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Evaluation of the potential of infrastructure funds: The case of inland waterways in Germany

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ABSTRACT

Given the critical need for sustainable transportation solutions, inland waterways (IWs) constitute a crucial yet underfunded mode of transport. This study examines deficiencies in current infrastructure funding and analyzes infrastructure funds (IFs) as an alternative funding mechanism and potential means to revitalize German waterways.

Central to this investigation is the analysis of the German population's willingness to pay (WTP) for such funds. To this end, a comprehensive online survey of German households was conducted, and multivariate regression analysis was employed to identify key factors influencing public support for various fund designs.

The results reveal that personal experiences with flooding significantly affect WTP and underscore the role of socio-economic variables in shaping public attitudes toward infrastructure funding. The findings indicate that well-designed IFs, combined with effective communication strategies to raise awareness of the importance of waterways, could significantly enhance public support. The study demonstrates that IFs have significant potential as a strategic tool for mobilizing public funding, thereby supporting the sustainable development and maintenance of essential yet underfunded infrastructure. IFs present a promising solution to the financial challenges facing critical public goods such as waterways.

1. Introduction

Inland Waterways (IWs) as a comparatively environmentally friendly mode of transport is to be attributed more importance and transport volume in the future (BMVI (Ed.)., 2016; Fichert, 2017), whereas a poor state of construction assets, a systemic maintenance backlog, and scarce or misallocated maintenance resources characterize the deteriorating infrastructure (Akkermann and Weiler, 2020; Hossain et al., 2019). This constitutes a risk to nearby industries and critical infrastructure and endangers human lives and well-being by potentially flooding settled areas due to bursting dams (Peng and Zhang, 2012).

Despite a lack of awareness about IWs and their importance among the population (Daehre, 2012), there is a strong association with a high hazard potential in events such as the breaching of a dam, contaminated culverts, or a bridge pier hit by a ship. Historical examples in Germany include the flooding of the Elbe and Danube rivers in 2002, the leakage of canal water during the construction of a new bridge in 2005, the rupture of a pipeline culvert and the associated interruption of the water supply, or a “simple” error in a control system, which led to flooding with property damage accounting to one million euros (Hüttelmaier et al., 2019).

In combination with the before-mentioned threats, neglected or misallocated maintenance measures of deteriorating construction assets, pose a serious risk to both business locations and the population (Oztanriseven and Nachtmann, 2020). Hence, efficient planning and implementation of these measures are crucial, considering the various regulatory requirements and complex set of responsibilities due to the different interests and powers of the federal, state, and city governments in Germany (Fichert, 2017).

However, the maintenance backlog and increasing transport volumes cause rising maintenance costs, requiring innovative and alternative financing approaches (Kumari and Kumar Sharma, 2017; Mostafavi et al., 2014). Public-private partnerships (PPPs) are one way to achieve this, although their success varies in practice (Fichert, 2017). Moreover, citizen participation in funds can alleviate financing problems (Njoh, 2011). A suitable fund design can enable citizens to better participate in decision-making and reduce opposition to corresponding infrastructure projects.

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The willingness to pay (WTP) of citizens and residents, who are directly or indirectly affected in case of waterway infrastructure failure, has received little attention in literature and practice so far and will therefore be considered in more detail in this paper. Accordingly, we aim to analyze the WTP of citizens for targeted investments through dedicated infrastructure funds in waterways and examine the potential impacts.

Our paper is structured as follows: The importance and problems of financing infrastructure are examined in more detail with a focus on waterways to provide a structured answer to the question of the WTP by citizens or households and explore possible consequences. Moreover, empirical methods and models of infrastructure financing are examined to determine the requirements for an effective financing system in order to exploit the merits of different models. The derived financing mechanism and its funds are presented, along with the data collection and processing applied to a case study in Germany. This is followed by an elaboration on the findings and a critical discussion.

2. Literature review

2.1. Inland waterway infrastructure

Infrastructure as a prerequisite for the mobility of goods and people is becoming increasingly important as globalization progresses, whereas the quality of infrastructure determines the production potential of an economy in the long term (Bardt et al., 2014; Behrendt and Trojahn, 2013). Transport infrastructure covers the fixed assets of transport routes as physical infrastructure and transport facilities for securing and routing as well as transshipment stations (Behrendt and Trojahn, 2013; BMVI, 2014).

Inland waterway transport (IWT) as an indispensable mode of transport worldwide (Oztanriseven and Nachtmann, 2020; Rohács and Simongáti, 2007) must use existing capacity reserves in the future to shift traffic from road to IWT, as it is a comparatively environmentally friendly mode of transport (Rohács and Simongáti, 2007), cf. Fig. 3. IWT thus represents an elementary component of logistics chains (Tonn et al., 2021), comprising regional water management in the areas of drinking and service water supply, irrigation, power plant utilization and wastewater disposal. Moreover, the infrastructure serves as flood protection for local residents, as ecological biotope and provides a high recreational value for people (Oztanriseven and Nachtmann, 2020).

Meanwhile, transport infrastructure is vulnerable to various risks, such as natural disasters, malicious attacks, and age-related component failure. Therefore, physical protection and resilience of infrastructure take on increased importance (Wehrle et al., 2020; Zio, 2016). However, considering the example of Germany, structures that are system-relevant for the operation of inland navigation are in an increasingly poor condition, characterized by a massive maintenance backlog. This situation has been caused by a prolonged lack of investment (BMVI, 2019) for which the government and administration are primarily responsible. The yearly investment deficit for waterways is around €500 million, compounded by inflation, addressing the existing maintenance backlog, and unaccounted-for measures (Daehre, 2012).

IWT in Germany covers approximately 230 million tons of freight annually transported on a 7300-km infrastructure network (Fig. 1). There is potential to expand this transportation volume, as shown in Fig. 2, and it highlights the need for a more sustainable transport infrastructure, as indicated in Figs. 1–3.

Meanwhile, about 50 % of the current building inventory of IWs was built before 1950, and other 10 % before 1900, whilst the high age and lack of maintenance measures lead to an overall poor structural condition. Approximately 55 % of the facilities were graded “insufficient” (Grade 4) or “adequate” (Grade 3), as shown in Fig. 4 (BMVI, 2015).

The increasing deterioration and a lack of maintenance of infrastructure make them structurally more vulnerable (Houlihan, 1994; Lenz, 2009; Wehrle et al., 2020). Accordingly, factors such as natural events, human error or terrorist attacks, could lead to the failure of facilities due to their poor condition, resulting in high economic losses and endangering human lives (Hüttelmaier et al., 2019; Tonn et al., 2021).

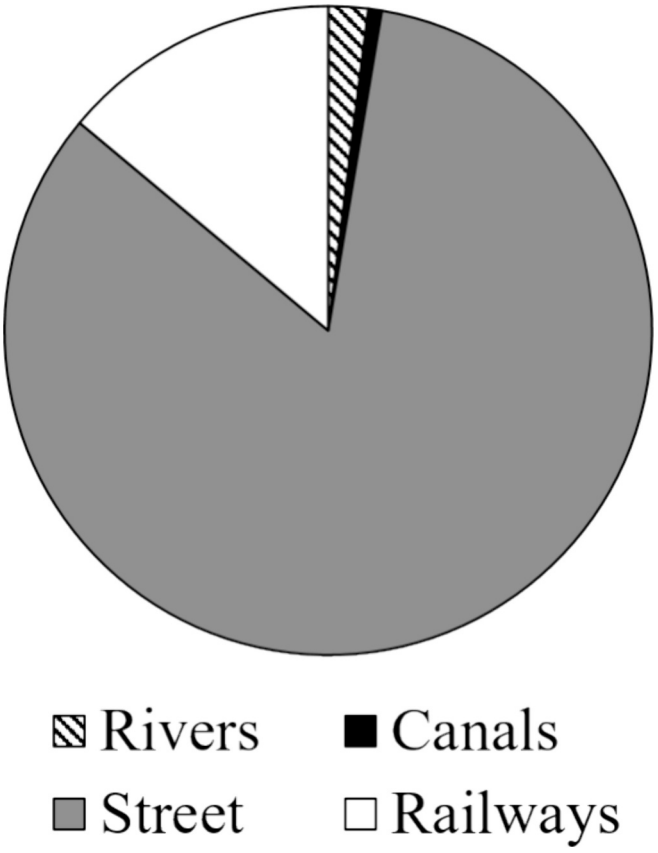

Fig. 1. Length of transportation infrastructure in Germany in the year 2020 (Destatis, 2022).

At the same time, infrastructure investment in relation to the development of GDP is declining, leading to a progressive depletion of assets due to underfunding (Bardt et al., 2014; Behrendt and Trojahn, 2013; Daehre, 2012).

Demographic changes, globalization, climate protection, environmental compatibility, and the scarcity of fossil resources will also shape the demands on transport infrastructure in the future (Daehre, 2012). Consequently, transport infrastructure, which has long been acknowledged as Germany's locational advantage, may become a disadvantage in the future (Bardt et al., 2014). The inadequate and deteriorating condition already results in annual economic costs in the range of several billion euros due to lost time, environmental pollution and higher operating costs (Kopper et al., 2013).

2.2. Stakeholder

The complexity of infrastructure planning increases due to the different responsibilities and interests of various stakeholders, which can change over time. These interests are diverse and sometimes conflicting (Fichert, 2017; Francis and Bekera, 2014). Stakeholders involved in waterways are identified in the following.

