage allotted to "Disaster Prevention".

As it can be seen the percentage of the budget allotted to Recovery and Reconstruction curves tends to diminish whereas the Prevention portion is increasing.

Efficiency of the funds allocated to the mitigative program

The increase of funding, Change in the policy from reactive to proactive and downwards trend in observed damages lead us to ask the following two questions. The first one seems relatively straigh-tforward and easy to answer: did all the mitigative measure really bring the expected results, i.e. reduce the damage?

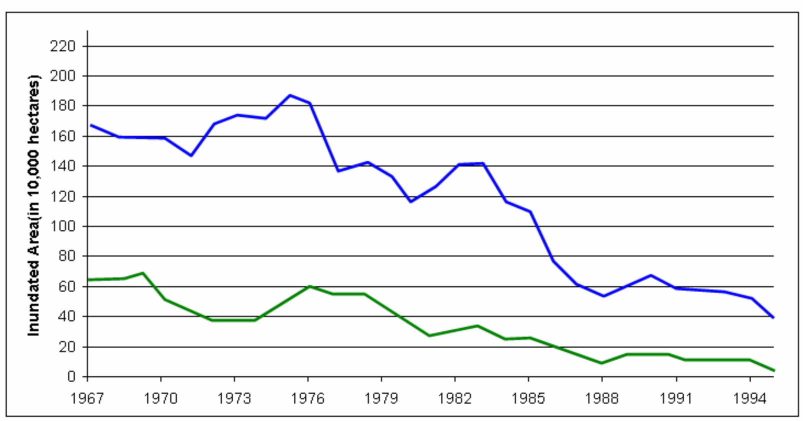


Fig. 8 Flooded areas vs. year

The second one is a thorny one: was the staggering mitigative invested amount "well spend" money?

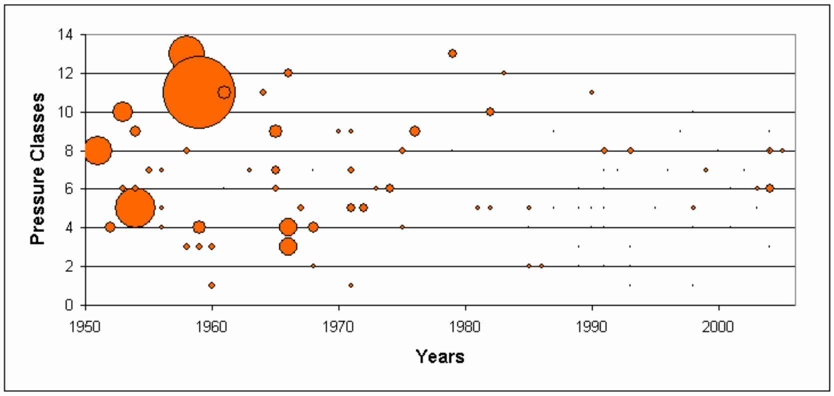


Fig. 10 Pressure classes vs. Casualties vs. year

A straightforward answer to the first question would be "yes, really" (see orange bubbles Fig. 10), as the size of the bubbles after the 70s significantly decreases, showing a tremendous decrease in casualties per event.

However, to be able to answer the second question, considering the simultaneous investment in mitigation, population increase and different type of losses (human lives, houses etc.) a more complex metric has to be developed. The losses data are quite abundant, including the Human Damage (dead, injured) and the Housing Damage (destroyed, inundated) categories.

To perform the comparison we selected two very similar events (based on available data and criteria defined above), one (a) in 1964, the other (b) in 1990 with significantly same paths, and same minimum pressure at the eyes.

Damages	1964	1990	Reduction
Dead	56	40	28.57%
Injured	530	131	75.28%
Houses destroyed	71269	16541	76.79%
Houses inundated	44751	18183	59.37%

Fig. 11 Differences in the damages caused by the 1964 and the 1990 typhoon

Fig.11 summarizes the damages reduction data when comparing these two specific phenomena of 1964 and 1990.

Of course we cannot compare these results with the amount of money spent by the government between the years, because even if we have the precise path we cannot say which mitigative measure had an impact and which did not for these specific typhoons. This is the reason why we have to keep a large scale study, country wide.

Doing the same analysis on the whole country gives us the results described below.

Damages	I	III	Raw Difference	Reduction(%)
Dead	12583	828	11755	93.42%
Injured	60844	8642	52202	85.80%
Destroyed Houses	2552115	402249	2149866	84.24%
Inundated Houses	3720251	384576	3156233	84.84%

Fig. 12 Differences in the damages caused in the first and the last Period

As for the first raised question the complete answer would be, "Yes, much, the reduction of all the damages is more than 80 % on the different targets (See Fig.12).

