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Development Impact Bonds in Financing Flood Risk Management

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Abstract

In this paper, the authors propose a new innovative solution to financing flood prevention and financing its consequences using the development impact bonds model. Firstly, the necessity of financing the flood problem is to be described as a public task, including the presentation of previous methods and solutions. Secondly, the authors derive a new model for financing flood problems basing on development impact bonds. This kind of financing comes from the New Public Management idea called "payments-by-results". The new model shows that there is a possibility to construct a financial mechanism, which allows financing anti-flood interventions, such as relocation of residents from flood-threatened areas, using private financial resources, and giving the government the guarantee to pay only for the success of the intervention, which means a guarantee of effective public spending. At the end of the paper a SWOT analysis into this solution is presented.

Keywords: flood risk; social impact bonds; development impact bonds; insurance companies; relocation.

JEL classification: G22; G23; H40; H54; H70; H84; Q54.

1. INTRODUCTION

Nowadays, in the face of the ongoing climate change and increasingly unpredictable natural phenomena it is essential that public authorities should take all due measures to counter the flood risk and perform successful recovery measures. There are two types of flood risk management, namely: damage elimination and prevention policies. Preventing floods can be performed by e.g. erecting flood embankments or building storage reservoirs. Additionally, it is also possible to limit the impact of floods by e.g. socially responsible relocation of citizens from the impact areas with a concurrent redefinition (rebranding) of their business activity (Thaler and Hartmann, 2016). At the same time, under newly devised spatial development plans, the periodically flooded areas must not be intended for settlement.

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The objective of the study is to find a sustainable way to finance the costs related to relocation from flood areas and rebranding business activity in this area. Three issues were the motivation for writing the article. On the one hand, a number of studies indicates the need to change the use of flood areas in order to reduce total losses (Barredo, 2009; Bubeck et al., 2017; Paprotny *et al.*, 2018). The second reason is the sources of the law. The Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 has established a framework for Community action in the field of water policy applies. There are a country's responsibilities in this matter.

The third reason for the preparation of this study is the governmental work having been started in Poland on the implementation of flood risk management. In the light of the act having been prepared, there are four types of activities: a) non-technical activities (e.g. new procedures); b) technical activities (e.g. construction of new storage reservoirs on rivers); c) business activity rebranding; d) relocations from flooded areas. In the article below, the authors focused on identifying the sources of funding for c-d activities.

Socially responsible relocations, i.e. relocations safeguarding financial benefits, are aimed at countering the impoverishment of the individuals or businesses affected by floods. Such relocations can generate benefits for both local communities and the local economy (at the province level). It must be stressed that the officials working on the relocation programmes are lacking in the "compass" showing the direction of fair financial resources allocation and the prevention (or mitigation) of the risk of impoverishment of particular entities (Cernea, 1997, 2000). As a matter of fact, the approach to planning under which many are relocated but only few "rehabilitated" proved a huge failure in preventing impoverishment. The recurring instances of relocation without rehabilitation reveal basic shortcomings in the policies of many countries, not only at the planning stage.

If the tasks are to be implemented successfully, it is essential that public authorities are equipped with relevant financial resources. One of the sources could be the traditional financing from the budget. However, in the authors' opinion, it is also possible to introduce an innovative form of financing, i.e. development impact bonds (DIBs) what is the main authors' contribution to the literature, presented in this elaboration. The paper opens with a short outline on the financing of public tasks into the elimination of flood damage and prevention of floods recurrence. Next, the authors put forward a new model of financing involving DIBs tailored to the needs of flood risk financing. The paper closes with a SWOT analysis of the proposed financial model.

2. FLOOD RISK AS A PUBLIC TASK

Despite all the legal actions taken already and multiple investments in infrastructure, periodically flooded areas still remain heavily populated (residential buildings) with additional facilities in place (including schools, preschools, nursery schools, convalescent homes, plants and factories), the destruction of which might cause serious social and economic damage. A number of detailed analyses into legally reducing the flood risk and facilities damage is there to be found in numerous publications. A comparison of the regulations of particular countries confirms that relevant solutions involving prevention, damage elimination and compliance with international guidelines (regulations for EU member states) are already in place (Begum *et al.*, 2007).

A combination of misconceived land planning, increased impoverishment and a number of other often unidentified factors makes the given inundation area even more vulnerable to natural catastrophes including floods in the first place. Flood as a natural phenomenon has always threatened the human kind. Over the past two decades, the ongoing urbanisation process and the intensified occurrence of natural phenomena have been the prime reasons behind increased flood damage.

