http://dx.doi.org/10.18778/1429-3730.39.03

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THE SUBJECTIVITY OF BEST PRACTICES IN FLOOD PROTECTION

SUBIEKTYWNOŚĆ NAJLEPSZYCH PRAKTYK W OCHRONIE PRZECIWPOWODZIOWEJ

Streszczenie

Pomimo ciągłych postępów w działaniach przeciwpowodziowych, ludzie i ich technologia mają ograniczony wpływ na występowanie powodzi, a w konsekwencji wyniki są zdecydowanie niewystarczające w stosunku do poniesionych kosztów. Ponadto, błędne decyzje i / lub nieodpowiednie rozwiązania mogą prowadzić do niepożądanych szkód. W artykule podkreśla się znaczenie działań profilaktycznych opartych na wszechstronnym rozważeniu różnych czynników ekonomicznych, społecznych i środowiskowych. Podkreśla się również fakt, znajdujący potwierdzenie podczas każdej powodzi, że nieustanny rozwój infrastruktury przeciwpowodziowej (np. wałów przeciwpowodziowych) paradoksalnie powoduje ograniczenie możliwości kontroli powodzi i skutkuje wzrostem zagrożeń. W artykule zaproponowano przegląd kryteriów stosowanych w poszukiwaniu najlepszej metody kontroli przeciwpowodziowej, uznając ryzyko i biorąc pod uwagę zewnętrzne składniki kosztów i potencjalnych zagrożeń

Słowa kluczowe: Kontrola przeciwpowodziowa, potencjalne zagrożenia, koszty zewnętrzne
Numer klasyfikacji JEL: Q 56

Introduction

Each preventive action aimed at mitigating the effects of disasters requires that all economic, social and environmental factors be comprehensively considered. Hence the need emerges to analyse criteria expressed using various measures. The ability to balance the proportions of various individual indicators translates into more or less dramatic intervention in the existing environment (not only the natural environment).

The title of this paper emphasises the problem of available flood control measures that in certain circumstances fail to protect people and property against

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floods. This problem is experienced by numerous communities during each flood that affects them. We intuitively feel that the measures employed are inadequate, but are we able to change our approach? The circumstances underlying the problem are complex, but a change is observed in understanding of the flood control concept. The type and importance of this problem may be compared to the difference between sustainable development and sustainability. It is not a play on words, but two different concepts. The first involves a libertarian approach to man's actions, a larger area where freedom of choice can be exercised, and rejects collectivist limitations; the second limits the space for choice and apparently introduces state interventionism.

Flood control and sustainable development

Does optimal protection guarantee sustainable development? If development is seen as a continuous process of social, economic and environmental changes with a "balance" of the three aforementioned factors ensured in the interest of future generations, we must conclude that we can only endeavour to achieve a balance that *reflects a policy and strategy for continued economic and social development without detriment to the environment and the natural resources on the quality of which continued human activity and further development depends*[18]. Fluctuations around the line of balance between the three factors are perceived as bearable, viable or equitable solutions (Fig. 1). Rational actions are aimed at minimizing those fluctuations. An increase in the fluctuations reflects a higher risk affecting the durability of the social contract with the absent, future beneficiary – the future generation (or rather future generations). It should be emphasised here that such a contract has utopian beneficiaries[19]. The roles of debtors and creditors in this social knot of obligations are mixed and played by generations, only the reference time changes, transferring to history consecutive debtors who leave behind effects, or more frequently burdensome consequences, that cannot be renegotiated by the beneficiary. And the beneficiary is forced to accept the existing conditions.

Although it is difficult to separate the two parties and draw a distinct borderline, it may be generally said that future generations play the role of creditors. Therefore, a question arises: who protects the social interest of those future creditors – are the debtors supposed to do this? This fact is one of the principal reasons of increased threat to the durability of the social contract. A typical conflict of interests emerges. This involves the need to intervene, to apply interventionist measures, to exercise external influence. Each preventive step violates the rules of

[18] Agenda 21, a programme document describing the method of preparing and implementing at a local level sustainable development programmes, adopted by the United Nations in 1992 at the Conference on Environment and Development in Rio de Janeiro.

