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EFFECTIVENESS OF FLOOD PROTECTION PROJECT VALUATION METHODS

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K e y w o r d s: effectiveness, indifference curve, flood protection, net present value.

A b s t r a c t

Projects for flood protection are increasingly the subject of investment projects in the field of water management. This is related to the increasing frequency of worldwide threats caused by extreme weather conditions, including extremely high rainfall causing floods. Technical and non-technical flood protection measures are also increasing in importance. In the decision-making process, it is necessary to take into account both the costs and benefits of avoiding losses, including an analysis of social benefits, whose valuation of non-market goods is an essential element. A comprehensive account of projects in the field of flood protection based on the estimated costs and benefits of the investment allows the economic efficiency from a general social point of view to be determined. Previous evaluations of the effectiveness of investment projects have mainly taken into account only categories and market values. The aim of the article is to identify the possibilities to expand the values of non-market assessments and categories formulated on the basis of the theoretical economics of the environment.

METODY OCENY EFEKTYWNOŚCI PRZEDSIĘWZIĘĆ Z ZAKRESU OCHRONY PRZECIWPOWODZIOWEJ

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S ł o w a k l u c z o w e: efektywność, krzywa obojętności, ochrona przeciwpowodziowa, wartość bieżąca netto.

A b s t r a k t

Przedsięwzięcia dotyczące ochrony przeciwpowodziowej coraz częściej stanowią przedmiot projektów inwestycyjnych z zakresu gospodarki wodnej. Ma to związek ze zwiększającą się częstotliwością występowania na całym świecie zagrożeń wywołanych ekstremalnymi zjawiskami klimatycznymi, w tym ekstremalnie wysokimi opadami deszczu, które prowadzą do powodzi. W ramach ochrony przeciwpowodziowej są wykorzystywane zarówno środki techniczne, jak i nietechniczne, które zyskują coraz większe znaczenie. Podczas podejmowania decyzji dotyczących wyboru rozwiązań konieczne jest wzięcie pod uwagę zarówno kosztów, jak i korzyści wynikających z uniknięcia strat, w tym przeprowadzenie analizy korzyści społecznych, których integralną podstawę stanowi wycena dóbr nierynkowych. Całościowy rachunek przedsięwzięcia z zakresu ochrony przeciwpowodziowej na postawie oszacowanych kosztów i korzyści wynikających z realizacji inwestycji pozwala określić efektywność ekonomiczną z punktu widzenia ogólnospołecznego.

W dotychczasowych ocenach efektywności przedsięwzięć inwestycyjnych brano głównie pod uwagę kategorie i wartości rynkowe. Celem artykułu jest wskazanie możliwości poszerzenia tych ocen o wartości i kategorie pozarynkowe formułowane na gruncie podstaw teoretycznych ekonomii środowiska.

Introduction

Recent decades have witnessed an increase in threats caused by extreme climatic events all over the world. They have caused an increasing risk to human safety and result in significant losses to the economies of individual states. In Poland, as in many European states, the greatest threat of all climatic events is related to extremely high rainfall. More and more frequently, intensive, multi-day rainfall tends to cover large areas causing floods, while short but heavy rains lead to sudden swelling of small streams and brooks, causing local flash floods (LORENC et al. 2012, p. 7).

Large floods occur in Poland once in about a dozen years. However, it seems that this frequency has significantly grown in recent years. This has been accompanied by systematic growth of economic losses, the volume of which depends on the intensity of human activity in areas at risk. For this reason, one of the basic principles of flood control is to limit business activity in these areas. Only as a second step should activities consisting in construction of preventive structures be taken (JOHNSON 1976, pp. 273–274). Progressive urbanization processes have resulted in a loss of retention properties held by natural areas and an increase in the surface runoff. The surface runoff index in undeveloped areas is 10%, while in areas with hardened surfaces it can reach 60–90% (MANTEUFFEL, BUKOWSKI 2010, p. 55). Table 1 presents the approximated estimates of losses caused by large floods occurring in Poland in recent decades.