Flood as a natural phenomenon has the following dimensions:

– environmental – the impact of flood on the environment; the impact of flood prevention technology measures on the environment (Badenko *et al.*, 2016);

– social – the attitudes of the community before, during and after the flood; the impact of the flood on the health condition of citizens and their physical and psychical condition; changes in attitudes to travelling and relocation;

– economic – material damage to infrastructure; losses caused by hindered economic activity; the costs of flood-prevention measures.

Many countries are taking various initiatives in order to minimise the occurrence risk of natural disasters and technology catastrophes (the instance of Canada described in: Shugart, 2001). The plans of actions pertaining to catchment areas should consider optimal technology and non-technology solutions in terms of flood prevention and damage limitation. The plans should be devised by the water administration in cooperation with local governments and local institutions. Intensifying actions at the local level, especially in terms of prevention, could be of key importance in flood damage limitation. Many sources point to this type of activity as one of the most effective measures to be implemented. One of the examples of providing successful protection and viewed by citizens as very attractive is the instance of Florence. Areas around the river Ema, a tributary of the city's biggest river, the Arno, are exposed to the risk of being flooded during high water. When the river is not in flood, these areas turn into parks to be enjoyed by the citizens (European Investment Bank, 2020, p. 30).

This paper provides a detailed description of two types of activity: relocation and business activity rebranding in catchment areas. (A detailed description of these activities in De Wet, 2006).

Within the subject area of this paper, the analysis deals with fluvial floods, as described in Table no. 1.

Table no. 1 – Types of flood under analysis

Flood type under EU classification	EU definition	Flood type under Polish classification prior to adoption of Flood Directive	EU codes*		
			S	M	CH
Fluvial flood (A11)	Flood as a result of the high water of rivers, streams, mountain creeks and brooks, canals, lakes and meltwater	Rainwater flood[1]	A11	A21	A39
		Flash flood[2]	A11	A21	A31
		Meltwater flood[3]	A11	A21	A32
		Winter flood[4]	A11	A24	A39
		Water overflowing floodbank	A11	A22	A33
		Destruction or damage of floodbank	A11	A23	A33

*Symbols: S: flood type by source; M: flood type by mechanism; CH: flood type by characteristics

A description of the threat scale of this flood type in Europe is provided in Table no. 2. The greatest fluvial flood coverage is in Romania and Austria. In the Netherlands, the coverage is ca. 3% of the country's total area, the threat being mostly sea water – A14.

Table no. 2 – Computed statistics per country in the event of a complete relocation (i.e., sensitivity factor = 100%) of people and assets within the relocation mask defined in Sect. 2.1.4. Risk reduction values are averaged over the years 2006-2010 and seven regional climate models

Country	Code	Country area [%]	Country population [%]	Risk reduction [%]	
				Expected damage	Population affected
Austria	AT	0.91	1.93	60	17
Belgium	BE	0.66	0.76	36	9
Bulgaria	BG	0.69	0.29	48	9
Croatia	HR	2.14	0.34	20	3
Czech Republic	CZ	0.73	1.12	78	27
Denmark	DK	0.02	0.00	1	1
Estonia	EE	0.23	0.11	5	14
Finland	FI	0.25	0.27	8	3
France	FR	0.64	0.66	37	10
FYROM	MK	0.69	0.91	77	19
Germany	DE	0.89	0.53	59	12
Greece	EL	0.21	0.01	35	1
Hungary	HU	2.97	0.47	20	3
Ireland	IE	0.27	0.49	52	18
Italy	IT	0.71	0.29	24	7
Latvia	LV	0.99	1.10	39	12
Lithuania	LT	0.89	0.93	50	27
Luxembourg	LU	0.75	2.21	66	23
Netherlands	NL	3.03	2.39	24	7
Norway	NO	0.28	0.80	62	19
Poland	PL	0.95	0.41	34	8
Portugal	PT	0.60	0.19	84	43
Romania	RO	1.50	0.23	37	4
Slovakia	SK	0.67	0.53	10	3
Slovenia	SI	0.66	1.46	55	21
Spain	ES	0.38	0.38	48	17
Sweden	SE	0.35	0.44	45	11
United Kingdom	UK	0.22	0.16	14	6

Source: Alfieri et al. (2016).

Therefore, a number of questions must be answered: is there any risk (i.e. probability) of facilities being flooded; what is the probability of the risk; what are the facilities at risk, specifically; what are the consequences of the flooding; how can the flood risk be eliminated; is it possible to minimise the risk; what work and activities can be performed to minimise or eliminate the damaged inflicted. A tool that serves to identify the facilities threatened with the flood risk is flood maps. They have been put in place in every EU member state. The analysis presented below deals with a localisation in the vicinity of the town of Oława on the river Oder. The maps offer a comparison of flood risk once in every 100 years against the map of flood risk. The other map provides identification of the

components of the threatened infrastructure: residential buildings – marked with the colour orange (flooding above the 2 metre level); public facilities (school, preschool, hospital, police station, nursery home, shopping mall, etc.) – marked with the colours violet and blue (flooding up to the 2 metre level and above the 2 metre level, respectively).