[19] The utopian nature of the beneficiary consists in the iterative change of the creditor.

sustainable development. Here, the role of the state as the guarantor of the social contract must be considered.

Another reason is the need for safety. The relationship between safety and freedom sets a limit[20]. These are two opposite desires that cannot be simultaneously satisfied to a maximum extent. The dark side of evolution shows that the laws of nature do not guarantee safety[21]. The resultant problem is that of multiple optimal solutions and allocation of resources, goods and rights. One value may only be chosen at the cost of another. Considering the good of an individual, such solutions are feasible if external costs are paid. There are always two conditions: external costs generated and the victim that covers them (such as an individual, a social group or community), often unconsciously. However, in an analysis of social needs this approach is unacceptable. How much of one good can we sacrifice in order to increase the resources of another good (or other resources). Generating external costs is a violation of the conditions of the social contract. Ultimately, safety as a task of the state must be understood as the safety of its citizens.

Social cohesion is a basic component of sustainable development understood as above. Minimization of disparities, exclusion and poverty is one of the principal components of social cohesion. Such an approach is opposite to the interventionism that is necessary in preventive actions. The supreme goods include life, health and safety.

Development determines progress; progress drives development. Innovation is the gain factor in this feedback process of development. Finally, success is determined by development. The problem of rational actions and minimizing deviations (external costs, side effects) emerges again with an antidote – stimulation of measures counteracting adverse events. Extensive development arouses doubts and concerns caused not only by depletion of resources but also by destruction of the natural environment. These concerns resulted[22] in the so called Rio declaration defining the principle of sustainable development.

In the area of flood control the main expected result was a reduction in the expected value of losses caused by floods. Therefore the choice of the best strategy was based on the criterion of "maximum loss reduction at definite costs" or "minimum costs for a definite loss reduction". The implementation of a flood control project cannot completely prevent losses caused by floods. The most advantageous solution is the one offering the lowest sum of implementation and operation costs and future flood-caused losses. This involves minimizing the social costs

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[20] W. von Humboldt, The Limits of State Action, "without security, there can be no freedom".

[21] Hobbes T. – the author of Leviathan (1651) in which he argues that the sole way to avoid evil affecting people in the state of nature is to establish a contract whereby unlimited, absolute power is transferred to the sovereign.

[22] The Conference on Environment and Development was held in 1992 in Rio de Janeiro, and resulted in the Rio declaration being adopted. The principle of sustainable development became a constitutional provision in Poland in 1997.

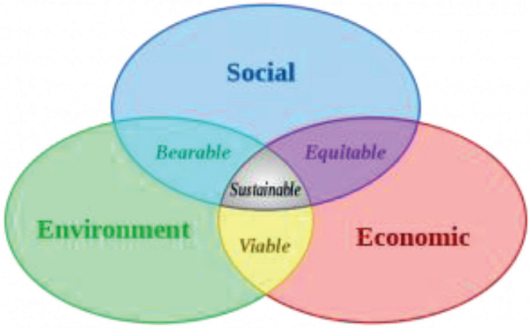

Figure 1. One of the goals of the Lisbon Strategy: sustainable development

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that must be incurred by society due to unavoidable floods (Słota, 1997), (Twaróg, 2002). In continuing this analysis, the relationship between external costs and the size of a capital expenditure project should be considered. The lowest external costs are generated by extreme capital expenditure projects. This results from the degree of intervention in other areas of the environment or social life, negligible in the case of small projects and limited in the case of project employing pro--environmental technology designed for expensive, large-scale solutions. A graphic interpretation of this optimization problem is shown on Fig. 2. The shadowed area illustrates social losses due to the implementation of an inadequate capital expenditure project (e.g. too high or too low embankments).