2.2.1. State/government

The state has various responsibilities, including providing services of general interest (Große Hüttmann and Wehling, 2013) and overseeing the planning, construction and operation of infrastructure of the public sector. These tasks can be carried out by government bodies at different levels, such as the federal government, the state or the municipality

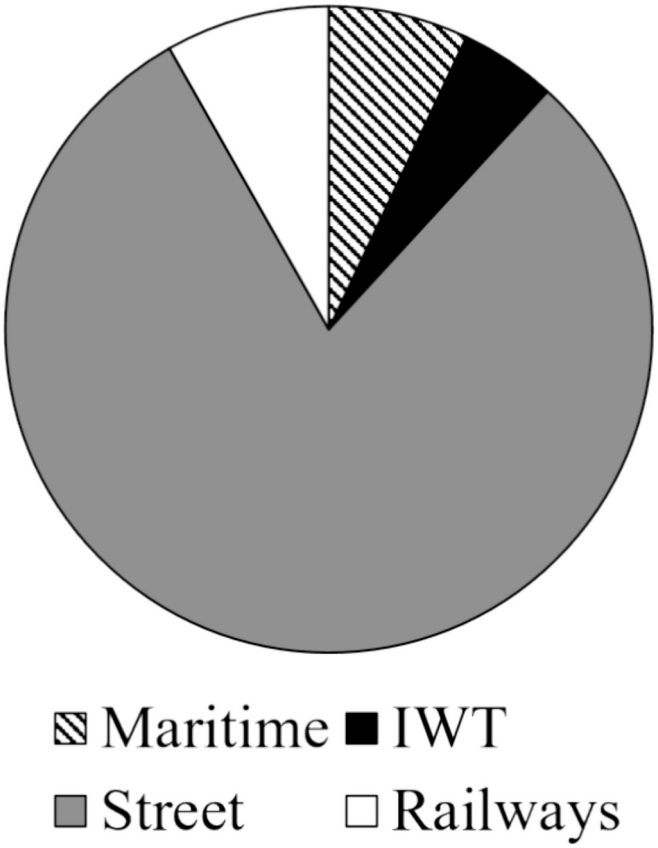

Fig. 2. Transport volumes by mode in the year 2020 (Destatis, 2021).

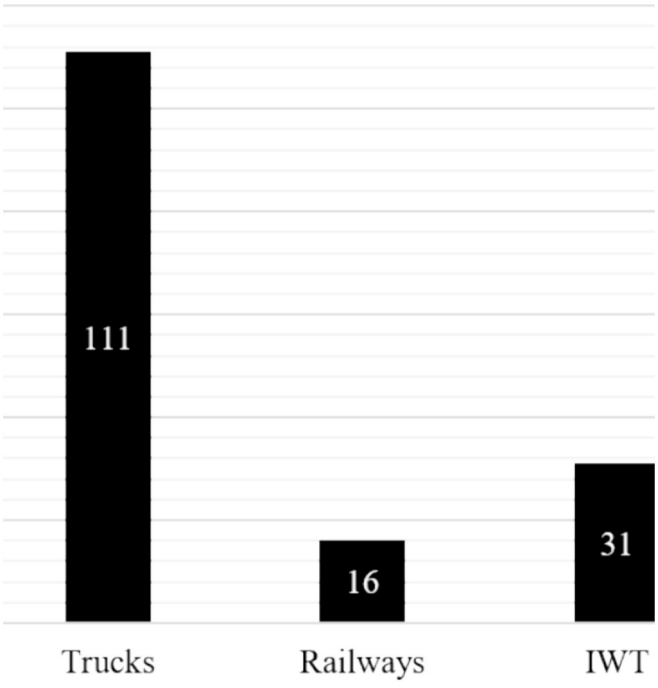

Fig. 3. Emissions in freight transport in CO2 equivalents (Umweltbundesamt, 2021).

(Daehre, 2012). The public sector has sovereignty over policies and legislation on planning and construction and is responsible for taxes and fees to provide modes of transportation. The fundamental interests of

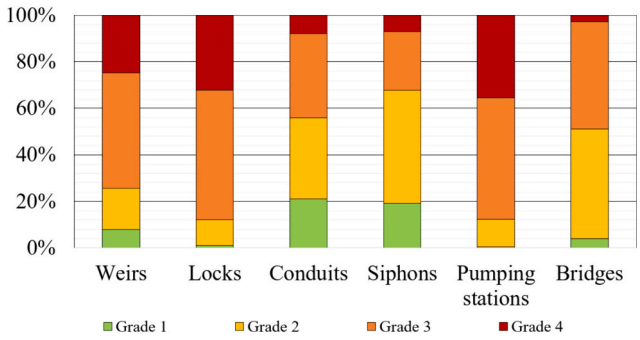

Fig. 4. Condition assessment of building structures in Germany (BMVI, 2015; Hüttelmaier et al., 2019) (BMVI, 2015; Hüttelmaier et al., 2019).

the responsible parties lie in a low risk of failure in order to keep failure costs low and to safeguard the reputation of their organization (Tonn et al., 2021). This is crucial for maintaining public support and trust.

The interests of the government's roles can be conflicting, as it acts as a project promoter on the one hand while seeking to preserve other public interests such as environmental protection and safety. The government must be careful to ensure that its actions have an incentive-oriented signal effect: If the government pays for damage caused by infrastructure failure, there is no incentive for potentially affected parties, citizens or companies, to insure themselves or to invest in measures to repair the infrastructure in advance (Tonn et al., 2021).

2.2.2. Population

The population primarily funds waterways through tax levies. Approximately 90 % of residences are not at risk of flooding and thus may be less affected by and concerned about the reliability of hydraulic engineering facilities (GDV, 2021). General interests in this matter include flood prevention avoiding indirect ripple effects causing shortages of supply (e.g., in the supply of power plants in the region), but also the avoidance of citizen-supported user financing such as a passenger car toll (Statista, 2013). This is particularly to be expected in the case of waterways where people may be unwilling to pay for a service that was previously free, potentially leading to resentment, political resistance and loss of votes (Kopper et al., 2013). In addition, special interests are also held by employees such as about 4400 IW skippers (Statista, 2021) and other indirectly dependent jobs in logistics, electricity and water supply or passenger transport.

Infrastructure projects need to take into account public perception, since involvement and communication with communities requires investing sufficient time and resources to reduce oppositional attitudes among the population (Geekiyanage et al., 2020; Mostafavi et al., 2014). Sufficient information exchange prevents project extensions due to the need to revise plans (Moss, 2011). Effective participation of local communities and residents should be enabled through planned and moderated participation to avoid chaotic situations (Geekiyanage et al., 2020; Njoh, 2011; Zio, 2016).

Although waterways provide the risk of flooding, the population is usually uninformed about flood damage and available insurance measures, which is reflected in underinsurance (Osberghaus, 2015). Furthermore, insurance is not available in all flood-prone areas or may be too expensive for people to afford, contrary to the need, which is particularly the case in endangered areas (Bubeck et al., 2013; Osberghaus, 2015).

Public perception is also generally crucial for the success of new infrastructure financing methods, especially since public support for infrastructure financing responds inelastically to economic factors. However, public support responds strongly to infrastructure-related factors: If there is an awareness among the population that infrastructure is in need of high maintenance or that its protective function is no longer guaranteed, there is a higher WTP (Mostafavi et al., 2014).

2.2.3. Industry

In 2017, shipping on German waterways and rivers contributed 6.36 billion euros, which accounted for about 0.22 % of gross value added (BMVI, 2021). Indirectly affected sectors must also be taken into account here. The four largest groups, each accounting for over 10 % of the total, in ascending order, are “coal, crude oil and natural gas”, “chemical and mineral products”, “coke and petroleum products”, and “ores, stone and wood products” (BMVI, 2021). The industry's expectations and requirements focus on functionality and capacities of IWs.

Besides industry stakeholders affected by logistics, we also have to consider the parties involved in planning and construction, since infrastructure planning is conducted in government agencies, offices, and private companies. Additionally, consulting agencies, engineering firms and other intermediary organizations have an influence on planning (Moss, 2011).

2.2.4. Investors and others

Private companies play a vital role in awarding projects under PPPs. However, there are currently no PPPs in the shipping industry. The goal of private capital investors is to generate profits on their investments (Mishra et al., 2013), which is why infrastructure investments without profit prospects are unattractive to them. Investing in infrastructure can be incentivized by lower volatility, portfolio diversification, and inflation mitigation (Gemson and Annamalai, 2015).

Other entities, for example in the form of NGOs but also other states or communities such as the EU, can also be regarded as stakeholders.

2.3. Function and deficits of funding of waterways

The demand for infrastructure investment in expansion and maintenance continues to rise due to increasing demand and use, with infrastructure projects requiring high levels of investment (Houlihan, 1994; Kopper et al., 2013). Since infrastructure is usually provided by the government, also the financing of German waterways is provided almost exclusively from public budgets with annual actual federal budget allocation of €1000 million, which has historically been cut by half (BMF, 2021) and which is subject to the principles of annularity, non-affection as well as specialty. Previously existing travel levies for partial user financing led to a situation where even the actual cash cow Kiel Canal (Nord-Ostsee-Kanal) exhibited a cost recovery of only 30 % (Heitmann et al., 2013). However, this mechanism has been largely abandoned (BMVI, 2019), while tolls and track access charges are well established in other modes of transport (Daehre, 2012).

Transport economists and industry representatives complain about insufficient investment in infrastructure and in some cases call for a fundamental revision of the financing mechanism in Germany (Fichert, 2017). Yet investing in infrastructure is one of the best ways to create economic growth and jobs (Kumari and Kumar Sharma, 2017; Sturm et al., 1999). The enormous discrepancy between the allocated funds and the actual needs prompted the development of a new concept for investment policy. However, most of the proposed solutions have faced criticism from stakeholders and other countries (Daehre, 2012; Kapesa et al., 2021; Mostafavi et al., 2014).

Even if broad-based *navigation levies* were reintroduced, they would not cover the costs of the infrastructure, especially since the Rhine, potentially the largest source of revenue, is exempted from levies by international treaties (Kopper et al., 2013). Even if all direct users and beneficiaries of waterways, for example power plants, the leisure industry or flood-protected communities, were included in the financing, it would still be unrealistic to fully cover all costs (Daehre, 2012; Heitmann et al., 2013).

Meanwhile, the possibility of (co-)financing through the private sector is justified by a legitimate economic interest in high quality and density infrastructure, whereas the large sums of investment combined with long construction and payback periods lead to risk-averse behavior (Gemson and Annamalai, 2015). Since the security of the population is one of the most important responsibilities of the state, involving private sector partners in critical infrastructure is traditionally challenging (Dunn-Cavelty and Suter, 2009) but nevertheless common for infrastructure operation. Using holding companies would allow for the financing of large projects while distributing financial risks (Gemson et al., 2012; Mishra et al., 2013).

