Interreg
Danube Transnational Programme
DAREFFORT

# Economic impact analysis of potential future system scenarios

# WP3 Deliverable 3.2.5

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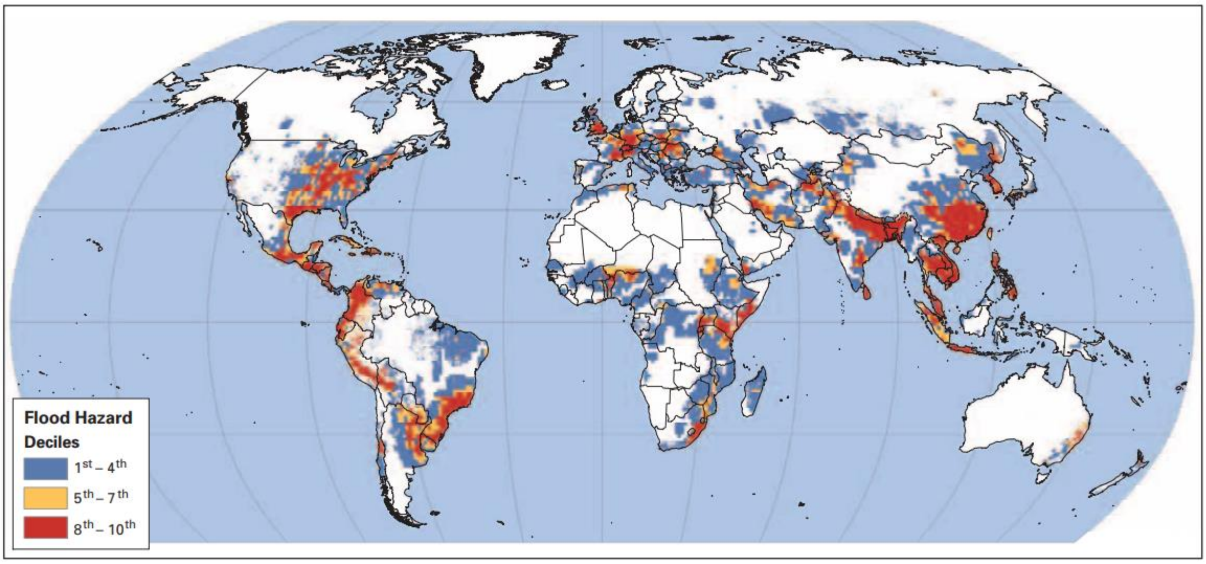
## Introduction

Since the ancient times, floods have been a natural disaster that humans have had to combat. In modern days, this is truer than ever before. The frequency of natural disasters such as floods is increasing due to climate change. Floods alone affect over 80 per cent of the world's population and more than a third of the world's landmass (Dilley et al., 2005). It is estimated that between 1980 and 2013, floods have resulted in death of 117,000 persons and caused economic damages of around 487 billion Dollar (Thielen-del Pozo et al., 2015).

Figure 1 shows the distribution of floods around the globe. More than 2 billion people around the globe live in regions that have high risks of floods occurring (coloured red). Areas that are at risk of being flooded are areas that generally have a high concentration of GDP (Dilley et al., 2005), which is to be somewhat expected as flood-prone areas tend to have higher levels of agricultural production and tend to be more developed economically.

**Figure 1: Distribution of hazardous areas - floods**




*Source: Dilley et al. (2005).*

Visible in Figure 1 is the fact that almost the entirety of the European continent is somewhat affected by floods. Since 1870, the percentage of population exposed to 100-year floods decreased very slightly, while coastal flooding has increased across the entire continent (Paprotny, 2018). However, this is an average across the countries of Europe. Certain countries, such as Austria have seen a stark increase in share of population exposed to flood hazards. Overall flood risks and thus flood management remain an important issue for Europeans. Pappenberger et al. (2015) studied the economic benefits of the continental-scale European Flood Awareness System (EFAS). The cost-benefit analysis revealed that for every Euro invested in the system, the return would be around 159 Euros (20 trillion Euro over 20 years). Improved forecast performances could increase this ratio to 1:202 or even up to 1:409 (Pappenberger et al., 2015).