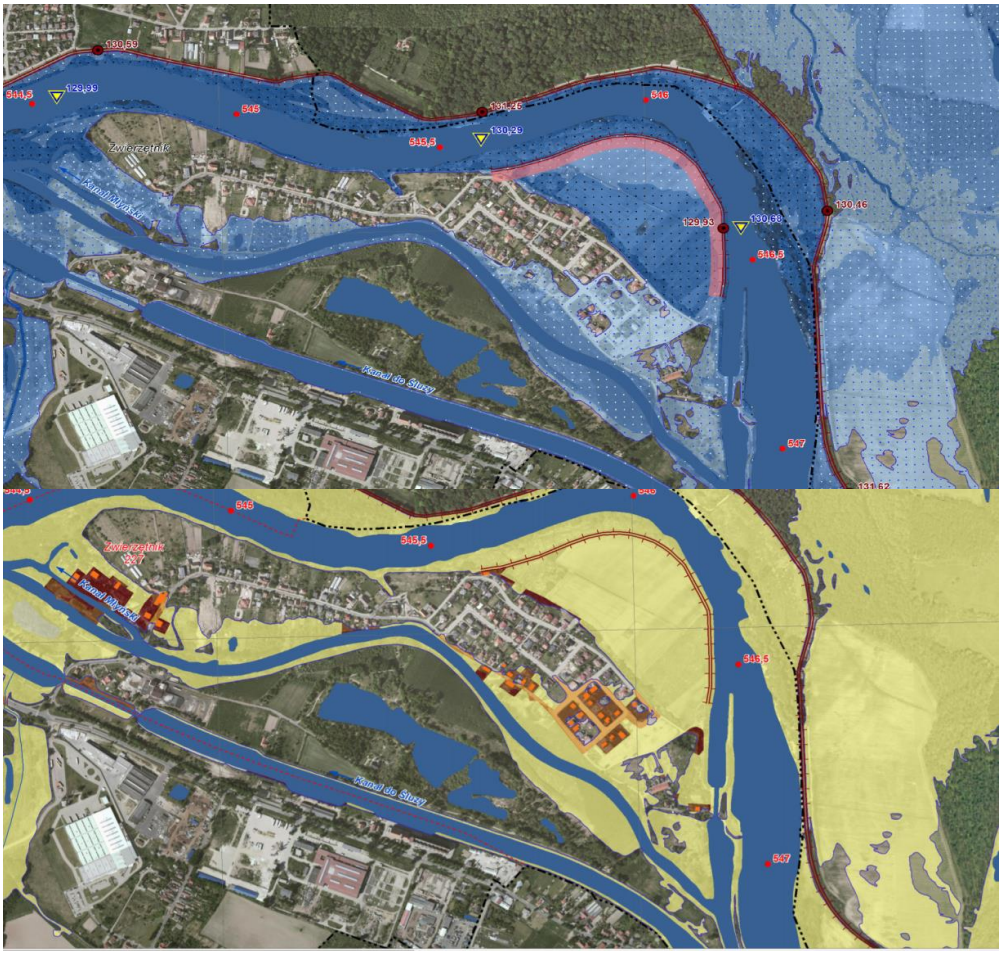

Figure no. 1 – A comparison of the flood threat and risk map against the threatened infrastructure – on the example of Oława, Poland
Source: own elaboration on the basis of http://mapy.isok.gov.pl/

Following the identification of the threatened facilities two types of action will be taken: relocation of inhabitants and change of the intended usage of facilities. Under relocation, all displaced inhabitants will be offered compensation for the loss of property. The replacement cost is usually computed as the market value of the assets plus the transaction costs (taxes, stamp duty, legal and registration fees, relocation costs, etc.).

Figure no. 2 – Damage components
Source: Jastrzebska et al. (2014).

However, damage, according to the data in the above figure and the solution applied in the insurance market, covers three components: a) the value of the material loss (e.g. the value of a production hall, machines, working capital, labour property destroyed in a fire), b) the lost profits (the lost income that would have been made if not for the random event), c) the costs resulting from the random event (the costs of property protection, the cleaning of flooded machines, the utilisation of the destroyed working capital, etc.). An important question is what approach to take in estimating the value of these components. In the event of a material loss should we use new replacement value or gross book value? How to assess the indispensible costs to be incurred if our organisation gets impacted? At the same time, the notion of a direct loss of the entity must be introduced (a loss affecting property assets) – it is the first of the discussed components. The other type is indirect losses (violating the financial interest of a given entity). Research findings reveal that in well-developed countries indirect costs are on average three to ten times higher than direct costs – especially when referred to relocating businesses (Li, 2018). In the event of a change in the intended usage of property or the type of business activity indirect losses can surpass direct losses multiple times (Bastia and Skeldon, 2020).