Public-private partnerships (PPP) are long-term, contractually regulated collaborations between the private and public sectors. They aim to achieve better performance, efficiency, cost savings and potential innovations that are unattainable by individual stakeholders (Fandel et al., 2012; Morasch and Tóth, 2008). These partnerships have been gaining increasing visibility and attention in the literature (Chou and Pramudawardhani, 2015). While public perception is also a success factor for PPPs (Cui et al., 2018), risks include the possible concealment of debts incurred, higher financing costs (since the government can borrow money on more favorable terms than the private sector), lack of transparency, venality, failure to deliver benefits, or distortion of political priorities (Eurodad, 2020). PPPs can also cause the free-rider problem, where individual participants only invest the minimum necessary in the collaboration in order to maximize their individual benefit from it (Falkinger et al., 2000; Givens and Busch, 2013; Rand and Nowak, 2013).

A *value-added tax* could take into account that investments in infrastructure gradually lift local land prices, granting the receipt of funds by invoking an objective unit of measurement (Coleman and Grimes, 2010). However, this results in sporadic payments that may not be sufficient to significantly contribute to infrastructure financing in realistic amounts.

Another option is the potential earmarking of parts of tax revenues, which is input-oriented and thus does not do justice to changes in financial needs, i.e. the required output. Fund structures, such as performance and financing agreements, offer the ability to combine user and tax funding, allowing for more targeted allocation to specific purposes while accompanying periodic reports on the condition. This approach enables better monitoring and better coordination and planning over the year, which eventually result in higher savings in total (Daehre, 2012; Kopper et al., 2013). This can be oriented toward bond funds, which derive their attractiveness from long periods of stable, low-risk cash flows, while the physical, economic and financial characteristics of investments in the transport sector make them especially suitable for investors (Panayiotou and Medda, 2014).

In general, fund-based models and thus citizen participation, in terms of shares and co-determination rights, can allow more investments according to individual needs (Yildiz, 2014). In this context, it is reasonable for infrastructure managers to issue bonds to reduce capital costs and at the same time to increase the acceptance of infrastructure projects (Beckers et al., 2014). For citizens, investing in infrastructure bonds can make sense at a market rate of return to risk ratio (Yildiz, 2014), while from an aggregated perspective, centralized issuance of citizen infrastructure bonds can reduce transaction costs and bond risks (Beckers et al., 2014). Other options include mezzanine financing, such as savings bonds or corporate bonds, financial vehicles in which citizens only participate financially, without voting rights or liability obligations, and cooperatives, which also allow stakeholders such as small businesses to participate (Yildiz, 2014).

2.4. Deficits of alongside mechanisms

While more money for transport infrastructure is necessary, it is not sufficient. Additional reforms of financing, planning and administrative structures are needed (Bardt et al., 2014). Moreover, a larger budget for transport infrastructure may cause debts or cutbacks in other departments (Daehre, 2012).

The German financing system itself contributes to the problem through inefficiencies and misaligned incentives. Financing of infrastructure in Germany exhibits the following shortcomings (Houlihan,

1994; Klockow and Hofer, 1991; Kopper et al., 2013; Moss, 2011; Wehrle et al., 2020):

- High investment requirements for individual projects
- Lack of attractiveness for investments from the private sector
- Financing system characteristics (i.e. annularity) lead to planning delays and uncertainty about future budget
- Lack of attractiveness of maintenance; prioritization of lighthouse-projects
- Lack of planning for maintenance reserves
- Competition with other governmental departments with limited budget
- Lack of qualified personnel and learning processes
- Complexity in planning (lifespan, large number of interfaces)
- Approval procedures; often multiple and long-winded
- Ineffective and inconsistent responsibilities (federal, state)
- Conflict of political interests: short-term election results vs. long-term benefits from infrastructure

Fig. 5 shows target points and levers for more efficient infrastructure financing, derived from this information. In terms of bureaucracy, the state should commit to strengthening capacities to ensure the effective deployment of fund resources (OECD, 2020).

To conclude, we encounter a conceivably unfavorable combination of high hazard potential, low public interest and complete dependence on public funding, which provides an underfunded and inadequate financing system. In simpler terms, this leads to problems in the form of staff and employment shortages and a lack of maintenance for existing infrastructure. Consequently, the existing infrastructure deteriorates, increasing the risks of individual parts of waterways failing. This results in a threat of economic losses and damages in the future, which in the long term affects the logistical attractiveness of the waterways, resulting in welfare losses and, in extreme cases, this constellation could even endanger human lives.

2.5. *Infrastructure funds*

Infrastructure funds became a recognized alternative investment opportunity during the early 2000s, with stable returns and lucrative diversification for investors (Panayiotou and Medda, 2014). Implementable in the medium term, they can ensure reliable funding for transport infrastructure (Kopper et al., 2013), while decoupling them from annual budget planning and avoiding the influence of political agendas. This suggests that financial resources can be allocated in an economically sensible way, which can lead to an improvement of conditions of transport infrastructure. Moreover, an exemplary fund for flood protection was established in France with the Barnier fund which is “almost self-sustainable” (OECD, 2020), showing the possible efficiency of a damage reduction component.

Private infrastructure funds first raise money from investors while a fund manager analyzes, evaluates, selects and then invests in existing investment opportunities in infrastructure projects (Bitsch et al., 2010; PwC., 2016). In addition to the fund, it is necessary to introduce a financing company for the various modes of transport and management of the fund, including the possibility of expanding PPP models (Daehre, 2012). As a result, the fund manager's expertise is utilized in the selection of investment projects, while at the same time enabling broad investment and diversification in various areas of infrastructure (Kleine et al., 2015). Panayiotou and Medda (2014) report potential yields of 15–20 %.

With this type of fund, stable returns with low risk are expected (Bianchi et al., 2014; Cohen, and James], and Kamga, C., 2013). Other benefits include directly available capital and better management, as well as the potential for faster, cheaper, and better project execution (Gemson and Annamalai, 2015). In this regard, long-term relationships between the private capital investor and investment recipient are beneficial (Morasch and Tóth, 2008).

The use of infrastructure funds has the following overall objectives (Daehre, 2012):

- Internalization of external costs and infrastructure costs
- Sustainable securing of financial requirements by earmarking funds (covering actual needs)
- Transparency regarding the use of funds
- Decoupling from the annual budget and thus stabilization of the financing process (independence from political cycles)
- Implementation of measures based on cost-benefit analyses and economic efficiency
- Optimal use of available funds from public and private sources

The type and structure of infrastructure funds can vary, with (1) the timing of the investment, (2) the type of infrastructure financing, and (3)

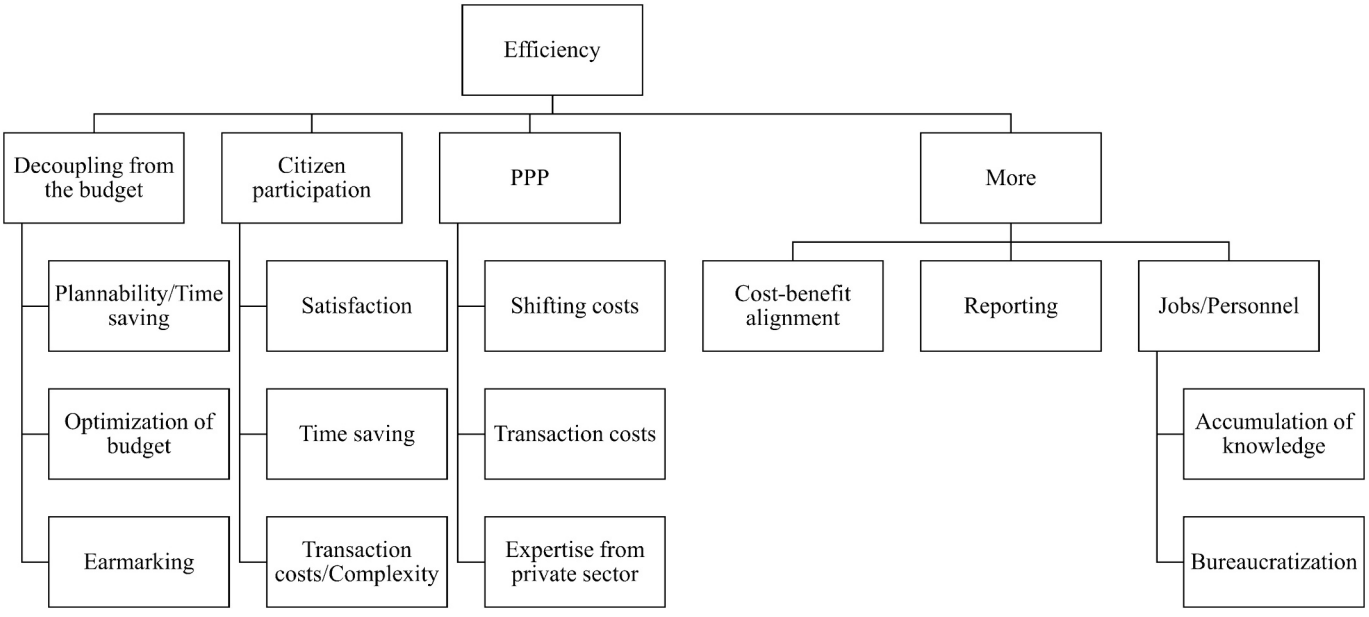

Fig. 5. Factors for a more efficient infrastructure financing.

the investment instruments as relevant characteristics, according to PwC. (2016):

(1) *Timing*: Investments can be made in construction phases (greenfield investment), associated with higher investment sums, risks and returns, or in operational phases (brownfield investment; i.e. maintenance of waterways).
(2) *Type*: Tax-financed infrastructure operation is more attractive from the fund's point of view due to the lower risk compared to user financing and is to be planned for in the contract design so that the government does not bear the entire project risk.
(3) *Instruments*: Equity as investment source can be realized by the emission of shares (or bonds in the case of debt capital) and usually offers a higher return. Alternatively, loan funds invest directly in projects by issuing loans.