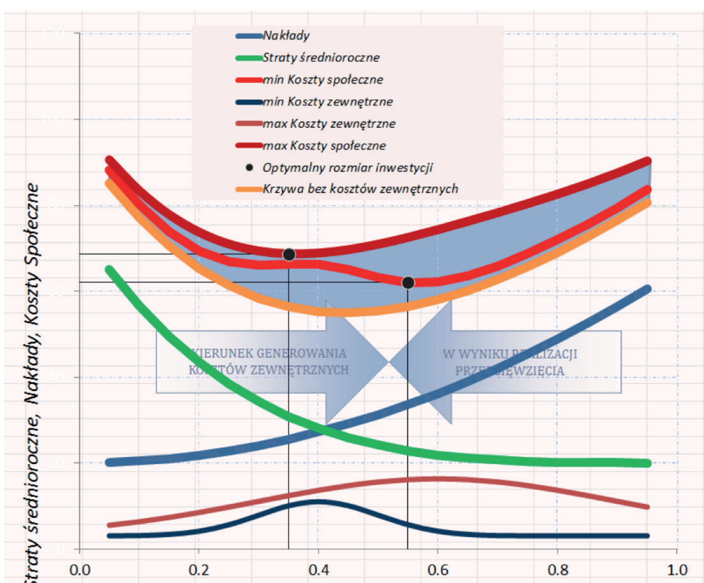

Figure 2. The effect of external costs on the optimal size of a flood control project

Selection of project size taking into account average annual losses and external costs – the risk analysis component in flood control

Failure to include external costs in the accounts of the investor (decision-maker) results in underestimated social costs that the implementation of the capital expenditure project entails. If the investor considered external costs, the higher expenses on project implementation would convince the investor to choose another version or size of the project. A higher cost would reduce the attractiveness of the project under consideration. The project version previously selected for implementation would exceed the identified social needs. This would mean that the project fails to meet the social expectations towards the level of protection against floods and thus causes an undesirable deadweight flood loss. The external cost function is an adverse side of the so called externalities understood as undesirable effects. The other side of externalities includes external benefits, a rare phenomenon, like charitable actions. This paper only considers externalities as a negative, unpredictable aspect of human activities in the area of flood control.

A condition for a rational choice in the scope of a capital expenditure project is consideration of external costs in the investor's accounts. Such a choice should also correspond to the social need for an adequate level of protection against floods. The point corresponding to the size of project satisfying the social need for protection against floods constitutes the optimum according to the criterion of socio-economic efficiency. A shift in this point may be achieved by a correction introduced as a Pigovian tax[23].

Flood losses are one of the principal components determining the effectiveness of flood protection. The concept and meaning of this measure was discussed by the author on numerous occasions [4, 9]. It should be emphasised that due to the indeterministic nature of floods, the value of flood losses is considered in stochastic terms and expressed as average annual losses. The value of average annual losses is described as follows:

$$L_{av} = \int_0^{\infty} p(Q_{max})L(Q_{max})dQ_{max} \qquad \text{Equation 1}$$

where:

$p(Q_{max})$ [.] – the probability density function of maximum flows,

$L(Q_{max})$ [PLN] – actual losses.

The social need for protection against floods is the resultant of the analysed components of hazards and their measure, i.e. risk. In risk scaling, the concepts of acceptable and tolerable risk appear, which are distinctly differentiated in view of an HSE

[23] Pigovian tax - the tax is named after the British economist Arthur Pigou who was the first to consider the problem of externalities. The Economics of Welfare, 1920.

definition (Health and Safety Executive, 1995). The concept of acceptable risk represents a level of risk agreeable to everybody whose life or health may be endangered, while tolerable risk is a level of hazard accepted by the society for socially justifiable reasons. An example is the construction of a dam with a multi-functional retention reservoir. The social interest in such a capital expenditure project is indisputable, but a potential hazard is generated in the valley which may become real in the case of disaster (a similar problem is posed by levees), and the community occupying the valley must accept this potential hazard. One of the frequently applied methods in determining the level of acceptance is the ALARP rule[24]. According to this rule, the risk whose level exceeds the limit of tolerance may be regarded as tolerable only if its reduction is impracticable or the costs of reduction are disproportionately high. This is not an equitable criterion. Most societies have adopted rational criteria based on the rules of equity and efficiency. All people have the right to a certain level of protection and any considered potential measures below that level are unacceptable [11].