Table no. 3 – An example comparison of direct and indirect damage of a manufacturing enterprise having to relocate its business activity

Damage type	Details
Direct damage:	– capital (material) damage – facilities depreciation, machines adaptation – destruction of part of floating assets – lost contracts – costs of machines transportation – legal costs pertaining to relocation or change in usage, claims pertaining to broken contracts (civil liability) – fines and contractual penalties
Indirect damage:	– production losses caused by downtime – additional costs of production adjustment, staff retraining – lost markets (with regard to small and medium size enterprises in particular) – exchange rates losses (in the event of importing spare parts from abroad) – loss of suppliers – extra time spent on searching new localisation and finding new markets in case of rebranding

Damage type	Details
	– costs of safety system reconstruction – costs of extra staff (to accelerate production and accomplish plans) – recruitment and training costs of replacement staff – training costs of replacement staff – implications of absenteeism (sick leaves) – negative psychological implications of relocation or rebranding affecting workforce – negative impact on relations with stakeholders – negative impact on publicity and advertising issues – having to rebuild company image when rebranding

Source: own elaboration.

It must be stressed that the actions taken under property relocation from flood-threatened areas or a change in the intended usage of facilities threatened with flooding should follow well-devised programmes covering both types of losses. Optimally, especially as regards residential buildings, the actions should include ready solutions such as dedicated residential districts and dwelling places. On the other hand, the additional backing in the form of infrastructure or psychological support would reduce indirect losses incurred by the relocated individuals.

It is also worth stressing that the implementation of these actions should be carried out, or at least coordinated, at the central level. The organisation of these processes depends to a large extent on the system of the state. In unitary states, the tasks pertaining to the flood risk should be carried out by government administration, or local government authorities, by means of relevant financial transfers. In federal states, depending on the degree of federalism, the tasks (including financing) can be implemented by states / lands / provinces, but coordination at the central level is still indispensible. What is more, in many cases, international coordination of actions (including financing) is also indispensible as the basins of many rivers cover the area of a number of countries (e.g. the Danube, the Rhine, the Amu-daria, the Syr-daria). These rivers often evoke conflicts of interest between the countries along their reaches. In order to mitigate the conflicts the countries ought to contribute financially to solving the issues with an involvement of development banks.

3. BUDGETARY WAYS OF FINANCING FLOOD RISK MANAGEMENT

In this part of the article, the authors wish to present the basic ways of financing flood risk management from the public authorities' budget in a model manner rather than on the example of a given country.

The traditional way of financing flood risk management is straight from the budget, especially the central budget including the budgets of particular ministries, such as the ministry of internal affairs or the ministry of the environment. The tasks financed from the budget include relief efforts or relocations from flooded areas. The tasks pertaining to flood risk are medium-term and long-term. Therefore, a separate fund should be launched to go beyond the traditional annual budget. In many countries, such funds are separated from the general budget for the needs of significant long-term investments. They are managed by relevant government agencies or national development banks[5].

On a multi-annual basis, flood funds would allow raising finance for implementing flood risk management tasks. The transfers into this type of funds can be (1) non-repayable

and (2) repayable. The non-repayable source (1) of financing ought to include fiscal incomes, especially income tax (PIT, CIT) and indirect tax (VAT). It would also be possible to receive income from the increased property tax paid by the inhabitants and entrepreneurs in flood-threatened areas, who in a conscious way expose themselves to the flood risk.

Flood funds could also be financed from repayable sources (2). The institution managing the fund (e.g. development bank) would take out loans and issue bonds. There are several reasons behind this form of financing:

– the positive effects of the thus financed tasks will be enjoyed by future generations, therefore it is well-grounded to transfer the investment costs on them;

– the current trends (fashion) in the financial markets to invest in ecology, the environment and local communities allow obtaining relatively low investment margins for the securities issued to finance green investments and cutting the costs of financing actions (described later on);

– in some countries, the loans taken out by development banks are not regarded as public debt which means that this form of debt financing would not cause negative consequences in terms of debt limits[6].;

– the bonds issued by the proposed funds or national banks could become an instrument in quantitative easing operations performed by central banks with a view to contributing extra capital to the economy, which plays a significant role, especially during periods of economic crisis.