Prerequisites ideally include sufficient availability, satisfactory regulatory underpinnings as well as funding mechanisms and aligned interests of fund managers and investors. In addition, it is important that investments spread geographically and across different infrastructures to be attractive and avoid idiosyncratic risks (Panayiotou and Medda, 2014), whereas the state must prevent the exploitation of infrastructure facilities by equity investors (Baird, 2013; Moles and Williams, 1995).

The cost-benefit analysis of the fund's design must consider that reduced costs through increased acceptance result in in faster completion and fewer legal costs. These reduced costs should be compared to the costs incurred through returns on the bonds and transaction costs of the bonds. It's important to note that the citizen participation should be based on financial stakes and no other forms of attachment (Beckers et al., 2014). Additionally, citizens are more willing to contribute financially to projects when local authorities lack financial resources (Zhang, 2014).

Factors influencing WTP are mainly the administration and use of financial resources, while the peer effect influences the acceptance of financing methods in that a new fund model with similar structures to already established funds (peers) leads to higher acceptance (Mostafavi et al., 2014). Another approach is to create a “proof of concept” with lighthouse projects and thus increase acceptance.

Due to the peer effect (Mostafavi et al., 2014; Zhang, 2014), major deviations from the norm should be made in gradual steps for new funds and financing methods. Proper communication about investment needs is also necessary to make citizens aware of the existing problem (Zhang, 2014).

The drawbacks primarily pertain to the state's perspective and, depending on the fund's design, may involve a possible shortfall in the predictability of funding in the case of phased financing (Gemson and Annamalai, 2015) as well as the problem of “obsolescing bargaining,” which describes the shifted bargaining powers before and after the construction of infrastructure (Post and Murillo, 2016; Ramamurti, 2003).

The suitability of a fund thus depends on various characteristics and the contractual arrangement, while a departure from or supplement to the current type of infrastructure financing and provision seems reasonable. The literature tends to focus on the participation of the private sector rather than on financing through organized citizen participation which is the approach taken in this paper.

2.6. Willingness to pay for transport infrastructure as public good

2.6.1. Concept

Goods can be classified into four groups based on the criteria of excludability (excluding people or groups from the consumption and use of the good) and rivalry (the consumption of the good by one user hinders or prevents the consumption of another) (Helfrich, 2014). Given that the broader population is less likely to use waterways directly but can still benefit indirectly from them, and assuming that exclusion, such as through conservation zones, is minimal, waterways and their associated construction facilities can be categorized as public good.

The efficient provision of a public good requires that the marginal cost of providing the good equals the sum of the marginal benefits, i.e. the sum of the consumers' marginal rates of substitution (marginal WTP) must equal the marginal rate of transformation for the public good (marginal cost) (Samuelson, 1954). Hence, the cumulated WTP must equal the actual expenditures (transformation). This condition does not require equal distribution of costs or WTPs into a fund. For example, factors like distance from home to a waterway may affect the marginal WTP of the individuals.

2.6.2. Related studies

Studies on the WTP of fund-based citizen participation in infrastructure financing barely exist. Most prevalent in terms of waterways and WTP studies, we find studies on public interest in mitigating flood risk (e.g. Ding et al., 2019; Hérivaux and Le Coent, 2021; Londoño Cadavid and Ando, 2013; Toledo-Gallegos et al., 2022).

In our research, Spegel (2017) found that the Swedish population is willing to pay 30 cents for flood risk prevention (related to property real estate), with water supply security experiencing the highest WTP as opposed to road disruption prevention.

The study closest to our goal of assessing empirical Willingness-To-Pay (WTP) is by Entorf and Jensen (2020). They analyzed the WTP for investments in security-related measures by public institutions, particularly for protection against floods. They used the contingent valuation method based on a nationwide survey to determine the price of security as a non-tradable good. They found that the average WTP was approximately €90, with a median of €50. Furthermore, Entorf and Jensen (2020) concluded that government initiatives aimed at protecting against flood risks can be successful, and that increased risk awareness has a critical impact on WTP.

3. Research methodology

3.1. Requirements for the financing mechanism

Infrastructure funds to be considered should achieve an improvement to the current situation of the German waterways, serve the objectives of fund financing as well as advantages of citizen participation. To this end, we explore the option of funding of waterways through voluntary contributions from households, without using funds meant for other modes of transportation. Various fund models that address different problems in existing financing are considered to address a lack of capital (section 2.3) as well as other structural problems in infrastructure construction (section 2.4).

Requirements and assumptions for the funds, moreover, comprise the following:

- Avoidance of the state's indebtedness or rivalry with other departments, which is why citizens and households can pay into the fund on a voluntary basis.
- It is assumed that the state acts as the initiator of the introduction of the funds and can therefore decide on the fund introduced.
- A reporting system for tracking earmarking, transparency and better assessment of financing needs is further assumed to be in place for all potential funds.
- Further potential exists in an internationally standardized reporting system, increased use of PPPs, the creation of positions for better planning and involvement of the population, and central data processing for more targeted prioritization of rehabilitation measures (Tonn et al., 2021).

Analogous to Entorf and Jensen (2020), the WTP of the population for public investment in protective measures to reduce flood damage should be identified and, in addition, the WTP for public investment in

the general improvement of the condition of the waterways should be identified by means of a fund.

The benefits for which households should state their WTP are divided into the two major components reduction of opportunity costs, e.g., the avoided costs of flooding by maintaining a dam, and the envisaged increase in the efficiency of the current government system. Fig. 6 serves to illustrate the two components, as well as the directions of impact.

3.2. Funds mechanism

3.2.1. Framework

The state entails design freedom over the type of fund to be introduced. Fig. 7 shows the decision framework of fund financing as a 2-stage decision process, with the government deciding whether to introduce a fund in the first stage. In the second stage, households decide individually on their WTPs in funds or private coverage (PC). Each monetary unit invested is intended to provide benefits, while the state does not reduce the previous, regular expenditures and investments regarding IWs. PC of households in the following refers to PC against floods and inundation, whereby the specific form (e.g. insurance, reserves, or other) and legal aspects are not specified here.

As depicted by Fig. 7, we consider three types of funds leading to the following four options for the state:

(0) *no fund,* i.e., *maintaining the status quo*: This default decision by the government means that no changes are made in infrastructure financing, so the only option for households here is PC. The status quo provides a real-world benchmark, i.e., households' WTP for PC is intended to represent an initial measurement without the influence of funds, government, or other depositors and replicates Entorf and Jensen's (2020) survey. The state's payout for this scenario is considered as a benchmark for evaluating the fund alternatives. The state's valuation for the status quo is set equal to zero, as a comparison for positive and negative deviations, respectively, from a guaranteed achievable outcome.

(1) *introduction of fund 1 (F1)*: F1 is an auxiliary fund for the additional financing of IW infrastructure, whereby households do not expect any returns and therefore no disbursement is required. The benefits of the fund result from the effects of the measures implemented. F1 is financed by annual contributions. The earmarking relates to expansion, maintenance, optimization of the state's allocation of resources, and counteracting staff shortages. For this scenario, the WTP is queried for investments in both F1 and PC.

(2) *introduction of fund 2 (F2)*: F2 generally shares the characteristics of F1, with F2 including an additional insurance component in the event of flooding and inundation, which covers the costs incurred by depositors in the event of damage. The insurance component could offset parts of the underinsurance (section 2.2.2) and reduce the public goods dilemma with the inclusion of insurance, which is exclusive, since it is no longer a purely public good in this case. To this end, a household's utility is extended by possible insurance coverage, while benefits from the insurance coverage are attributed only to persons who paid in F2.

(3) *introduction of fund 3 (F3):* resources of F3 are to be spent on reforming the financing of all infrastructure funding to address structural problems, adopting and communicating the following goals by a credible third party as fund provider:
   a. funding independent of annual budget decisions.
   b. more positions and staff; and
   c. enhancing opportunities for community participation.

   The key difference between F1 and F2 is the scope of the fund, as F3 is intended for the reformation of all modes of transport (road, rail, etc.), while the other funds are limited to waterways. F3 also seeks to fundamentally change funding directly, thus representing a break with current structures.

3.2.2. Survey design

The aspired data regarding the WTP of households for the funds is determined via an online survey, based on the basics of survey design, covering replicability, structure, comprehensibility, topic orientation, answerability, sensitivity, social desirability, fatigue factors, and influenceability, among others (Brancato et al., 2006). The survey is designed as a web panel survey with random participants, with a random distribution of the survey link.

The final survey consist of 54 questions divided into five parts. It takes approximately 10 to 15 min to complete, and the questions are completed anonymously. Fig. 8 provides an overview of the structure of the questionnaire, which is provided in the appendix.

The introduction contains selected images that illustrate examples of waterway components and use. The subsequent Likert scales are 7-point from 0 to 6 to derive independent explanatory variables for the WTP. In addition, the general level of knowledge about water-related threats and risk perception of the population are determined. Risk perception is also related to the extent to which the population is affected in terms of dependencies due to flood risk or economic interdependencies between the respondent and IWs.

Subsequently, we state the relevance, the deteriorating condition, and funding gap of waterways before we query the WTP in scenarios 0–3, where respondents are free to enter values in euros.

Survey participants are then randomly assigned to one of four groups from Table 1 and answer the questions regarding WTP again, with participants now asked to answer the questions from the perspective of their assigned group, omitting F3. The four groups were chosen to measure the influence of housing location and employer concern, as it is suspected that these factors have a high influence on the WTP. The numbering in the matrix corresponds to the numbering in both the questionnaire and the data set.

Subsequently, we ask about influencing factors of WTP and repeat the Likert scale questions to test any shifts in respondents' perceptions or assessments as a result of the knowledge and awareness gained about waterways and their and other potential situations during the survey. The survey concludes with sociodemographic inquiries, including age, gender, income, and household size.

3.2.3. Assumptions about actors' actions and fund outcomes

Based on the considerations from game theory and the characteristics of funds, hypotheses are made regarding fund financing. These are listed by Table 2.