One of the most significant reasons for increasing flood losses is the deteriorating condition of protective facilities, caused by their unsatisfactory maintenance. Before the largest flood of recent decades in 1997, which brought about the highest economic losses and the deaths of over 50 people, 25% flood control dams existing at that time were in urgent need of restoration. The condition of 20 out of 240 retention reservoirs was similar (AMBROŻEWSKI 1997, pp. 166, 167). In March 2010, the Supreme Audit Office found that a half of the flood control dams in the Lesser Poland Province (the region that suffered the greatest losses as a result of floods of May and June 2010) did not guarantee safety due to their poor technical condition (*Znowu...* 2010).

Table 1

The extent of losses caused by floods in selected years in Poland

Type of loss	Year											
	1934*	1958	1970	1977	1979	1980	1981	1982	1983	1997	2001	2010
Flooded area [thousand ha]	250	352	156	215	470	1745	80	111	14	521	402	400
Destroyed and damaged buildings [thousands]	22.0	27.0	23.0	10.0	17.7	26.0	7.5	6.6	1.07	2.39	25.9	2
Destroyed and damaged bridges	102	1207	1,400	612	147	135	29	617	47	4,048	2254	1,469
Destroyed and damaged national roads [km]	100	596	751	2321	478	348	68	618	140	14,432	56343	81,160
Destroyed and damaged dams [km]	100	330	100	38	118	14	47	94	29	721	450	185
Number of evacuated persons [thousands]	0.1	55.6	35.0	20.0	33.2	4.0	1.3	16.0	2.0	150.0	20	23
Victims	x	x	x	x	x	x	x	x	x	54	18	9
Losses in PLN mln, price level of 2013	1,096	1345	1,777	2990	2,102	6,028	660	984	490	23,635	4,600	11,197

x – no data

* Losses of 1934 recalculated to the 1999 price level by dividing the losses by the exchange rate to the USD in 1934 (5.3 PLN/USD), multiplied by the average rate in 1999 (3.98 PLN/USD) and by the USD inflator in the years 1934–1999 equal to 12.42 (U.S. Department. 2003). Other losses were recalculated with the Polish consumer price index.

Source: Own study on the basis of the BOROWSKI (1984), *Powódź 2010 będzie*... (2010), *Już*... (2010); *Ochrona*... (1995–2009 passim), *Środki*... (2010).

Flood protection measures can be divided into technical and non-technical means (KLEDYŃSKI 2011, p. 244). Technical means primarily include hydrotechnical structures and engineering operations. They are classified as:

– active protection means – facilities and operations that may affect flow and water levels in water courses, such as retention and balancing reservoirs or polders,

– passive protection means – measures and facilities aimed at preventing water flooding beyond the designated area, such as embankments.

Apart from technical means, non-technical measures, including activities and regulations discouraging people from settling on or developing flood plains, or encouraging them to leave those lands and withdraw intensive forms of economic use from those areas, are increasingly gaining in importance. This group of measures include spatial planning, construction law, insurance, education, etc. (KLEDYŃSKI 2011, pp. 244, 245).

Traditionally, while choosing the flood protection variant, the guiding principles were, first of all, technical parameters of facilities required to ensure the assumed level of safety, such as the elevation of the embankment, or the capacity of the retention reservoir. However, since such an approach does not take into account the value of protected areas, it does not include the efficiency of the protective measures applied. While taking decisions concerning the choice of solutions, their costs are taken into account, but the benefits resulting from avoidance of losses are not considered.

The previous evaluations concerning the efficiency of investment undertakings mainly focused on categories and market values. The aim of this article is to demonstrate the possibilities of extending those evaluations with non-market values and categories established on the basis of theoretical foundations of environmental economics.

Research methods

The basis for conducting an economic evaluation of the protection of polders against floods can be provided by the model developed by MANTEUFFEL (1987, p. 102). It assumes the following effects resulting from the growth of flood control expenditures:

– reduction of flood losses in properties located in the protected area, taking into account the change in its value over the period covered by the calculation;

– reduction of losses caused by interruption or deterioration of economic activity during the flood and removal of its effects;

– intensified development of protected areas resulting from an improved safety level;
– savings in operating costs of flood control facilities;
– savings in costs of flood control actions.