Now to be able to answer the second question explicitly the comparison of these numbers to the considerable 115’714 billion yen spent in the “all Disaster Management” program is inevitable. Unfortunately, we do not have information related to the partition of the investments specifically allotted to typhoon mitigation. Thus the whole amount will be used for the calculations, and the final results discussed bearing in mind that only a portion of the investment has been used for the purpose.

Now that we have shown that the risk reduction was effective, we are going to focus our attention on the investment afforded by Japan to save a life. Indeed, this study does not attribute a cost to human life (Mooney, 1977, Jones-Lee, 1989, Marin, 1992, Pearce, D.W. et Al., 1995), a notion often considered repugnant and ethically unacceptable, but looks at how much money the government spent to save the life of a citizen potentially exposed to flooding.
In other words, we will measure the mitigative investment a society is ready to make to save a life or its Willingness to Pay (WTP) attitude.

Obviously the WTP is strongly influenced by cultural, religious, philosophical and quite evidently economic considerations as it simultaneously considers a society’s “view on risk” and “response to risk”. Marin (1992) indicated that in the UK, at 1990 prices, the WTP was in the order of 2M£ to 3M£, and other studies (Lee & Jones, 2004) define ranges between 1.9MUS$-9MUS$ for Developed Countries, with an average at approximately 3.5MUS$.

Due to the lack of detailed data, this study is based on rough estimates of costs of consequences for physical damages as follows:

- price for an average destroyed house of 30 million yen,
- an inundated house and an injured person of 3 million yen.

These assumptions lead us to calculate that the Japanese government spent an unknown (to us) portion of 41’593 billion yen (net of damages to houses, injured people) to save a total of 11’755 lives (reduction of victims between Period I and Period III). Now, if the 53% of population growth is taken into account, then the number of lives saved has to be considered proportionally higher, leading to an adjusted theoretical reduction of 18’425.

The resulting cost is 2.26 billion yen per life, being understood that only one part of this was allotted to typhoon mitigation. If we were now to assume that 10% of this cost was actually devoted to typhoons, the value would be realistic compared to the 0.2 billion other have formulated (2.2MUS$). Additionally, as most certainly the percentage devoted to typhoons was higher, one can see that the investment per life (adjusted to demography) saved falls well within the order of magnitude (higher end) of the WTP considered by other Developed Countries.

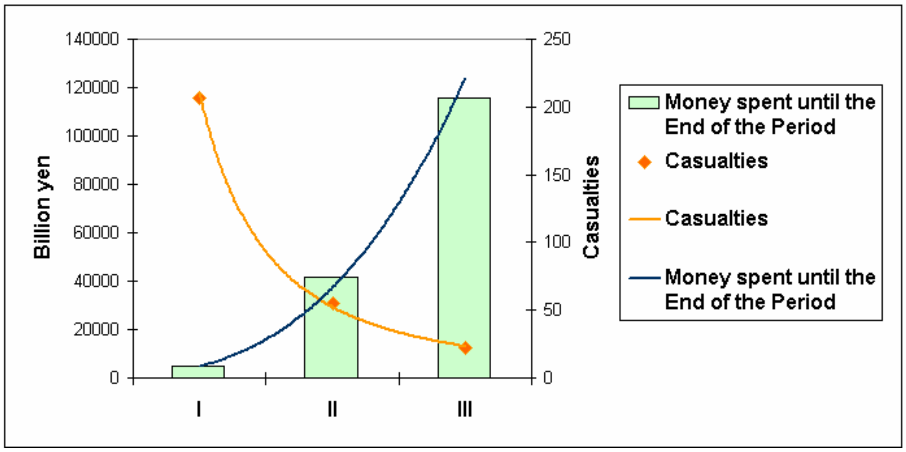


Fig. 13 Risk mitigation vs. investments in the three Periods

In Fig.13 we have plotted the amount spent until the end of Period III vs. the theoretically (adjusted to demography) number of lives saved.
The curves clearly indicate a well known phenomenon in risk mitigation, i.e. the fact that early program stages bring dramatic reductions of the risk level, thus present very high efficiency, whereas as risk levels decrease, larger and larger investments are necessary to gain little reduction.

This kind of approach, completed by the cost-benefit analysis constitutes an excellent tool to support rational decision making on mitigative and humanitarian programs. As the world evolves and climatic changes bring new challenges to humanity it will be necessary to bring transparency and accountability in the mitigative decision making, both at strategic (which hazards to tackle) and tactic (how to mitigate the selected hazards) level.

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