4. Case

4.1. Survey

The web panel survey was conducted from early April 2021 to mid-June 2021 and resulted in 113 fully completed questionnaires. The small sample size is largely due to the low response rate (<20 %), as surveys about WTP for services related to waterways tend to generate little public interest. Many WTP studies work with similar or even smaller sample sizes (e.g. Adegun, 2017; Alfnes et al. (2006); Botelho and Costa Pinto, 2002; Londoño Cadavid and Ando, 2013; Ubilava and Foster, 2009).

Nevertheless, we can observe some representativeness, when looking at socio-demographic characteristics: The average age was 40.84 years, while the gender distribution (male/female/diverse) was as follows (50.4 %/45.1 %/4.4 %). Similar data for Germany comprises an average age of 44.5 years (Statista, 2022) and a gender distribution of (50.7 %/49.3 %/0.0 %) (Bundeszentrale für politische Bildung, 2022). For the sample of our study, we also obtain a very similar income distribution to that of households in Germany for 2021. The average net household income as declared by our respondents was about 3620€ compared to 3517€ for German households overall. Education levels are still comparable, but our sample has slightly higher educational qualifications

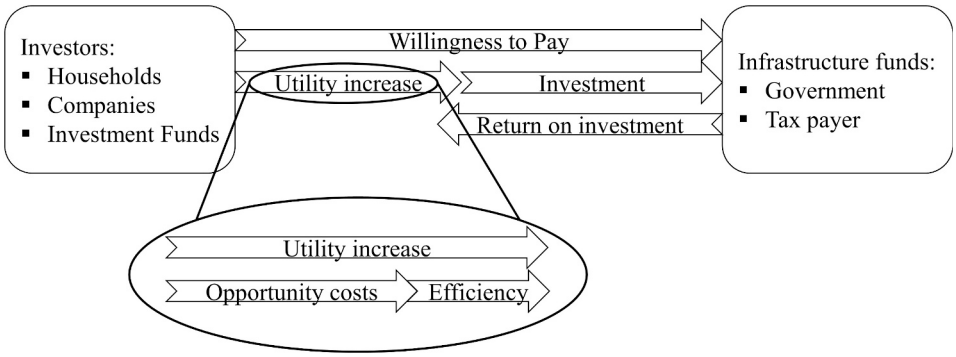

Fig. 6. Context of Willingness to Pay, Utility increase and Investment.

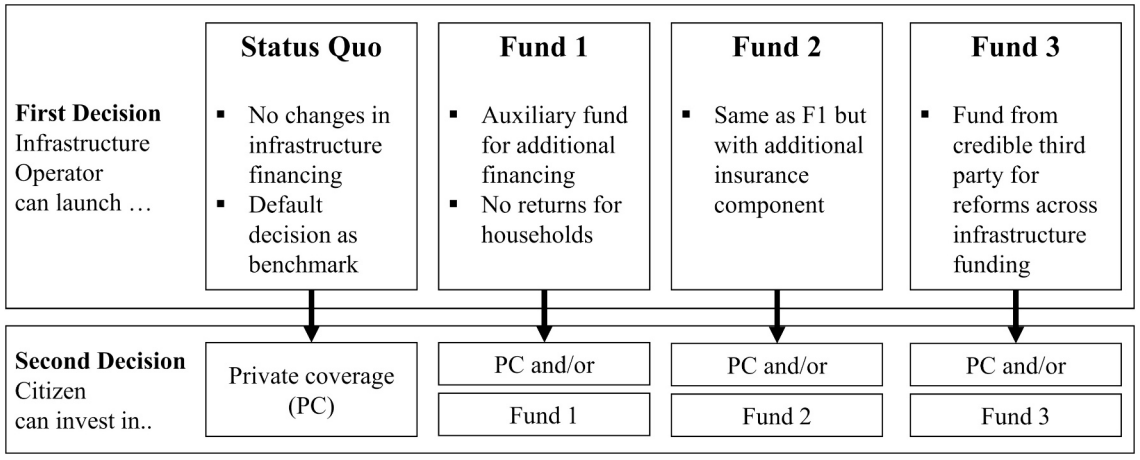

Fig. 7. Decision Framework.

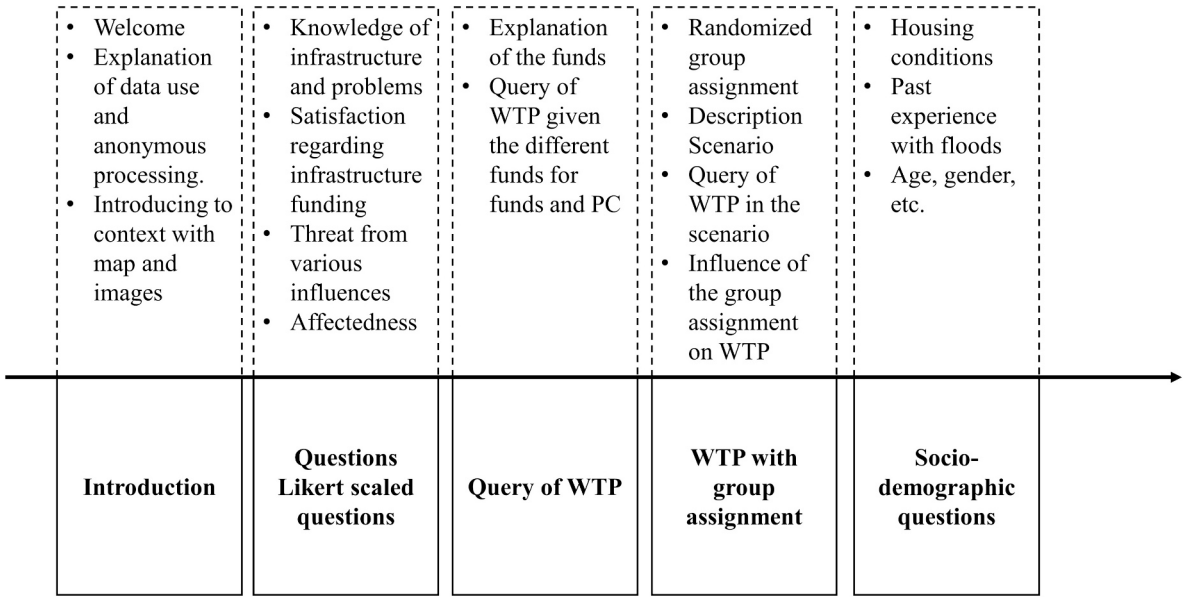

Fig. 8. Survey Design.

per category relative to the population.

According to Entorf and Jensen (2020), logarithmization of WTP data was performed as follows: all WTPs were incremented by a value of 1 before being logarithmized to avoid losing data with a value of 0 and to overcome the possibility of negative WTP's due to the right skewness of the data.

Table 1
Grouping matrix.

		Housing – distance to the nearest IW	
		Short	70 km
Employer	High dependence on IWs	Group 1	Group 3
	Independent of IWs	Group 4	Group 2

Table 2
Hypotheses.

Hypothesis	Fund	Formulation	Basis
H1	F1	Modal value of WTP for F1 is 0 €.	Rationality assumption of households; WTP for F1 low.
H2	F1	(Median of) WTP for F1 is around 50 €.	Comparable studies show unexpectedly high WTPs of about 50 €, cf. section 2.6
H3	F2	WTP for F2 is marginally higher than WTP for F1.	Exploitation of insurance component, since insurance coverage is available at marginal cost: the insurance component does not discriminate by deposit amount, but only nominally whether a payment is made
H4	F2	WTP for F2 is equal to sum of F1 and PC at F1.	F2 takes over the two functions of F1 + PC
H5	F2	WTP for PC at F2 is close to 0 €.	PC is already covered by F2
H6	all	Home ownership has a significant impact on WTP	Flood damage affects property/assets
H7	all	Doubts about the WTP of others have a high ranking (large influence).	Free-rider problem (section 2.3)
H8	all	Likert questions show significant differences in repeated measurement	Acquired knowledge and situation awareness

4.2. Results

4.2.1. Descriptive data

The WTPs show exhibit high standard deviations according to Fig. 9, with a mode of 0€ for all specifications. The median for PC, for the status quo, and in the case of F1 or F2, is also 0€, illustrating the right skewness of the data.

The median value for F1 is 29.19€, which is is significantly lower than that for F2 (45.08€) but higher than that for F3 (18.08€). F3 has the lowest mean value but, at the same time, the lowest standard deviation, indicating a more reliable estimation value.

Fig. 10 illustrates the WTP broken down by group (Table 1), with Group 1 consisting of 40 of the 113 participants randomly assigned. Group 2 (3, 4) have 26 (27, 20) participants, respectively. Boxplots of WTP, grouped by assigned group, for funds and PC show discernible differences between groups.

Within the scope of the ANOVA with repeated measures, group 1 exhibits generally higher WTP than the other groups, with the exception of WTP for F1. Group 4 also shows relatively high WTP compared to groups 2 and 3. The mean values of WTP for group 1 have roughly doubled compared to the WTP before grouping. In particular, group 2 shows a reduction in WTP for PC, while group 4 shows an increase in WTP for PC.

4.2.2. Test statistics

4.2.2.1. Change of WTP by group assignment. Since group assignment significantly affects WTP, Wilcoxon tests are conducted to determine whether central tendencies show significant differences before and during group assignment. The test statistics for group 1 can be taken from Table 3, with significant results ($p < 0.05$) found only for this group.

All previously visually detected differences for group 1 are significant according to the tests and WTP is increasing. When examining the change in WTP for group 2 (Table 3, G2), only the change for PC in status quo, PC at F1 and WTP for F2 are significant, with WTP decreasing. No clear conclusion can be drawn from the non-significant tests. The Wilcoxon test for group 3 (Table 3, G3) is only significant with respect to the decreasing WTP for PC at F1. WTP for PC in status quo is significantly higher after assignment to group 4 than before (Table 3). Examining the change in WTP of group 4, only the changes for PC in SQ and PC at F1 and WTP for F2 are significant. In these cases, the WTP increases. No clear conclusion can be drawn for the non-significant tests. The results show that group assignment affects WTP differently, with differences in terms of (1) specific WTP and (2) direction of effect. For group 4, WTP increases, while for group 2 it decreases.