Over the past few years the idea of investing in green projects has gained considerable popularity on the financial markets. Consequently, there emerged a type of thematic bonds called *green bonds*. Green bonds are issued to finance specific types of green initiatives. The only feature that differentiates green bonds from regular bonds is the issuance purpose. They do not differ in any way in terms of their construction. One particular advantage of green bonds is that their issuance is usually very welcome by investors due to a low risk of issuance failure and relatively low interest margins. By investing in green bonds investors not only make returns but also engage themselves environmentally to demonstrate their green attitudes and social responsibility. A drawback of this type of bonds is the obligation to obtain green rating which hikes the cost of issuance. To conclude, green bonds are an effective source of financing on condition that the issuance is on a large scale. Then, the benefits drawn from lower investment margins compensate the one-off cost of conducting a rating (Wisniewski and Zielinski, 2019, p. 55).

Poland is the pioneer country on the sovereign green bonds market. The Polish issuance of 13 December 2016 was the first one ever done by a state government. Demand exceeded supply considerably which resulted in issuing 50% more capital than originally stipulated – an issuance of 750 mln euro with the margin lower than market average. The green rating by Moody's was GB2 (very good) which is the second highest rating possible. The other countries that have since issued this type of bonds include France, Nigeria, the Netherlands, Chile, Sweden, and Germany (Climate Bonds Initiative, 2019).

4. FLOOD BONDS – A NEW APPLICATION OF DEVELOPMENT IMPACT BONDS

An alternative to the financing of flood risk management from the budget is the methods based on the solutions known from the New Public Management, in particular

those methods which greatly involve the private sector in the implementation of public tasks, and also those which improve the effectiveness of public expenditure under the payment-by-result formula (public authorities will pay for the implementation of the given task only on achieving the targets).

Before the new solution is presented, let us first introduce the idea of NPM. This doctrine of public administration management means a departure from performing administrative tasks (the bureaucratic model) to management based on the economic evaluation of performance with the application of market mechanisms (the managerial model). The concept of NPM first emerged in the Anglo-Saxon countries in the 1980s following the economic crisis of the preceding decade and the increased significance of the service market and the increased customer expectations about the quality of services (Marchewka-Bartkowiak, 2014, p. 1). As a matter of fact, NPM means transferring management solutions to the public sector (Ferlie *et al.*, 1996, p. 9). In practice, NPM occurs as a change from monolithic bureaucracies towards alternative arrangements such as privatization or the creation of quasi-autonomous organizations or public–private partnerships. Moreover, governments have begun to experiment with performance-related budgeting, accruals accounting, implement benchmarking, contracting-out, public–private partnerships, etc. (Homburg *et al.*, 2007, p. 2).

The doctrinal elements of NPM include: direct and professional public sector management, evaluating the quality of the performed tasks by means of certain standards, more attention put to performance evaluation, desegregation of public sector units, increasing competitiveness in the public sector, implementing management styles borrowed from the public sector, and boosting discipline and thriftiness in exploiting public resources (Czarnecki, 2011, p. 13).

The postulates of NPM include "focus on results" which can be defined as "the philosophy of taking actions where the process of meeting the target is not as important as the final result." This postulate can be realised by means of properly drawing up contracts that describe in detail the anticipated results. In this way, the public sector demonstrates that it attaches great importance to a value obtained with available financial resources (Zawicki, 2007, p. 155). From this postulate the "payment by result" formula can be derived. The implementation of a public task under this formula can concern any type of programme where payment is made at the closing stage, after meeting certain targets, as opposed to the traditional approach where the transfer of resources is made prior to the project launch (Wisniewski, 2018, p. 104).

An unquestionable advantage of the "payment by results" formula is the possibility of rationalising public expenditure. However, the formula is not deprived of drawbacks. There is the issue of indexing social results, which are often immeasurable (Cooper *et al.*, 2016, p. 65). Another issue is the risk of "dehumanising" the actions that are aimed at meeting the goal at any cost (Larsson, 2016). This mechanism may lead to the so called "creaming", i.e. giving up difficult social issues in favour of more effortless interventions, the results of which are achieved quickly and easily. Another issue is the risk of too much centralization in managing programmes and the risk of administration costs exceeding the revenues, particularly in the event of complex projects or projects of little social impact (PriceWaterhouseCoopers, 2014, p. 4).