As results from observations of social behaviour during the flood in the Żuławy region in 1983 and the flood in the south of Poland in 1997, it would advisable to include, as a flood control improvement effect, the feeling of safety of persons inhabiting, temporarily staying at or carrying out their business activity in protected areas (LIZIŃSKI 2007, p. 36). The feeling of safety of persons related to polders should be considered an additional effect of flood control, although its evaluation is difficult.

The starting point for evaluating non-market goods is to determine the source of the economic value of goods. The neo-classical theory of economics assumes that this value results from the usefulness provided by the consumption of those goods (consumption can also be non-material) – i.e. goods are valuable when they contribute to satisfying (certain) human needs. The value of goods is composed of two aspects: functional – if a consumer directly uses the goods or has such a possibility (use value), and non-functional – if the satisfaction is derived not from using the goods, but from the mere fact of their existence (non-use value) (ŻYLICZ 2009, p. 8).

The total economy value concept of natural resources is applied in the environmental economics (called. The total economy value concept) which is based on the assumption that each resource has its value, which gives it depending on the method and the effect of its use (WOŚ 1995, p. 71). PIERCE and TURNER proposed the following distribution of the total economic value:

1. Use value, including:
– the value arising from direct use,
– the value arising from the indirect use of the resource.
2. Non-use value:
– optional value,
– bequest value,
– existence value (PIERCE, TURNER 1990).

An example of direct utility value may be the market price of wood or water consumption or for irrigation. From the forest functions it is resulted that an indirect use value of the forest need to recognize as the value of landscape, biodiversity, oxygen production and carbon dioxide reduction. Water used for consumption or irrigation also form the landscape, can be used in sport and transport, create conditions for biodiversity, namely have a value resulting from indirect consumption.

The optional value follows from the shift in consumption over time and towards future needs. Additional values may result from prolonged functioning of ecosystems, as well as better opportunities to use resources in the future as a result of the development of science and scientific and technical progress.

The bequest value as part of the natural resources total value which can be passed to future generations. The altruism of the present generation and solidarity with future generations is noted in this value. This value implements intergenerational solidarity, which underlying the sustainable development. For some groups it has utility value because it gives them satisfaction with transfer of resources to other, endowments them.

Existence value is assigned to the fact of the natural resources existence regardless of the benefits that they bring now or will bring in the future. This value is particularly high in the case of rare, unique objects. It can therefore in theory and in practice skip division of use and non-use, and the total economic value (TEV) represented as the sum of direct consumer value (W_{kb}), indirect consumer value (W_{kp}), optional value (W_o), bequest value (W_{dz}) and existence value (W_e)(LIZIŃSKI 2010, p. 121):

$$\mathrm{PWE} = W_{kb} + W_{kp} + W_o + W_{dz} + W_e$$

Many investment, in particular in the sphere of flood protection investments affect the state of protected resources including human capital and natural resources. It is therefore appropriate to take into account non-market effects of these investments.

The starting point for evaluating non-market goods is to determine the source of the economic value of goods. There are several methods leading to an approximate evaluation of effects for which no market exists where their prices could be determined. The most popular of them include:

– contingent valuation method,
– travel cost method,
– hedonic prices method.

The assessment of all values of environmental resources and services is based on the assumption that the maximum amount that individuals are willing to pay for given environmental goods or services (at a given level of income and other features) provides a proper evaluation of the economic value of these goods or services.

Figure 1 presents the consumer's indifference curves for environmental goods and for market goods purchased for financial income at their disposal. Going from point A of the indifference curve U_2, to Point B, the consumer can pay an amount equal to $D_0 - D_1$ for improvement of the environment from status S_0 to S_1, which is described as willingness to pay (WTP). This is an amount which may be deducted from the initial level of income, leaving the total usefulness at the same level as before the improvement of the environmental quality. Additionally, the consumer retains the same total usefulness while passing from Point A to C . However, deterioration of the environmental quality requires compensation in the income equal to $D_2 - D_0$, which is the so-called willingness to accept (WTA).