An effective flood risk management is necessary for mitigating the impact of floods on population, property and the environment. Early warning systems, which allow for early responses, require high level of forecasting data. Forecasting remains one of the most powerful tools in flood management (Pappenberger et al., 2015). These systems are highly effective at reducing damage caused by floods. A recent study which focused on early warnings via the advanced prediction of precipitation information in the San Francisco Bay region concluded that an introduction of such a system would yield strong economic benefits (Johnson et al., 2020). The resulting benefits such as avoided flood damages, increasing water supplies, enhancement of ecological, recreational, and transportation services would strongly outweigh any costs (Johnson et al., 2020).

Thus, effective flood forecasting becomes an absolute necessity to minimize damages to life and property in the Danube basin. Certain upstream regions such as Bavaria, Salzburg, Upper- and Lower Austria already have the necessary tools and supranational coordination, which allows for effective flood preparation and water management. Allowing downstream countries access to this data would greatly increase their ability to create higher quality forecasts and allow them more manoeuvrability to counteract the incoming floods. An issue with most modern economic valuations of flood preventative measures is that the effects of measures are often only studied on a local level. Regional and supra-regional effects are often neglected (Dehnhardt et al., 2008). DAREFFORT's outcome of allowing hydrological and meteorological data of nations along the Danube basin to be easily accessible to one another will be a major milestone in increased flood prevention in this area, and result in a supra-regional economic analysis of the effectiveness of the flood prevention measures.

Flood prevention methods can be categorized into three separate groups, following the LAWA 1995[1] guidelines (Dehnhardt et al., 2008).

1) Land management
   Land management focuses on increasing an areas resistance to flooding and ability to take more water in, by removing impervious surfaces.

2) Technical flood protection
   Flood protection via structural engineering is a core part of effective flood management. Dikes, dams, flood control reservoirs, dams and other structures can effectively minimize the damage potential of floods to a certain region.

3) Flood prevention
   This point will entail the core strategy of DAREFFORT and its flood preventative measures. This area focuses on behaviour of both authorities and population (mitigating damages due to early warning systems, emergency plans, etc). It is suitable even during extreme occasions, when technical flood protection is not enough against the incoming water masses. Since the average flood protection level in Europe is well below the required level to thwart a hundred-year flood occurrence (Pappenberger et al. 2015), flood prevention forms a key compo-

[1] Bund/Länder-Arbeitsgemeinschaft Wasser (LAWA) is a working body of the german Umweltministerkonferenz (Conference of environment ministers).

nent in combating stronger floods occurrences. Updated building codes, early warning systems, establishing emergency plans and risk provisions are some of the more common methods used to counteract floods, especially those of extreme intensity.

The DAREFFORT deliverable 3.2.5 *Economic impact analysis of potential future system scenarios* executes an ex ante estimation of the economic effects resulting of the outcome of the DAREFFORT project in different scenarios.

The first chapter gives an overview about the methodology used in this deliverable. A two-step approach, consisting of a cost-benefit analysis (CBA) and an input-output analysis (IOA), was chosen.

Chapter 2 presents shortly the different *potential future system scenarios*, which has been elaborated by Marius Matreata (PP6, National Institute of Hydrology and Water Management) and revised by the lead partner and other project partners

A summary of the underlaying data is provided in chapter 3.

In chapter 4 the centrepiece of this report is presented: the execution of the economic impact analysis of Scenario 0 and 1.

Based on the previous chapter, chapter 5 shows the results of the economic impact analysis and supplements it with a qualitative valuation of possible effects in Scenario 2 and 3.

Conclusions are drawn in chapter 6.

# 1 Methodology

## 1.1 Cost-benefit analysis

A cost-benefit analysis (CBA) is used to determine, appraise and present a policy, project, investment or decision with respect to its costs and benefits. It is an analysis of the expected benefits and the expected costs used to draw conclusion regarding net benefits of implementing the project. A CBA has two main uses

1) To analyse the amount of cost and benefits of a project and attain if the benefits outweigh the costs
2) To offer a way to compare various projects and/or decisions via an assessment of the total expected costs and benefits

In general, a CBA compares two different states of the reality (counterfactual). It compares the situation with and without an intervention or project and not the situation before and after. Future costs are contrasted with future benefits. As one Euro today has a higher value than a Euro in one year, future values need to be discounted by a discount factor. In the literature, discount rates of 5.0 per cent p. a. are not uncommon (European Commission, 2008). However, in the light of the European low interest rate environment, and the long-time frame (till 2060), a conservative approach was used, and an interest rate of 2.5 per cent p. a. is assumed.