Assuming that increased expenditures on a flood control project entail an increased capability of achieving its objective, and adopting the operational reliability of the flood control system or facility as the measure of achievement, is may be stated that increased reliability entails an increased cost and reduces flood losses, but external costs occur at the same time. The foregoing relationship may also be described as a function of project size or risk. The average annual loss function increases and expenditures decrease with increased risk. The relationship to project size is shown below.

$$F_{C_{soc}}(I) = L_{av}(I) + N(I) - E_z(I) \quad \text{Equation 2}$$

or, more frequently, directly:

$$F_{C_{soc}}(I) = L_{av}(I) + N(I) + C_{ex}(I) \quad \text{Equation 3}$$

is the decision variable, i.e. we seek the following formula

$$I \rightarrow \min[F_{C_{soc}}(I) = L_{av}(I) + N(I) + C_{ex}(I)] \quad \text{Equation 4}$$

where:

I – size of the capital expenditure project,
$F_{C_{soc}}(I)$ [PLN] – the social cost function taking into account the risk value,
$N(I)$ [PLN] – expenditures on the project,
$L_{av}(I)$ [PLN] – average annual loss function,
$E_z(I)$ [PLN] – the externalities function where external benefits are on the positive side and external costs are on the negative side,
$C_{ex}(I)$ [PLN] – external cost function.

[24] ALARP – as low as reasonably practicable.

The vicious circle of flood protection (of subjective solutions)

Floods pose a serious hazard to the development of people, in particular the urban population. The demographic growth, urbanization trends and climate changes augment natural threats. These circumstances impose on land managers the obligation to acquire knowledge how to plan and how to manage an urban environment, effectively minimizing the hazard. A strategic approach requires that all risk components be analysed, and those currently manageable be prevented using available methods, and that measures for preventing or mitigating the remaining risk components be considered. The resources engaged in the described decision-making process are insufficient, ineffective and consequently unreliable in most cases, as confirmed by the history of recent years. The vicious circle of flood control destroys the "results" of previously taken measures, contributing to the generation of continually growing flood losses. These facts bring us to considering the matter of rationality of this game played with nature.

A flood, correctly understood, is an undesirable social, economic and environmental event. The origins of floods lie in hydrological conditions, in the existing flood control infrastructure with limited capabilities, and in deficiencies in the decision-making processes carried out both in normal operating conditions and in emergency situations. The process of flood control activities leads to a limited influence of man and technology on flood events, and consequently the results are dramatically inadequate compared to expenses incurred.

The continual development of flood prevention infrastructure (e.g. embankments) paradoxically results in a limitation of flood control and escalates potential hazards.

It is worth consideration whether or not there are opportunities for development in areas that apparently are excluded from development. The "Floodpolis[25]" project addresses the above problems, emphasising their importance for optimal protection against floods. The results will include an approach to safe spatial planning in areas at risk with preserved parity between minimum risk and sustainable growth. This approach emphasises equal opportunities in contemporary, growing societies and provides equal rights for developing various personal capabilities. It is not discriminatory to the owners of land or properties located in the areas at risk, and minimizes disparities in development opportunities.

Using an approach that preserves the topology and "logic" of water runoff, a catchment approach with the bottom-up versus top-down rule preserved (an analysis and decomposition, and a synthesis), we are able to correctly embed in our concept the interrelationship between spatial planning and flood control, the most important components in the practical implementation of environmental

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[25] Floodpolis, Twaróg (the Faculty of Environmental Engineering of the Cracow University of Technology) & Kęsek (the Faculty of Architecture of the Cracow University of Technology) 2014.