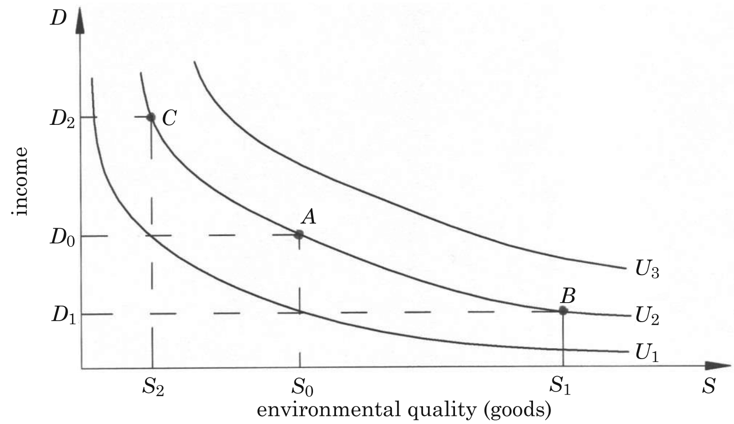

Fig. 1. Customer indifference curve for two types of goods: income D and environmental quality S
Source: own study.

The above general model can be also applied to evaluate the usefulness of flood protection safety, or to evaluate the acceptance of flood risk. WTP and WTA provide a financial measure for non-market goods for the consumers. For various reasons, theoretical and technical, most economists support the application of WTP in empirical research.

Assuming that the feeling of safety of persons related to polders at risk of flood is a good or a service resulting from improvement in flood control measures, the model of economic evaluation proposed by MANTEUFFL (1987, p. 101) can be extended as follows (LIZIŃSKI 2000, pp. 69–71):

$$\mathrm{NPV} = \sum_{t=0}^{m} \frac{1}{(1+r)^t} \left[\sum (S_{it} + \mathrm{RT}_{it} + \mathrm{KEB}_{it} + \mathrm{KAP}_{it}\, \mathrm{WPB}_{it} - \mathrm{KI}_{it} - \mathrm{KEZ}_{it}) - \mathrm{KW}_t\right] \tag{1}$$

where:

NPV – net present value of the project (with NPV > 0 as a condition of effectiveness),

m – calculation period,

t – current index denoting the number of the year,

i – index denoting the number of the protected area,

r – discount rate,
S – expected value of flood losses in the property in the protected area,
RT – effect of intensifying the development of the area,
KEB – costs of operating flood control facilities avoided as a result of the project,
KAP – probable saved costs of flood control operations,
WPB – value of the increase in the feeling of safety as a result of the undertaking, calculated with the use of the CVM or HPM method,
KI – investment expenditures in the protected area,
KEZ – current (operating) expenditures in the area,
KW – expenditures related to the undertaking as a whole, which cannot be assigned to only one protected area.

Research results

The proposed computational model was used to evaluate the economic effectiveness of investments planned to be carried out as a part of the project entitled „The Comprehensive Flood Protection of the Żuławy Marshlands – Stage I – the City of Elbląg".

The project is one of the elements of the first stage of the program entitled „The Comprehensive Flood Protection of the Żuławy Marshlands – 2030 (including the 2015 stage)" also known as the „Żuławy Programme – 2030" commissioned by the Director of the Regional Water Management Board in Gdańsk. The project involves reconstruction of the flood protection system, reconstruction of technical flood control infrastructure and ensuring efficient operation of the drainage system for polder buildings in the Elbląg city area. Technical solutions applied within the project are based on embankments and sheet piling, while reconstruction of the drainage system involved reconstruction of drainage ditches, main courses of stormwater drainage systems based on the commonly-applied system of pipelines and ducts, with pre-treatment facilities and pumping stations. As part of the project, a Local System of Flood Risk Monitoring and Response Support was constructed, including construction of telemetry measurement stations with flood forecasting modules. The Local System covers the city of Elbląg and the entire Elbląg Żuławy. The total value of investment expenditures amounted to PLN 42,320,000.