A CBA can include both quantitative and qualitative data; however, it is far easier to include quantitative information since the construction costs and benefits of a new dam are easier to analyse than the new feeling of safety that the surrounding residents might have after its construction.

A limitation of CBA is the issue of including non-market values. Ethical questions, such as the price/value of a human life, leave room for concerns and discussion. A clear strength of CBA is that it is a “useful tool which has its main strength that it is an explicit and rigorous accounting framework for systematic cost-efficient decision-making” (Mechler, 2005). It has become a popular tool to use in the United States, especially during the Reagan administration and "at times dominated the policy debate on natural hazards" (Burby, 1991).

## 1.2 Economic footprint[2] – input-output analysis

An input-output analysis is a macroeconomic tool, which can, among other things, be used for estimating the economic impacts of various positive or negative shocks in terms of changes on employment or gross value added. In this study, this method is used to quantify the economic footprint of improved flood forecasting in the Danube River Basin. Economica, as the leading institute in Europe in economic impact analysis, maintains a sophisticated portfolio of so-called “satellite accounts” for this purpose, based on state-of-the-art research.

[2] The “Economic footprint” is a method to quantify economic impacts of companies, sectors or systems, designed by Economica. Economica holds a trademark protection for the German term “ökonomischer Fußabdruck”.

### *1.2.1 Input-output-tables*

Input-output tables describe an economy by focusing on detailed economic "sectors". They are symmetric, based on an industry by industry (NACE x NACE) or a product by product (CPA x CPA) classification. The European System of National and Regional Accounts (ESA) promotes *product by product* input-output tables (IOT, pl.: IOTs), therefore almost all Member States provide such tables.  For this project, an EU-wide multiregional Input-output table for the year 2020 was used. As Moldova, Serbia, and the Ukraine have to be analysed as well, they were approximated by countries assumed to be similar. This is possible, as only the structures of the economies have to be similar, not their size. This means that they should use similar technologies, similar ratio of human capital per machine capital and the like. Therefore, Moldova was approximated by Bulgaria, Serbia by Hungary and the Ukraine by Poland. IOTs have the general advantage of allowing further economic evaluation of direct and indirect effects. These are the impacts generated within the supply network (indirect effect).

Figure 2 shows an exemplary domestic IOT with simple numbers in it. Please note that for the sake of simplicity we use "good" and "sector" synonymously from now on.

**Figure 2: A simplified domestic input-output table.**

| | Good 1 | Good 2 | Good 3 | Total | Private Consumption | Public Consumption | Final Consumption | Capital Formation, Valuables | Exports | Total Final Use | Total Use |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Good 1 | 1 | 2 | 1 | 4 | 5 | 0 | 5 | 6 | 3 | 14 | 18 |
| Good 2 | 3 | 17 | 10 | 30 | 10 | 0 | 10 | 10 | 2 | 22 | 52 |
| Good 3 | 0 | 10 | 10 | 20 | 5 | 5 | 10 | 5 | 7 | 22 | 42 |
| Total | 4 | 29 | 21 | **54** | 20 | 5 | **25** | 21 | **12** | **58** | **112** |
| Use of imported products | 1 | 3 | 2 | 6 | 2 | 1 | 3 | 5 | 1 | 9 | 15 |
| Taxes less subs. on products | 1 | -2 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 5 | 6 |
| Total | 6 | 30 | 25 | 61 | 23 | 7 | 30 | 28 | 14 | 72 | 133 |
| Employees' comp. | 1 | 2 | 3 | 6 | | | | | | | |
| Cons. fixed capital | 3 | 4 | 3 | 10 | | | | | | | |
| Oth. taxes on production | 6 | 14 | 8 | 28 | | | | | | | |
| Operating surplus | 2 | 2 | 3 | 7 | | | | | | | |
| Gross Value Added | 12 | 22 | 17 | **51** | | | | | | | |
| Output | 18 | 52 | 42 | **112** | | | | | | | |