The best known organisational-financial solution the construction of which follows the payment-by-result formula is *impact bonds*. This mechanism is also broadly known as *social impact bonds* (SIBs) or *development impact bonds* (DIBs). Under this solution, public

authorities commission a private entity with a particular social or development task and oblige themselves to pay by result. The private institution or a third sector party strives to achieve the goal and strives to raise finance to that end. Financing is provided by investors who count on making profits higher than the market average and earning the image of socially responsible, but who must also calculate the risk of not making returns on their investment in case of failing to achieve the targets. Therefore, in order to ensure financing, investors often strive for guarantees from public entities, foundations or charities (Marchewka-Bartkowiak and Wiśniewski, 2015, pp. 210-211; Necel and Wisniewski, 2019, pp. 69-71).

The purpose of this article is to advocate the application of impact bonds in financing flood risk management tasks, especially the organisation and financing of relocation of individuals and businesses from flood-threatened areas including redesigning land use. The adaptation of the financial-organisational model based on the impact bonds concept for the implementation of the actions mentioned above is presented in Diagram 1.

The contracting party would be public authorities (a relevant ministry or central agency for water-infrastructure development), and the intermediary (organiser) would be a special purpose vehicle (SPV) or a fund whose prime goal would be to raise capital from investors (bonds issuance – *flood bonds*), safeguarding the implementation in particular areas threatened with flood risk (task delegation, execution financing), and finally SPV or a special fund would subcontract particular tasks to immediate contractors. The contractors could be units of local government or some other entities responsible for local and regional aquatic policies. They would intervene directly with the owners of property in the flood-threatened areas (expropriation, devising spatial development plans).

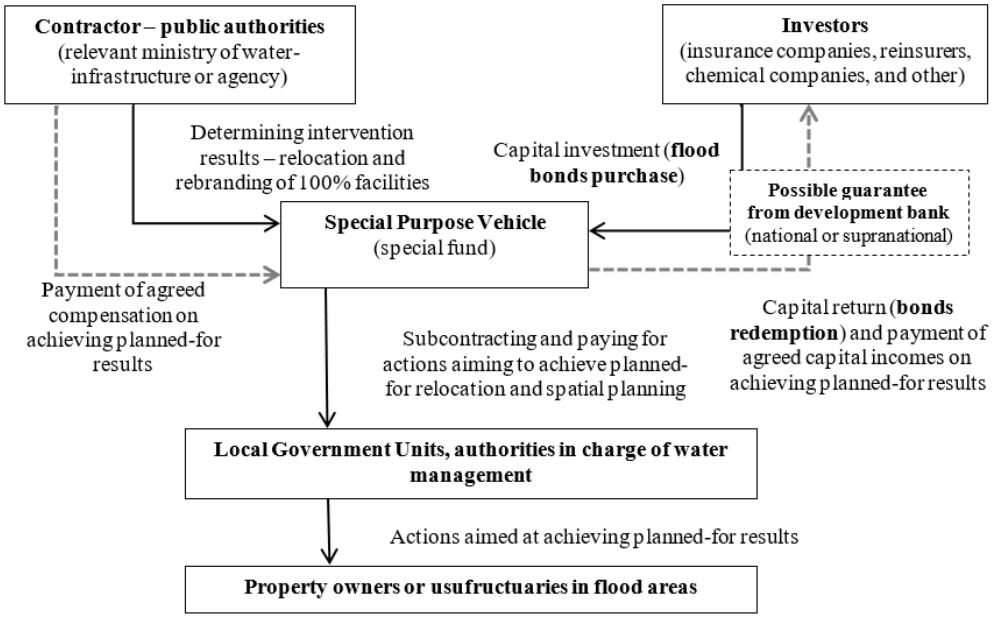

Diagram 1 – The financing of project tasks with flood bonds under the payment-by-result mechanism
Source: own elaboration on the basis of: Griffiths and Meinicke (2014, pp. 7-9); Costa et al. *(2012 pp. 3-4); Callanan and Law (2012, pp. 3-4); Corrigan (2011, pp. 12-13).*

This type of investment could appeal to insurance companies, reinsurers, chemical companies, etc. For instance, in the Polish insurance market, there is an obligation to develop a prevention fund from a proportion of the premiums paid to insurance companies. The prevention fund does not exceed 1% of the premiums collected over one fiscal year (art. 278 item 2 of the Act on the Insurance Business). At the end of 2018 the written premium of the whole insurance market amounted to PLN 31.9 bn (ca. EUR 7 bn) which translates into a prevention fund of PLN 300 mln (ca. EUR 67 mln). This still leaves space for investing the insurance fund in flood bonds and building up the image of being socially responsible. Reducing the threatened facilities and businesses in flood-risk areas also reduces potential losses of insurance companies (Kousky, 2017). Thus, insurance companies can easily fulfil the role of investors under the flood bonds concept. The same goes for reinsurers whose prime interest is the protection of the whole of the insurance market.