While calculating operating costs, the schedule of investment implementation was taken into account, assuming that operating costs will rise in the year following the completion of a given task. The structure and the amount of operating costs of the pumping stations was established on the basis of operating costs related to maintenance of flood control facilities obtained from the Żuławy Authority for Land Improvement and Water Facilities. Information about the amount and the structure of operating costs related to stormwater drainage system maintenance was derived from the study of the Elbląg Water Supply and Sewage Works prepared at the request of the City Hall in Elbląg. The maintenance costs for the monitoring system were calculated on the basis of operating costs of the Crisis Management Department of the City Hall in Elbląg. Table 2 presents unit operating costs at current prices of 2010 and the cost structure.

Table 2

Unit annual gross costs of operating individual new elements of the system, arising as a result of project implementation

Specification	Unit	Quantity	Unit cost [PLN]	Total annual costs [PLN]	Structure [%]
Payment for monitoring operation services	pcs	1	300,000	300,000	100
– energy costs	PLN			120,000	40
– labour costs	PLN			120,000	40
– service costs	PLN			30,000	10
– material costsąpcs	PLN			30,000	10
Payment for pumping station operation	pcs	1	60,00	60,000	100
– energy costs	PLN			18,000	30
– labour costs	PLN			18,000	30
– service costs	PLN			12,000	20
– material costsąpcs	PLN			12,000	20
Payment for cleaning separators and settling tanks	pcs	twice a year	4,000	8,000	100
– energy costs	PLN			1,600	40
– labour costs	PLN			2,000	50
– service costs	PLN			0	0
– material costsąpcs	PLN			400	10

Source: the City Hall, the Elbląg Water Supply and Sewage Works, the Żuławy Authority for Land Improvement and Water Facilities.

The forecast of operating costs took into account only the difference between operating costs related to maintenance of the designed system and the currently incurred costs. The calculations were carried out at variable prices, assuming an increase in costs consistent with the estimated increased inflation rate, and an increase in payroll costs consistent with the estimated real wage growth rate.

Investment implementation does not involve any additional source of income for the city. Its main aim is to improve flood safety of inhabitants, achieved by modernization of existing and construction of new facilities and structures (embankments, sheet piling) and by modernization of the stormwater drainage system in selected areas of the city. The result of the Project is improvement of flood safety in the area of more than 23,000 ha, affecting more than 65,500 people.

The analysis of social benefits resulting from the project included the following elements:

– reduction of flood losses in the property of inhabitants;

– reduction of flood losses in industry, taking into account property losses as a result of disrupted production and costs suffered in relation in flood control operations;

– reduction of flood control operations suffered by the city,

– reduction of costs related to psychological losses caused by the possibility of evacuation and suffering property losses (both with regard to natural persons and enterprises),

– improvement of environmental (life) quality, evaluated with the use of the hedonic price method – the value of the improvement was evaluated on the basis of an increase in the value of land situated in the areas covered by modernization of stormwater drainage system,

– improvement of tourist and recreation value of the river as a result of engineering water conditions in the drainage area within the town boundaries and as a result of engineering the outflow of significant amounts of pre-treated (desandings, separators) of rainwater.

While establishing social benefits, which are the external effect of project implementation, the following assumptions were made:

– as regards the benefits concerning improvement of the river water quality – it was assumed that this effect would be fully perceptible from 2016; until then, the value will increase every year starting from 2012. This increase will be linear, until the target value is reached in 2016;

– as regards benefits concerning reduction of property losses and costs of flood control operations – the flood that affected Elbląg in 2009 provided a basis to calculate those effects. It was assumed that the water level occurring at that time corresponded to a 100-year high. Due to the fact that it is not possible to determine when a flood of this magnitude will take place, it was assumed that the probability of its occurrence in each consecutive year equals 0.01 (it results from the probability of a 100-year water). Additionally, it was assumed that the constructed flood protection system will contribute to reducing property losses proportionally to the growth of the protection system elevation (from 2.20 to 2.80, i.e. by 27.3%);