objectives set by the WFD and the Floods Directive and in meeting developmental needs. This approach enables us to highlight the existing opportunities for spatial planning in urban and rural areas that are classified as flood plains and exposed to the flood risk located in developing countries. Solutions may be proposed that are designed to implement this type of spatial planning concept with safety of population preserved, external costs avoided and risk minimized. Spaces will be opened for both floods and the environment. This proposal is ground-breaking in its foundations, and casts a new light on spatial planning combined with a flood protection concept. The principal objective is to indicate development opportunities in areas that are apparently excluded from development. Additional results of this approach include emphasis placed on equal opportunities in contemporary, growing societies, on equal access to development, and non-discriminatory treatment of owners of land and properties located in problematic areas. The expected economic and environmental results are positive, although immeasurable and scarcely definable. The approach described is aimed at minimizing external costs through sustainable development, equalization of opportunities, social inclusion, opening space for floods, and the environment.

Definition of optimal size for a flood control project

A flood, correctly understood as an undesirable social, economic and environmental event, has an indeterministic nature, and therefore probability theory must be used in analysing it. Regardless of the aforementioned factors determining the origin of a flood, experience gained, in particular in the year 2010 (not only in Poland), confirms that the currently applicable flood protection procedure provides limited possibilities of human influence and limited technical measures, and this results in disproportionately poor effects as compared to expenses incurred. Continual extension of flood control infrastructure paradoxically limits our influence on floods and results in an escalation of potential hazards.

All these factors must be considered in order to solve the problem of optimum project size (e.g. the height of embankments). Naturally, this is a capital expenditure process and as such represents an activity extended in time. Therefore, the discount and accumulation function must be included in our analysis. A simple profit and loss account will be sufficient in this phase.

The result of flood control actions may be assessed using various criteria (Twaróg, 2002), some of which are listed below:

- reduction of flood wave peak with a given probability of excess,
- a changed probability density function of maximum flow appearance,
- a change in characteristic flow values,
- a change in average annual loss values,
- an increased area of protected land.

A reduction in the value of average annual losses is adopted as a reliable measure of protection efficiency. Active and reactive protection components are very often combined in flood control activities. This does not complicate our calculations. Each result may be separately denoted (Twaróg, 2002) as follows:

- for active protection activities

$$E_{ac}(I) = \int_{0}^{\infty} [p(Q_{max}) - p'(I, Q_{max})]L(Q_{max})dQ_{max} \qquad \text{Equation 5}$$

- for reactive protection activities

$$E_{rc}(I) = \int_{0}^{\infty} [L(Q_{max}) - L'(I, Q_{max})]p(Q_{max})dQ_{max} \qquad \text{Equation 6}$$

The flood protection result given above should be reduced by the hazard potential; let losses due to the hazard potential be expressed by the following equation in the entire sample space of the random variable:

$$U_{haz}(I) = \int_{0}^{\infty} q_u(I, Q_{max})L_{dis}(I, Q_{max})dQ_{max} \qquad \text{Equation 7}$$

where:

I – project size

$L(Q_{max})$ [PLN] – the function of flood losses in a valley,

$E_{ac}(I)$ [PLN] – the result of active flood protection,

$E_{rc}(I)$ [PLN] – the result of reactive flood protection,

$q_u(I, Q_{max})$ – the probability density function of the random variable of maximum flows affecting the hazard potential for the capital expenditure project,

$L_{dis}(I, Q_{max})$ [PLN] – losses due to an increased hazard potential, e.g. a disaster affecting the structure,

$U_{haz}(I)$ [PLN] – hazard potential,

$p(Q_{max})$ – the probability density function of appearance of a random variable, taking into account the hydrological chance variation,

$L(Q_{max})$ [PLN] – flood losses,

$p'(I, Q_{max})$ [.] – a probability density function of a random variable of maximum flows changed due to the project implementation,

$L'(I, Q_{max})$ [PLN] – flood losses changed as a result of project implementation,

Q_{max} [m^3/s] – a random variable describing maximum annual flows,

Therefore, we can express the sought solutions for the decision variable (project size) in the area of flood protection by maximizing the criterion:

$$max\,E_{impr}(I) = max[E(I) - U_{haz}(I)] \qquad \text{Equation 8}$$

where:

$E(I)$ [PLN] – the result of flood protection,

$E_{impr}(I)$ [PLN] – an improved result of flood protection.