4.2.2.2. Fund hypothesis testing. Our hypotheses (section 3.2.3) are considered mainly qualitatively and answered according to Table 4. Thus, H1, H2, H4, and H5 can be tested with respect to Fig. 9 and Fig. 11, whereas H3 requires a Wilcoxon-Test (Table 5) and H6 requires a Mann-Whitney-*U* Test (Table 6).

A Mann-Whitney-U test is used to examine the sample divided into homeowners ($n = 45$) and renters ($n = 68$) for differences in WTP.

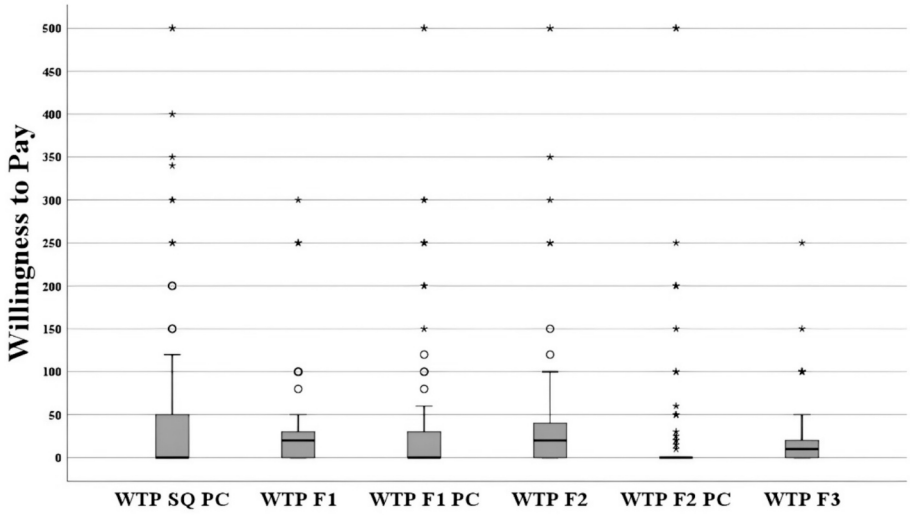

Fig. 9. Willingness to Pay into funds and private Coverage (PC).

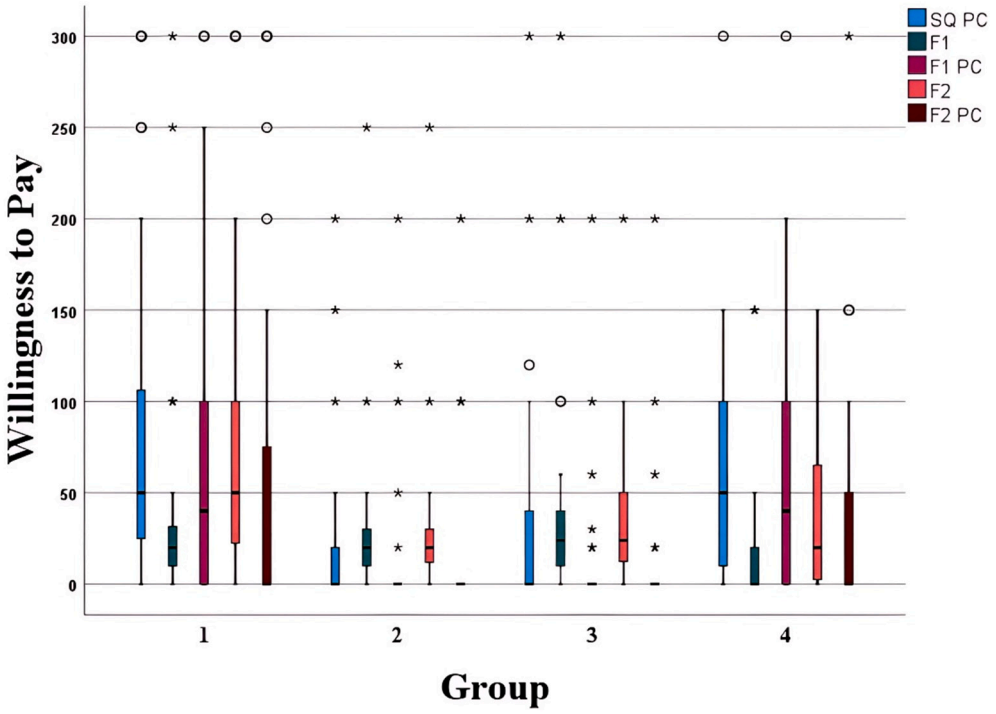

Fig. 10. Willingness to Pay broken down by groups
(14 Data points not displayed with WTP >499).

Table 3
Wilcoxon-Tests of groups.

	WTP (↑↓→)	Mean before	Mean after grouping	*Z*-Value	Significance p	Effect strength r, if significant
G1: SQ PC	↑	71	116	−3.784	***	0.60°
G1: F1	↑	42	59	−2.243	0.025*	0.35
G1: F1 PC	↑	53	110	−3.970	***	0.62°
G1: F2	↑	51	105	−4.551	***	0.72°
G1: F2 PC	↑	46	105	−2.814	0.005**	0.44°
G2: SQ PC	↓	50	22	−2.044	0.041*	0.4°
G2: F1	–	–	–	–	0.929	–
G2: F1 PC	↓	41	19	−2.075	0.038*	0.41°
G2: F2	↓	47	32	−2.235	0.025*	0.44°
G2: F2 PC	–	–	–	–	0.785	–
G3: SQ PC	–	–	–	–	0.484	–
G3: F1	–	–	–	–	0.052	–
G3: F1 PC	↓	41	16	−2.366	0.018*	0.45°
G3: F2	–	–	–	–	0.783	–
G3: F2 PC	–	–	–	–	0.109	–
G4: SQ PC	↑	37	68	−2.423	0.015**	0.54°
G4: F1	–	–	–	–	0.917	–
G4: F1 PC	↑	9	67	−3.317	***	0.74°
G4: F2	↑	39	41	−2.147	0.032*	0.48°
G4: F2 PC	–	–	–	–	0.108	–

strength r: ° for strong effect.
* significance: for $p < 0.05$.
** for $p < 0.01$.
*** for $p < 0{,}001$

According to the results, significant differences exist in WTP for PCs, while the state's decision (SQ, F1, F2) has only a small impact on significance: WTP for funds is not significantly different between homeowners and renters.

4.2.2.3. Influencing factors of WTP. Suggested influencing factors are ranked by subjects, with results shown in Fig. 11: "Distance to waterway" has the highest average influence (lowest rank 2.55) on WTP, followed by "Housing relationship" (2.83) and "Confidence in effective use of funds" (2.89) "Return on fund" (3.8), "Being affected in the past" (4.42) and "Doubts about others' WTP" (4.5) occupy comparatively lower positions.

The relatively low influence of "Doubts about others' WTP" on WTP contradicts the free-rider assumption. This is presumably due to the fact that there is no threat of free riding in the literal sense: if too few people are willing to contribute, the fund cannot be set up. Additionally, the lack of return on funds also only occupies the third place.

Table 4
Hypothesis testing.

Hypothesis	Result	Proof
H1: Modal value of WTP for F1 is 0 €.	confirmed	Fig. 9
H2: (Median of) WTP for F1 is around 50 €.	not confirmed	Fig. 9; Median 20 € (Mean 29 €)
H3: WTP for F2 is marginally higher than WTP for F1.	confirmed	Table 5
H4: WTP for F2 is equal to sum of F1 and PC at F1.	Case-dependent, see proof	If the medians are used for the analysis, the hypothesis can be confirmed (20 = 20 + 0), whereas if the mean values are used, the hypothesis is rejected (45 ≠ 29 + 40) (Fig. 9). In addition, the high standard deviation should be taken into account when using the mean values.
H5: WTP for PC at F2 is close to 0 €.	confirmed	Fig. 9
H6: Home ownership has a significant impact on WTP	not confirmed	Table 6
H7: Doubts about the WTP of others have a high ranking (large influence).	not confirmed	Fig. 11

Table 6
Mann-Whitney-U Test influence of housing on WTP.

	WTP owner	WTP renter	Z-Value	Significance p	Effect strength r, if significant
Sq PC	109	20	−3.563	***	0.34 (medium)
F1 PC	79	13	−3.002	0.003**	0.28 (weak)
F1				0.096	
F2 PC	61	7	−2.511	0.012*	0.24 (weak)
F2				0.367	
F3				0.421	

strength r: ° for strong effect.
* significance: for $p < 0.05$.
** for $p < 0.01$.
*** for $p < 0,001$.

almost all questions, while it is evident that the answers rarely show major deviations from the value 3 (expected value with normal, equal distribution) in the mean value. “Knowledge of condition” (1.96), “Existential consequences” (4.35), “Consequences society” (1.96) and “Existential consequences_2” (4.65) are the extremes with deviation

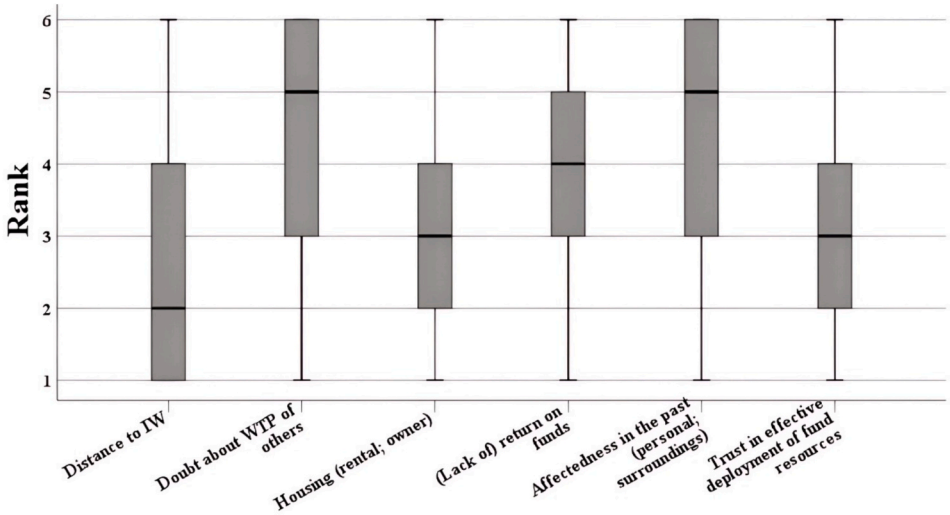

Fig. 11. Ranking of influencing factors (high rank = low rating).