– as regards benefits concerning reduction of psychological losses – it was assumed that the feeling of anxiety and resulting mental discomfort is a constant phenomenon accompanying inhabitants of flood areas. A fear of evacuation and of possible loss of property occurs continuously and concerns every year, regardless of the fact of whether a flood occurred in a given year or not. News about new floods occurring increasingly more frequently in Poland and in other countries intensifies the feeling of anxiety. The feeling of threat can be reduced by constructing (modernizing) flood control facilities. The analysis assumed that benefits concerning a reduction of psychological losses would be proportional to the growth of the embankment elevation in the municipal flood control system. The value of the effect concerning reduction of psychological losses was calculated with the use of the WTP method. To determine the WTP amount, a survey questionnaire was used, created for the purpose of the research carried out in the Żuławy Research Centre ITP, concerning evaluation of intangible value of goods and services. The survey was carried out on a representative sample of 155 persons. In this group, six persons did not provide a response to the question concerning willingness to pay for the improvement of flood safety. In the first stage of selection, of the respondents who answered, persons inhabiting the area of the Żuławy region were selected from this group as potentially threatened with floods caused by water courses or water reservoirs at risk of an inside-polder flood. A further analysis was carried out for the selected group of 72 respondents. In the second stage, persons with household income per capita exceeding PLN 1,500 were eliminated from the group (it was assumed that the area of Project implementation was inhabited mainly by persons of low and medium income) and who declared amounts exceeding 30% income per capita (as it was assumed that responses in which the declared amounts accounted for a significant part of monthly income proved that the respondents did not understand the question correctly). The WTP amount was calculated as the arithmetic mean for the 55-person sample. Thus, the calculated index amounted to PLN 540/person/year;

– improvement of life quality was determined using the hedonic price method, on the assumption that environmental quality, being one of the components of total life quality, is one of the elements affecting real estate prices. Consequently, a change in environmental quality (both negative or positive) is reflected in the price of real estate in the area affected by the change. When other parameters remain unchanged (the size of the flat, the type of the building, the number of rooms, etc.), the change in price results from the change in the environment. In the analysis, an increase in the unit price of one square meter of plot in the area covered by the investment was assumed to be a carrier of benefits concerning the improvement of environmental quality (and of life quality in general). This benefit will occur on a one-time basis (the growth process is not continuous, the growth that emerges may be sustained only by a certain period), in the second year after the completion of a given investment task.

Table 3 presents the values of social benefits related to project implementation for selected years, updated to the current level of prices using the inflation rate based on the forecasts of the Ministry of Economy.

Table 3

Social benefits resulting from the project

Type of benefits	Unit	2010	2011	2012	2013	2014	2024	2034	2039
BENEFITS FROM LIFE QUALITY IMPROVEMENT									
Value of the effect	[PLN ’000]	0	0	0	32,797	0	0	0	0
Total	[PLN ’000]	0	0	0	32,797	0	0	0	0
IMPROVEMENT OF WATER QUALITY IN THE RIVER									
Value of the effect	[PLN ’000]	0	0	306	626	964	2,076	2,684	3,052
Total	[PLN ’000]	0	0	306	626	964	2,076	2,684	3,052
REDUCTION OF PROPERTY LOSSES									
Inhabitants	[PLN ’000]	0	0	0	0	1	1	2	2
Industrial plants	[PLN ’000]	0	0	0	0	1	5	6	7
Total	[PLN ’000]	0	0	0	0	2	6	8	9
REDUCTION OF COSTS OF FLOOD CONTROL OPERATIONS									
Value of the effect	[PLN ’000]	0	0	0	0	0	1	1	1
Total	[PLN ’000]	0	0	0	0	0	1	1	1
REDUCTION OF PSYCHOLOGICAL LOSS RELATED TO									
Evacuation of inhabitants	[PLN ’000]	0	0	0	0	73	151	151	151
Property losses of inhabitants	[PLN ’000]	0	0	0	0	7	18	24	27
Property losses in industry	[PLN ’000]	0	0	0	0	4	4	4	4
Total		0	0	0	0	84	173	179	182

Source: own study.

On the basis of estimated costs and benefits resulting from implementation of the investment, its economic effectiveness from the perspective of general society was determined. The basic index of effectiveness evaluation, which is NPV (calculated from formula 1) was supplemented with additional indices such as internal rate of return, payback period and the benefit-cost ratio. According to guidelines provided in the „Methodology of determining economical effectiveness of investments concerning water, land reclamation and water supply for rural areas. In the industry instruction of the Ministry of Agriculture and the Institute for Land Reclamation and Grassland Farming”, the social discount rate was assumed at the level of 8%. Social discount rate in the economic analysis reflects the social point of view on future benefits and costs measure method in relation to the present. Its height is dependent on macroeconomic conditions in the country, the type of the investor or sector, whose investment concerns (eg. transport, environment, energy).