*Source: Economica.*

The core of the table, formed by the intersection of the sectors in the upper left part, is the intermediate goods matrix, shown in purple. It reveals the business-to-business relations within an economy. Rows report deliveries, whilst columns contain purchases. For example, sector 1 delivers one unit to itself, two units to sector 2 and one unit to sector 3 (upmost purple row). On the other hand, it receives one unit from itself, three units from sector 2 and nothing from sector 3 (left purple column).

Since goods are not the only cost element, additional rows are added below, containing imports, taxes less subsidies on products and gross value added (GVA) with all of its components (wages, consumption of fixed capital, other taxes on production, and surplus). Intermediate goods input plus imports plus taxes less subsidies plus GVA sum to each sector's output, which is the last row in Figure 2. This is the value of all goods of a sector produced in the economy. Output is often similar, but practically never identical, to turnover, as production and sales usually deviate from each other.

As goods are not just purchased by other companies, extra columns are placed to the right of the intermediate goods matrix. Here one finds, broadly speaking, private consumption, public consumption, gross capital formation, changes in valuables and inventories, as well as exports. They sum to total use. As all goods which are produced have to be consumed (or stored) somehow, the sum of each row (total use, orange part) equals the sum of the corresponding column (output, orange).

Please note that

- Private consumption uses a territorial definition: it equals the consumption of all private households within the economy. Foreign households consuming within the economy (tourists) are therefore counted as "private consumption" while domestic households consuming abroad are not.
- Imports can be exported directly. In real IOTs the value is small, but usually strictly positive.
- Taxes on *products* are reported in the row below imports, while taxes on *production* are part of the GVA.
- Gross Domestic Product (GDP) equals GVA plus taxes less subsidies on products. In the example, we thus have a GDP of 51 + 6 = 57.
- A domestic IOT reports how much of each good is exported, but not, what they are used for. For example, we know that three, two, and seven units of goods 1, 2, and 3 respectively are exported, but their use in the destination country is unknown.[3]
- A domestic IOT reports what imports are used for, but not which goods are imported. E.g. three goods are imported for the production of good 2, but it is not stated how much of these imports is of good 1, 2, or 3.

#### 1.2.1.1 Gross value added

Gross value added, often shortened to just "value added", is among the main measures to capture economic activity. If taxes on products are added and respective subsidies subtracted, gross domestic product (GDP) is calculated.

Instead of starting right away, it is advisable to have a closer look at how GVA is embedded into the concept of economic activity. Economic analysis of a company first leads to its output (most often

[3] Sometimes the destination or a group of countries (e.g. EU) are reported, but never the usage.

called "production value" until recently) and revenue (or turnover) which differ mainly by changes in inventories (everything produced but not sold for revenue is stored in the inventory). Revenue is used to cover a multitude of costs and to produce surplus as shown in Figure 3. Costs fall into two parts: on the one hand intermediate goods (supplies, thus goods and services from other companies) are required which are transformed within a company and sold to its customers; on the other hand, are the costs of this transformation. Here from, two definitions of GVA can be derived: the first explains what is created (creation side) and the second explains what it is used for (use side).

***First definition (creation side)***: GVA (orange in Figure 3) is the difference between turnover (purple) and costs for intermediate products including imports (dark grey) as well as taxes less subsidies on these products (light grey). Intermediate products are those goods and services which are transformed into other goods and services within a company. For example, wires, screws, and microchips are intermediate goods for producing gauges, while the machine to manufacture the gauges is an investment (investments are not transformed, they wear off over time which is called depreciation or consumption of investments or of fixed capital). If the intermediate goods are into transformed into the gauge, it is more useful and can thus be sold for more than the intermediate goods' price. This additional value is called GVA. Figure 3 replicates the numbers of Figure 2, so GVA again equals 51 Euro: 112 Euro turnover (labelled "Output (production value)") minus 61 Euro for intermediate products (54 Euro for domestic products, 6 Euro for imports, 1 Euro for taxes less subsidies on products – only the production side is shown). One can also see the composition of these 51 Euro GVA which directly leads to the second definition.