Table 5
Wilcoxon-Test: differences between funds.*, **

	WTP F1	WTP F2	WTP F3	Z-Value	Significance p	Effect strength r, if significant
F2-F1	29	45		−3.976	***	0.37
F3-F1			18	−4.610	***	0.43°
F3-F2		45	18	−5.875	***	0.55°

strength r: ° for strong effect.
* significance: for $p < 0.05$.
** for $p < 0.01$.
*** for $p < 0,001$.

4.2.2.4. Likert scales. Fig. 12 illustrates the responses to the Likert questions before and after the group assignment, with the latter being marked with the suffix “_2”. The full range of response options is used for greater than one.

A *t*-test[1] to analyze differences under repeated measurements reveals significant differences between the responses given at the beginning and end of the survey; exceptions to this are the assessment of threats to waterways from climate change and from structural deterioration of dams, respectively (Table 7).

The ratings of the threats, the probability of failure and the consequences in case of failure of the waterways increase. Only the estimation of satisfaction with the condition of the waterways declines. The fact that 9 out of 11 responses show significant differences, combined with the relatively low self-assessment of knowledge on the topic (2.14) and knowledge of the condition of the waterways (1.96), suggests a lack of awareness among the population. Potential reasons for this may include disinterest, perceived relevance, or the topic's high complexity.

[1] Possible violation of the normal distribution assumption can be neglected with the sample size (113)

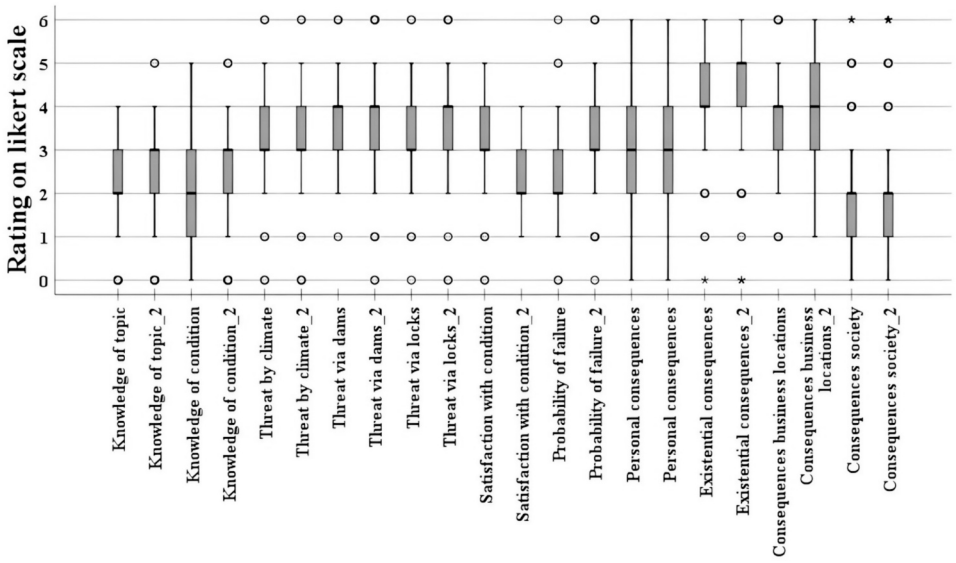

Fig. 12. Answers to Likert-scaled questions
("_2": repeated measure; value 0: total rejection; value 1: total approval).

Table 7
T-test for differences in likert questions; N = 113.

Topic	Likert value	Rank before (mean)	Rank_2 (mean)	T-Value	Significance p	Effect strength r, if significant
Knowledge of topic	↑	2.14	2.53	−4.451	***	0.39
Knowledge of condition	↑	1.96	2.55	−6.656	***	0.53°
Threat by climate	–	–	–	–	0.256	–
Threat via dams	–	–	–	–	0.460	–
Threat via locks	↑	3.19	3.7	−4.984	***	0.43
Satisfaction with condition	↓	3.21	2.2	11.898	***	0.74°
Probability of failure	↑	2.38	3.39	−10.404	***	0.7°
Personal consequences	↑	2.69	2.95	−3.051	0.003**	0.28 (weak)
Existential consequences	↑	4.35	4.65	−3.291	0.001**	0.3
Consequences business locations	↑	3.72	3.92	−2.77	0.007**	0.25 (weak)
Consequences society	↑	1.96	2.13	−2.117	0.036*	0.2 (weak)

strength r: ° for strong effect.
* significance: for $p < 0.05$.
** for $p < 0.01$.
*** for $p < 0{,}001$

4.2.3. Regression

After a general WTP for the funds and PCs has been established and the influence of individual parameters on the WTP has been analyzed, regression models for the WTP are presented below. For the variable inclusion method, "forward and backward selection" and "stepwise" procedures show similar results, but they include only a few variables, focusing only on significant ones, which may bias the results. Therefore, a regression model with the inclusion method is used, in which most of the variables considered relevant are included.

4.2.3.1. WTP for PC at scenario 0. Since the WTP are logarithmized (section 4.1), the regression model is formulated according to eq. (1). The corresponding analysis of variance (Table 8) shows the listed variables and that the model is significant ($F(15,97) = 10.589$, $p < 0.001$).

$$log(y) = \alpha + \beta_1 \bullet x_1 + \beta_2 \bullet x_2 + \ldots + \varepsilon \quad (1)$$

The quality of the model, corrected R^2 (R^2), is 0.562 (0.621), resulting in an effect strength of $f^2 = 1.28$, which corresponds to a strong effect according to Jacob Cohen (1992). Furthermore, it is assumed for the interpretation that the Gauss-Markov assumptions are acceptably met.

We use the HC-3 method for the interpretation of the regression coefficients, to avoid any problems with heteroscedasticity (Hayes and Cai, 2007). The highlighted values are significant at the 0.5 % level (at the 1 % level with footnote). Table 8 shows that only 5 variables exhibit a significant effect on WTP.

Using the example of the variable "WTP SQ" (query whether already paid in PC), an increase in WTP of 121.6 % can be expected when the variable increases from 0 (No) to 1 (Yes). That is, a person who is already paying into PC is willing to spend 121.6 % more on PC than a person who is not yet paying into PC. It should be noted at this point that these are approximate percentage changes (log-level model).

4.2.3.2. WTP F1 and PC. The regression model of **WTP for F1** shows significance ($F(15,97) = 6.64$, $p < 0.001$) with a quality, corrected R^2 (R^2) of 0,43 (0,507), resulting in a strong effect $\left(f^2 = 0.75\right)$.

Seven variables show statistical significance for WTP in F1 with biggest significance of WTP for PC in case of F1 (0,422) and the affectedness by floods in the environment of the respondents (0,375). The regressions model for **WTP in PC** in case of F1 exhibits significance ($F(15,97) = 8.167$, $p < 0.001$) and a quality of the model (corrected R^2 (R^2)) of 0,49 (0,558), resulting in a strong effect $\left(f^2 = 0.96\right)$.

Five explanatory variables demonstrate statistical significance, with

Table 8
Regression Data.

	S0 PC		F1		F1 PC		F2		F2 PC		F3		F1 group	
df	15; 97		15; 97		15; 97		15; 97		15; 97		14; 98		20; 92	
F	10.589		6.64		8.167		4.236		5.266		2.019		1.792	
p	<0.001		<0.001		<0.001		<0.001		<0.001		0.024		<0.001	
R^2 (korr)	0.562 (0.621)		0.43 (0.507)		0.49 (0.558)		0.302 (0.396)		0.364 (0.449)		0.113 (0.224)		0.462 (0.558)	
f^2	1.28		0.75		0.96		0.43		0.57		0.13		0.86	
	Coeff	**Sig**	**Coeff**	**Sig**	**Coeff**	**Sig**	**Coeff**	**Sig**	**Coeff**	**Sig**	Coeff	Sig	Coeff	Sig
Personal consequences	0.008	0.919	−0.117	**0.047**	0.079	0.256	−0.024	0.743	−0.003	0.962	−0.034	0.642	−0.065	0.224
Consequences business locations	0.065	0.543	0.172	**0.027**	−0.077	0.421	0.127	0.151	−0.072	0.453	0.033	0.764	0.133	0.112
Consequences society	0.239	**0.000**	−0.157	**0.014**	0.276	**0.000**	−0.108	0.137	0.247	**0.001**	−0.019	0.808	0.056	0.296
Personal consequences	0.800	**0.001**	0.486	0.152	0.150	0.633	0.421	0.522	0.421	0.615	0.321	0.603	0.452	0.227
Surrounding affected	0.410	**0.016**	0.375	**0.007**	0.155	0.422	0.496	**0.001**	−0.045	0.821	0.335	**0.096[b]**	0.376	**0.012**
Residence (coded)	0.115	0.474	0.175	0.197	−0.271	**0.093[b]**	0.157	0.333	−0.194	0.282	0.136	0.436	0.174	0.173
Distance (coded)	−0.259	**0.040**	0.033	0.731	−0.234	**0.026**	0.033	0.787	−0.310	**0.005**	−0.024	0.843	0.016	0.869
Sex (coded)	−0.102	0.321	−0.227	**0.043**	0.086	0.516	−0.349	**0.008**	0.094	0.571	−0.165	0.226	−0.216	**0.009**
Income (coded)	0.025	0.265	0.035	**0.017**	0.002	0.901	0.035	**0.090[b]**	0.019	0.389	0.051	**0.015**	0.062	**0.000**
Housing	−0.208	0.227	0.125	0.428	−0.345	**0.070[b]**	0.068	0.715	−0.152	0.342	−0.050	0.780	0.081	0.590
WTP SQ	1.216	**0.000**								1.216				
WTP F1 PC log			0.422	**0.000**										
WTP F1 log					0.538	**0.000**		**0.005**						
WTP F2 PC log							0.365	0.314	**0.019**					
WTP F2 log														
Scenario 3.0													0.352	**0.043**
Scenario 4.0													−0.541	**0.002**
WTP F1 PC log Group													0.139	**0.097[b]**

two being significant at the 1 % level. WTP for PC in the case of F1 has the largest significant effect (0.538). The influence of being affected by floods in the respondents' neighborhood is not significant compared to the regression model for WTP in F1.