In order to reduce the investment risk (a failure in conducting intervention results in default on payment by the public sector and bonds redemption by SPVs) the flood bonds mechanism could be equipped with a warranty of, say, 60% return provided by potential development banks – national or supranational, such as the European Investment Bank (EIB), the European Bank for Reconstruction and Development (EBRD), the World Bank.

The financing of such projects (payment by result, interest payout, provision of warranty) could be part of EU programmes. This idea alludes to the Project Bonds Initiative pursued by the European Commission and the EIB in the years 2012-2016. The purpose of the Initiative was the financing of large investment projects in the area of public utilities with public resources backed with the warranties or subordinated debt of public authorities to obtain relatively higher credit ratings and lower costs of debt servicing (Marchewka-Bartkowiak and Wiśniewski, 2014; Mosionek-Schweda, 2016).

The project under discussion could also take advantage of issuance tranching, e.g. the original issuance could concern areas most threatened with flood risk; the next issuance would cover less threatened areas, and so on. Another issue to consider is the trigger, i.e. an objective measure of intervention effectiveness which makes it possible to decide whether the given task was actually completed and, consequently, whether the contracting party will pay for the intervention and capital costs (investor margin), and whether the issuer will redeem bonds. Measurement propositions based on the effectiveness of prevention activities are presented in the following section.

Another important issue to consider is the duration of interventions. Social projects usually took a medium financing term, but some interventions also took a year or even 18 months to complete. Due to the immensity of interventions, intricacies of law and the duration of legal proceedings a proper approach to take would be long-term financing, as long as 10 years. Therefore, the issuance of bonds in a few tranches can streamline the whole process and help organise it in time and facilitate the evaluation of its results.

5. EVALUATION OF EFFECTIVENESS OF FLOOD BONDS INTERVENTION – CONSTRUCTION OF A TRIGGER

The actions taken to change the intended usage or perform relocation are actions aimed at mitigating risk realisation (damage prevention actions) and coercive actions reducing the risk which cannot be prevented.

The actions taken to mitigate risk should provide tangible results such as damage limitation. We can use the following equation to measure economic effectiveness:

$$E = \frac{R_1 - R_2}{N},$$

where:

E – effectiveness coefficient; its reciprocal $\frac{1}{E}$ determines how many years it takes for risk mitigation investment capital to be returned by reducing the damage caused;
R1 – annual amount of loss prior to the launch of actions;
R2 – annual amount of loss following the completion of actions;
N – amount of investment capital.

Due to the incidental nature of flood damage it is difficult to speak about savings on a year-to-year basis. Therefore, in terms of the flood bonds trigger the time period is set as 10 years. When calculating losses and expenditures we should consider the actions taken and benefits gained by all the parties involved. However, it is essential that the calculation of results should be performed on a regular basis by local government units and central administration with a view to evaluating investment viability. This requires conducting an update on the inventory of facilities and an evaluation of the change in their intended usage.

The ratio of the limited damage against the costs incurred being positive (E>1) means that the actions taken are economically viable. A large simplification of the ratio makes its practical calculation very difficult because the expenditures on damage limitation are realised on a one-off basis or over a short period of time (e.g. the rebranding of a chemical plant or the relocation of an extended care facility) while the benefits are spread over a number of years. In effect, the N value is usually the total expenditure of a given administration unit responsible for flood risk management. The R values represent the discounted values of future results as well as the estimated losses reported by facility owners and usufructuaries. Moreover, in calculating effectiveness we should not only consider direct damage limitation but also limitation of indirect damage which has the biggest impact on the financial stability of the threatened or relocated entities.

Table no. 4 – The effectiveness measures of the actions taken

Effectiveness coefficient value	Details
FOR E = 0:	– Prevention expenditures do not cause the total value of random damage to decrease – From the commissioner's point of view prevention expenditures are pointless – No premium payment for investors
FOR 0 <E < 1:	– Prevention actions are economically non-viable, as then R1-R2, i.e. the savings made on the damage (economic results) are smaller than the expenditures – No premium payment for investors; guarantee launched by Polish National Bank of Development
FOR E > 1:	– Prevention actions are economically viable, as then R1-R2, i.e. the savings made on the damage (economic results) are higher than the expenditures
FOR E = 1:	– Prevention actions are neither viable nor non-viable – i.e. from the economic point of view they are insignificant, as then R1=R2 – No premium payment for investors

Source: Own elaboration.

Another, and more precise, method of evaluating the effectiveness of risk mitigation actions uses the mathematical compensation function ($y = f(x)$) which determines the amount of losses made depending on the mitigation actions taken. Obviously, the actions taken usually only lead to a diminished costs or losses cumulation to be faced by local or central authorities. Therefore, in order to make correct calculations it must be assumed that the total cost incurred by the given organisation is the sum of all the expenditures towards risk limitation and the costs involved during the event.