***Second definition (use side)***: as can be seen in Figure 3, GVA also is the sum of salaries, wages, consumption of fixed capital, social contributions, taxes less subsidies on production, and surplus. Thus, GVA is used to pay the production factors: work (wages, salaries, social contributions), fixed capital (consumption of fixed capital), public services (production-based taxes less subsidies), and entrepreneurship (surplus). Using this second definition, it becomes clear why output is finally better suited to describe GVA than turnover. Imagine the case that the company has produced goods worth 112 Euro, as shown in Figure 3, but only sold goods worth 61 Euro. The difference between turnover and costs for intermediate goods (including imports) would be 0 Euro, while in reality the company added quite a lot of value to those intermediate goods – it just did not sell them yet.

Looking at these concepts from a distance, one can also see the close relation to accounting.

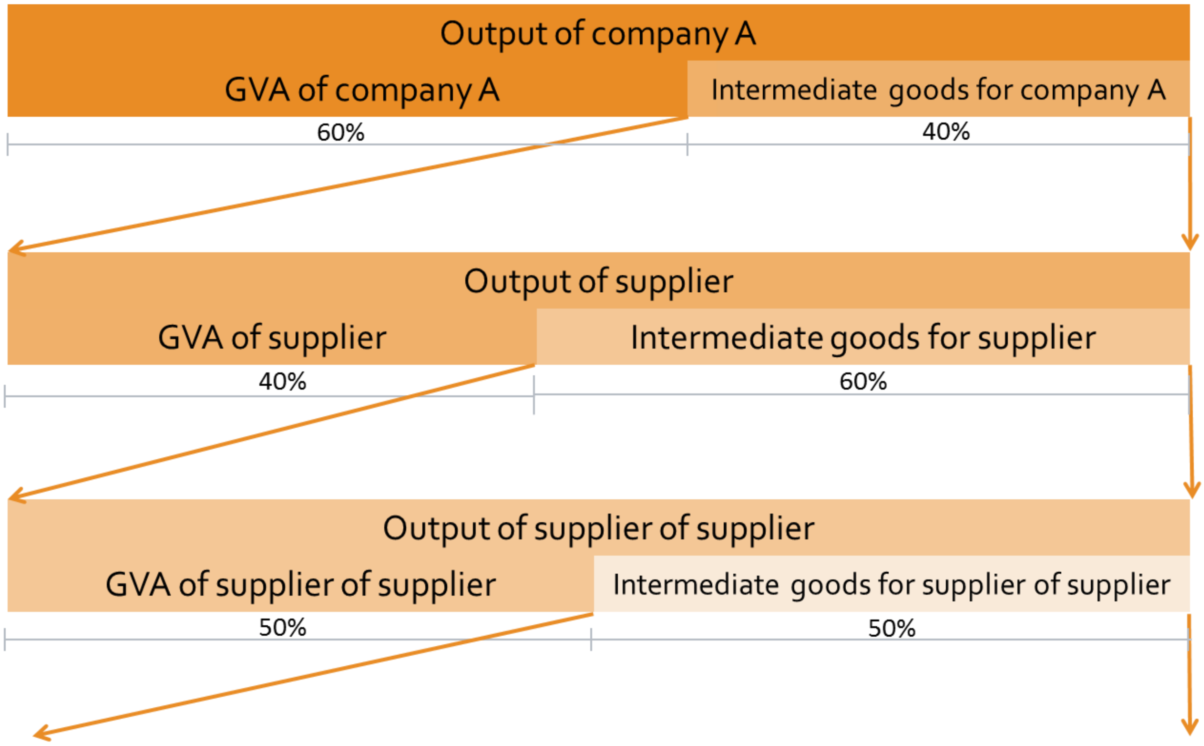
**Figure 3: Structure of GVA (orange) as the difference between output (purple) and intermediate products (dark grey) including taxes less subsidies on products (light grey)**


*Source: Economica.*

High GVA grants high income to the four factors (employees, producers of fixed capital, public sector, entrepreneurs). Then, surpluses and wages increase consumption which in turn fosters the economy. The complete circulation of funds and resources is studied by the input-output analysis.