4.2.3.3. WTP F2 and PC. The regression models for household WTP in the scenario where F2 is introduced by the government are presented as follows. The regression model for WTP for F2 shows significance (F (15,97) = 4.236, p < 0.001). The goodness of the model, corrected R^2 (R^2), is 0.302 (0.396). Therefore, we observe a strong effect $\left(f^2 = 0.43\right)$.

Among the 15 explanatory variables, four have a statistically significant influence on WTP, including gender. A male respondent has a 35 % lower WTP for F2 than a female respondent, while household income has a significantly lower impact (0.035). The regression model for WTP in PC for the case of the introduction of the F2 shows significance (F (15,97) = 5.266, $p < 0.001$), with a goodness of the model, corrected R^2 (R^2), of at 0.364 (0.449) and thus a strong effect $\left(f^2 = 0.57\right)$.

Only three of the variables included in the model have a statistically significant influence. The assessment of the consequences for society has a positive influence. A rating one rank higher in the Likert scale suggests 24.7 % increasing WTP. Similar to the results for the regression of F1, it appears that WTP for PC positively influences WTP for the fund and vice versa.

4.2.3.4. WTP F3. The model shows statistical significance (F (14,98) = 2.019, $p = 0.024$) and a goodness of fit of R^2 (R^2) = 0,113 (0,224). This results in a small effect $\left(f^2 = 0.13\right)$. Thus, the regression model for F3 appears to have only a limited fit. Without prejudice to the discussion, it is evident that the model's goodness of fit and effect size are low, especially compared to the regression models for F1 and F2. The significance level of the model is also notably weaker, with only two explanatory variables having a significant effect, one of which is significant only at the 1 % level. Household income (0.051) and being affected by floods in the respondents' neighborhood (0.335) both exhibit explanatory influence.

4.2.3.5. WTP F1 with group assignment. Finally, an exemplary regression model is presented, which accounts for the scenarios of assignment to different groups by including dummy variables for the corresponding groups. Additionally, the dichotomous variables of influence (Yes, No) with respect to employer and place of residence are incorporated into the model. The coefficients lack information regarding the dummy variables for assignment to group 1 (scenario = 1.0). This is expected, since one of the dummy variables can be mapped over the others and is therefore excluded from the model (if it is not dummy-2, −3, or − 4, it follows that it is dummy-1).

The model shows significance (F (20,92) = 5.802, $p < 0.001$). The goodness of the model, corrected R^2 (R^2), is 0.462 (0.558). Therefore, a strong effect results $\left(f^2 = 0.86\right)$.

Six of the included variables demonstrate a significant influence on the independent variable. "Surrounding affected" and " WTP F1 PC log Group" are significant, with a positive influence on WTP, similar to the data without group assignment.. The dummy variables (representing group assignment) have a significant influence for groups 3 and 4, which is also confirmed by the Wilcoxon tests.

The multicollinearity test is performed using the data in Table 8. It is observed that all variance inflation factor values are below 10, and more precisely, below 3, indicating that there is no issue with multicollinearity (Wooldridge, 2013).

5. Discussion

5.1. Findings

In summary, the proposed infrastructure funds can be financed by household, thereby supporting an overall improvement of infrastructure condition.

Nevertheless, the WTP of households for the three funds varies. In the survey, F1 receives a mean (median) WTP of about 29€ (20€), which is lower than the WTP for F2 with 45€ (20€), but higher than the WTP for F3 with 18€ (10€). Compared to the WTP values reports in similar studies (64–69, 30–76, 36–148, 50, 315; Entorf and Jensen, 2020), these WTP values are relatively low. Possible reasons for the lower WTP include the low awareness of the waterway and the timing of the survey, which coincided with the COVID-19 pandemic and its associated economic challenges.

A general WTP for the public good is measurable; this finding contrasts with the theoretically expected behavior according to game theory but aligns with behavior observed in experiments.

The difference of the WTP between F2 to F1 does not appear to correspond to the WTP for PC, although no formal test was conducted. This suggests that respondents may have less trust the insurance component of F2 compared to PC or may exploit the insurance coverage. Exploitation is possible because F2 does not differentiate based on the amount of the deposit, meaning that a WTP of €1 provides the same "insurance protection" as a higher WTP, which is likely underestimated.

However, since the WTP for PC in the case of F2 is close to zero, it is more likely that the insurance component is being exploited. If a lack of trust were the cause, a higher value of PC would be expected. Other influences not considered here are also conceivable. Regardless of the reason for the slightly higher WTP for F2, an adjustment must be made, or the additional cost of insurance will not be covered.

A possible reason for the low WTP for F3 could be that the fund's objectives are either unclear or are perceived as too general.

The Wilcoxon tests regarding group assignment indicate that the influence variables "dependence of employer" and "distance of residence to waterway" are relevant. The influence "distance of the place of residence to the waterway" is particularly dominant. This is evident from the fact that the direction of action (increasing or decreasing WTP) is reversed if "dependence of the employer" is kept constant and "distance of the place of residence to the waterway" is varied. Conversely, if "distance of residence to waterway" is kept constant, there is no reversal of the direction of action. The finding that "one's own home appears more important than one's employer" is intuitively understandable (given the high direct financial damage and emotional loss), but cannot be further elaborated here.

An examination of the coefficients of the regression models for F1 and F2 reveals differences between the funds. For both funds, having been affected by floods in the past, gender and household income have a significant influence. For F1, the assessment of the Likert scale questions regarding the threat (due to failure of the waterway) to one's own existence, individual economic locations and society are also significant.

Household size, place of residence (urban or rural), and home ownership do not have a significant influence in the regressions, in contrast to the findings from Entorf and Jensen (2020) who note that age, gender, and education are significant in other studies. In this paper, this statement is only confirmed for the influence of gender.

The influence of home ownership on WTP for PC is not found in the regression models of WTP for funds. Additionally, the distance of the home from the waterway does not show significance in the regression models for F1 and F2, which is inconsistent with the results from the Wilcoxon tests.

5.2. Limitations

Due to the complexity and elusiveness of the topic, combined with many hypothetical questions, the WTP estimates for a hypothetical fund with abstract implications can hardly be equated with realistic payments. Instead, they primarily indicate trends relative to each other.

The implementation of the survey could be optimized by repeated surveys, an increase in the number of participants, and the inclusion of a professional pilot survey for feedback and validation, as well as the consolidation of the items queried.

Few studies and regressions have been conducted in this specific research area resulting in a lack of comparative values and references. Moreover, identifying clear, causally based relationships and thus influencing variables in this complex context is challenging. Despite these limitations, the findings contribute valuable insights, as the basic interrelationships are still accessible.

5.3. Remark on the role of trust

While the WTP for risk reduction typically depends on the population's perception of risk (Birkholz et al., 2014; Bubeck et al., 2013), the WTP for efficient use of funds to strengthen infrastructure is more strongly influenced by citizens' trust in the state and the efficiency and reliability of public services of general interest. Scandinavian countries, for example, traditionally place a larger share of public services in the hands of the state and at the same time have an above-average level of trust in the state and public institutions (Marozzi, 2015; Yamamura, 2012).

However, trust is not only a prerequisite, but also a potential gain from such a fund initiative. Involving citizens in the financing of public infrastructure promotes their interest, awareness and knowledge of infrastructure-related risks. Moreover, the transparency of the financing and decision-making processes that accompanies a public fund also contributes to this (Mabillard and Pasquier, 2016).

6. Conclusion and outlook

The survey data indicate an existing WTP for the funds and waterways which is >0€. Overall, additional financial resources under the funds can contribute positively to societal benefits, provided that the deficits in alongside mechanisms (section 2.4) are addressed, at least in the long term. Infrastructure funding problems can thus be circumvented or mitigated. The regression models for the funds show and confirm significant influences on WTP.

These findings suggest that citizen participation in infrastructure financing through infrastructure funds is both financially feasible and beneficial. The problems surrounding waterway financing could be mitigated in the medium term, warranting further research in this area.

Policy recommendations include verifying the feasibility of such initiatives under regional laws and regulations, addressing deficits in infrastructure financing, and active involving the population in these processes.

The problems and shortcomings identified provide a strong foundation for follow-up research and investigation. Verification of these findings with a larger data set is recommended. Additionally, other factors, with presumed gains in knowledge, should be included in a renewed survey.

Sociometric parameters are used to approximate the representativeness of the study participants. However, online studies on infrastructure funds typically have a small number of participants due to low response rates. Nevertheless, the results demonstrate significant effect strength, implying relevant validity. Therefore, further studies would benefit from a larger data set to verify the findings and enhance statistical power.

One point for further investigation is the compatibility of the fund models with existing legal regulations. For simplicity, the feasibility of the measures was assumed in the paper, but this assumption needs to be examined for any more realistic considerations. Therefore, the identified role of funding of waterways and the possibilities of citizen participation

are of high relevance. Moreover, the social rate of return of infrastructure can be observed (Gardner and Henry, 2023).

The modeling of the impact of the funds on waterway financing needs additional research, as existing evidence in this area needs to be supplemented. Further influencing factors should be considered to expand the scope of the research. For example, innovations in infrastructure funding, such as public funds, should consider circular infrastructure (Coenen et al., 2023). Therefore, future iterations of this research could benefit from perspectives of circular economy policy (Hartley et al., 2020) and circular start-ups (Henry et al., 2021). Moreover, the overlaps with impact investing and social bonds should be explored (Chiappini, Marinelli et al., 2023).

Availability of data and material

Fundamental data is included in the article and its supplementary information files. The complete datasets during and/or analyzed during the current study are available from the corresponding author on reasonable request, due to file sizes.

Competing interests

The authors declare that they have no competing interests.

CRediT authorship contribution statement

Rebecca Wehrle: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Marcus Wiens:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization. **Frank Schultmann:** Writing – review & editing, Supervision, Funding acquisition.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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