This formulation of the problem makes the solution that previously would be regarded as an optimal or rational one lose its position in favour of solutions representing a lower hazard potential. This approach implements the principle of social level of flood protection. A question arises about the function of losses due to increased hazard potential. Emphasising the accidental nature of occurrences resulting from the existing hazard potential (e.g. disasters), we may conclude that financial losses and the probability density function are shifted towards events with very small probabilities of excess. The hazard potential component taken into account substantiates the statement that the existing flood protection level does not meet social expectations towards flood safety which leads to an apparently paradoxical but justified conclusion: the implementation of a flood protection concept has adversely affected flood protection efficiency.

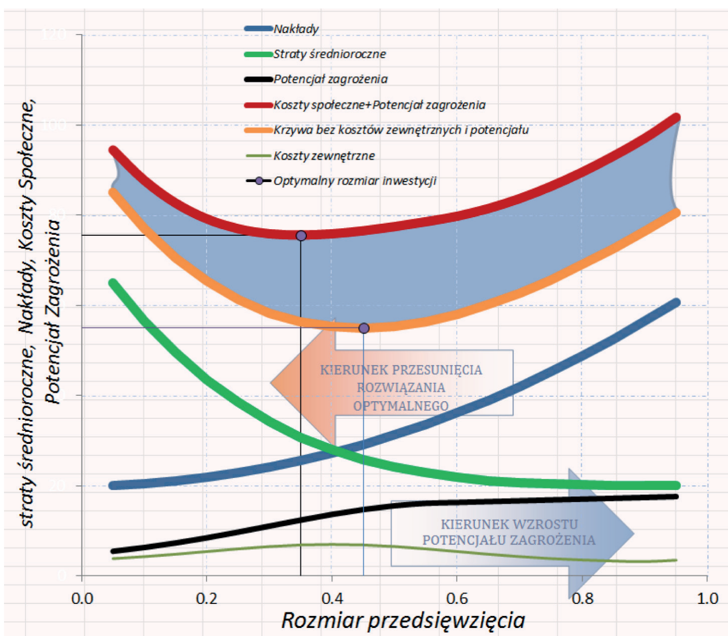

Figure 3. The effect of hazard potential on the optimal size of a flood control project

Conclusion

A flood, correctly understood, is an undesirable social, economic and environmental event. The origins of floods lie in hydrological conditions, in the existing flood control infrastructure with limited capabilities, and in deficiencies of decision-making processes carried out both in normal operating conditions and in emergency situations. The process of flood control activities results in a limited influence of man and technology on flood events, and consequently the results are dramatically inadequate as compared to expenses incurred. Both a wrong decision and an unsuitable solution in flood prevention may lead to undesirable damage. This paper also emphasises the fact that is confirmed during each flood: the continual development of flood prevention infrastructure (e.g. embankments) paradoxically results in a limitation of flood control and escalates potential hazards. This paper proposes a revision of the criteria used in seeking the best flood control method, by considering the risk, by taking into account externalities (external costs or external benefits) and the hazard potential. The concept of stream energy is proposed in the assumptions as a measure of hazard potential.

When the hazard potential component is taken into account, the size of a flood protection project may be reduced and facilities with smaller dimensions become attractive, Fig. 3.

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Summary

Despite the continual process of and progress in flood control activities, nevertheless humans and their technology have a limited influence on flood events, and as a consequence the results are dramatically inadequate compared to expenses incurred. In addition, wrong decisions and/or an unsuitable solution may lead to undesirable damage. The analyses contained below emphasis the role of preventive actions based on a comprehensive consideration of the various economic, social and environmental factors. This paper also emphasizes a fact that is confirmed during each flood: the continual development of flood prevention infrastructure (e.g. embankments) paradoxically results in a limitation of flood control and escalates potential hazards. This paper proposes a revision of the criteria applied in seeking the best flood control method, by considering the risk and taking into account external cost components and the hazard potential.

Key words: flood control, potential hazards, external costs

JEL classification: Q56