6. THE PROSPECTS OF FLOOD BONDS

The proposed organisational-financial solution – flood bonds – is an innovative adaptation of the mechanisms of development impact bonds. The prospects of its application look very promising. The table below presents the results of a SWOT analysis. The comparison reveals a number of difficulties in financing the results of relocation with flood bonds. Nevertheless, it is a tool that can be used to create a comprehensive mechanism for financing the results of the planned-for prevention actions.

Table no. 5 – A SWOT analysis of flood bonds as an instrument for financing flood risk management tasks

Strengths	**Weaknesses**
- relatively higher rationality and effectiveness of public expenditure and savings involved - financial risk transfer from public to private sector - system of incentives for non-public entities to encourage financial resources sharing for achieving own goals or CSR tasks - final result orientation rather than public resources expenditure - discouraging public entities and private businesses from relocating into catchment areas	- transfer of some tasks traditionally implemented by public sector – negative image of not being responsible - results difficult to measure – difficult assessment of benefits achieved by public authorities and results for citizens - risk of failing to achieve long-term results - long duration of task implementation - authority abuse in dealing with relocation of entities - mechanism complexity can reduce entities' interest in relocation
Opportunities	**Threats**
- increased interest of non-public entities (e.g. insurers) in financing public tasks in order to mitigate risk in key operation area - damage compensation issues can be solved once and for all on realising flood risk	- project failure risk due to change in financing and implementing tasks pertaining to flood prevention - lack of acceptance on the part of investors who fail to grasp the mechanism - high project costs

Source: own elaboration on the basis of: Wiśniewski (2019, p. 225)

7. CONCLUSIONS

Protection against flooding is considered as an element of ensuring public safety. It is also related to the principle of sustainable development and environmental safety. The states are obliged to take active measures aimed at flood protection. In an abstract sense, there are particular activities in order to achieve the goal (non-technical activities; technical activities; redefinition (rebranding) of business activity or relocation). At the same time, it should be clear that everyone has the right to remuneration for damage caused to the subject by

restricting his right to property or the freedom to use the goods that he or she owns, especially if we consider the rebranding or relocation. The accurate calculation of these damages and the possession of funds on these damages covering are the responsibilities of a government.

The late 1990s saw a relocation of about twelve million residents under development projects (Cernea, 2000 p. 11). In most cases, they were forced decisions/actions. The individuals and entities involved were forced to relocate due to floods and other natural catastrophes. The solution proposed in this paper is, on the one hand, taking prevention actions aimed at building a comprehensive system of relocation and rebranding, and on the other, a stable mechanism for financing these actions. In effect, it will be possible to create a solution (in compliance with international regulations) under which individuals and businesses will make independent decisions about relocation. By engaging private entities the burden on the central budget will be lessened. Flood bonds introduce innovative solutions in the financial market and serve as the fulfilment of certain social responsibilities.

This will allow different regions of the world to define the areas of cultural and economic diversity. Further research will contribute for even better adjustment of the calculation of incurred losses to the expectations of residents. As a result, the efficiency of the applied solution will increase.

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Notes

[1] Rainwater (summer) floods:
- tempest – local floods along mountain creeks and small lowland watercourses (catchment area A<50 km2) caused by local storms and downpour
- frontal – wide range floods in montane, submontane and low-lying areas,
- widespread – similar to frontal floods, caused by rainfall affected by montane orography (the lie of the land).

[2] Flash flood – a peculiar type of frontal flood with local range, rapid course (typically shorter than 6 hours), caused by heavy rain of stormy nature; it can occur any place, typically in montane areas; urban areas are also conducive to its occurrence (urban flood); it could also be caused by hydrotechnical facilities failure.

[3] Meltwater flood – caused by the rapid meltdown of snowcap.

[4] Winter flood:− dam flood – during the downflow of ice, caused by the floe, typically in river bottlenecks, under bridges;−frazil ice flood – caused by the rapid formation of frazil ice (a.k.a. shuga) and anchor ice which clogs the free flow of river causing backwater.

[5] For instance, the Polish National Road Fund and Railroad Fund administered by the National Development Bank of Poland (NDBP) which collects revenues from taxes and charges towards the financing of road and railroad investment projects.

[6] For instance, in Poland the liabilities of the NDBP are not considered public debt. Alas, in the face of the European debt calculation methodology (SNA and EDP) development banks are part of the general government and thus their liabilities are part of public debt (Wiśniewski, 2019, pp. 102, 109).

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