Figure 2 presents the development of the net present value of the investment depending on the length of the period for which the evaluation is made. It shows that the payback period for the project described is seven years. Such a short period necessary to obtain the total return of the expenditure results from a one-time benefit in the form of improving life quality, which, according to the assumptions made for calculation purposes, will occur in the second year after the completion of a given investment task. This is the reason for the significant growth of NPV observed in 2013.

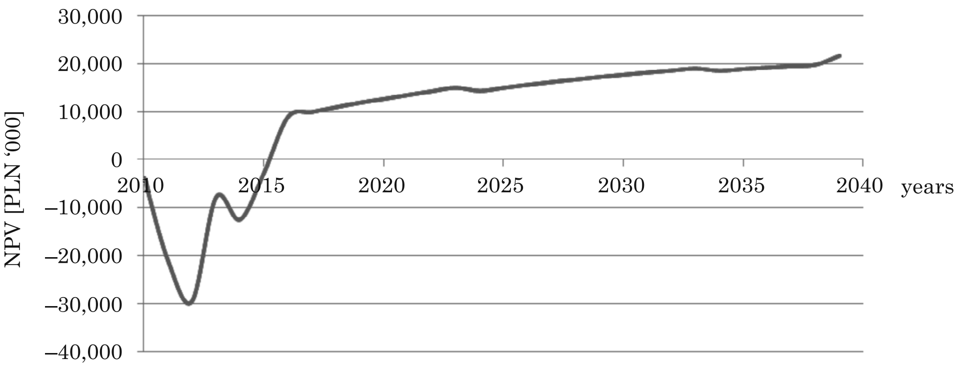

Fig. 2. Variation of net present value of the investment in the 30-year period of the analysis
Source: own study.

Summary

Apart from technical means of flood protection, non-technical measures, including activities and regulations discouraging people from inhabiting and from intensive development of flood plains, or encouraging inhabitants to leave those areas and withdraw intensive forms of economic use, are increasing in importance. However, since a „technical" approach does not take into account the value of protected areas, it does not include the efficiency of the protective measures applied. When choosing a solution, its cost are taken into account, although the advantages resulting from avoidance of loss are not considered.

Investments in flood protection area affect all of them protected resources including human capital and natural. By economic assessment of these investments valuation of protected resources based on the total economic value concept is justified. It contains an use value, including the value resulting from the direct use and value derived from an indirect use of the resource and the non-use value consisting of an optional value, bequest and existence value.

According to the proposed calculation model in assessing the effectiveness of projects in the field of flood protection should be considered the following social benefits resulting from the implementation: reduction of flood losses in inhabitants' property, reduction of flood losses in industry, reduction of costs related to flood fighting operations, reduction of costs related to psychological losses, improvement of environmental (life) quality evaluated with the hedonic price method, improvement of the tourist and recreational value of the river.

Overall calculations concerning a flood control project, based on estimated costs and benefits resulting from investment implementation, can be used to determine the economic effectiveness from the perspective of general society. The basic ratio of effectiveness evaluation – NPV – may be supplemented with additional ratios such as internal rate of return, payback period and benefit--cost ratio. An important issue is the choice of the discount rate, the value of which depends on the type of the project.

The obtained values of indices describing the effectiveness of the investment are:

– discount rate	r=8%
– economic internal rate of return	ERR=21.64%
– economic net present value	ENPV= 21,542,000 PLN
– payback period	5 years
– benefit-cost ratio	B/C=1.45

The presented results show that the investment is justified from the social point of view (calculated ENPV is higher than 0, while ERR exceeds the assumed discount rate). On the other hand, comparison of the results of the economic analysis with the results of the financial analysis justifies the need to support the investment with public funds. The above-presented results prove the economic effectiveness of the investment from a social perspective.

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