The shares of the four factors in GVA vary largely from sector to sector. As an example, the share of wages, salaries, and social contributions in Austrian real-estate services is a mere 8 per cent of GVA, while it reaches more than 91 per cent in residential care services.

**Figure 4: Value added is purchased in the form of intermediate goods – different supply levels**




*Output and GVA produced at the same level share one colour*
*Source: Economica.*

To fully understand the concepts of output, intermediate goods, and GVA, it is necessary to understand the hierarchy of supply networks. The upmost part of Figure 4 shows the composition of company A's output. It consists of around 60 per cent GVA and 40 per cent intermediate goods. The latter are purchased from suppliers. Intermediate goods for company A are produced by these suppliers, so for them these are their outputs which in turn contain 40 per cent GVA and 60 per cent intermediate goods. Again, the suppliers of the suppliers need GVA and intermediate goods (50 per cent each).

Note that:

- upmost output and GVA (dark orange) are direct effects, while everything taking place in the suppliers' GVA chain below is called indirect effects,
- this GVA chain is theoretically infinitely long,
- this GVA chain actually is not simply a chain but a GVA network, as almost every company has more than just a single supplier,
- this GVA network nearly certainly contains circles of different lengths,
- every product finally consists of 100 per cent GVA, as explained below.

The last remark is visualised by aggregating all GVA as done in Figure 5. Direct GVA (dark orange) plus indirect GVA (lighter shades) sum to the directly stimulated company A's output. Therefore, it becomes clear that every product finally consists of pure GVA.

**Figure 5: Value added is purchased in the form of intermediate goods**


*Source: Economica.*

Again, note that:

- the higher the share of direct GVA in a product (the dark part of the lower bar), the smaller the share of indirect GVA (the brighter parts of the lower bar) and vice versa,
- suppliers may be located abroad. After a number of supply-steps, GVA is "imported" from a foreign economy almost certainly. The more GVA is produced domestically, the better for the economy. Large economies (e.g. Germany) tend to have a higher share of domestic GVA than smaller economies (e.g. Slovenia, which has to import many products and thus GVA).

#### 1.2.1.2 Input-output analysis

Returning to the nearly untraceable complexity of the GVA network and the appropriate methods to handle that kind of data, IOTs have to be introduced. Figure 6, a copy of Figure 2 for the sake of simplicity, shows the 3x3 intermediate goods matrix in the upper left corner (purple): in the columns one can read how much each sector purchased, while in the columns the deliveries to other sectors and final users are given.

As everything which is produced has to be used in some way (even if it merely stored somewhere), these 18 units of output of sector 1 have to be booked in the same sector's row: it sold 1 unit to itself, 2 units to sector 2 and 1 unit to sector 3, therefore it produced a total of 4 intermediate goods. In addition to that it also produced 14 units for final use (5 private consumption, 6 capital formation and changes in storage and inventories, 3 exports). The 4 units of intermediate use plus final use of 14 units thus equal 18 units of total use which are equal to the output of good 1. Therefore, the numbers in the lowest row are equal to the numbers of the rightmost column.

Real IOTs feature a much larger number of sectors, usually around 65, and more detailed accounting structure.

Examples:

- As one can now read off the IOT, sector 1 does not need any direct supplies from sector 3. However, it purchases 3 units as supplies from sector 2 which buys 10 units from sector 3. Therefore, sector 3 also benefits – indirectly – if sector 1 grows.
- Several supply chain circles are clearly visible. For example, each sector purchases from itself (the diagonal from upper left to lower right, 1 – 17 – 10), which can be considered as "degenerate" or micro circles. But also sector 1 purchases from sector 2 (3 units) and the other way round (2 units). Thus direct "there-and-back-again" circles can be found by searching for non-

zero values in the cells mirrored by the diagonal. An even longer one starts at sector 1, purchasing 3 units from sector 2, which purchases 10 units from sector 3, which again purchases 1 unit from sector 1.

- The IOT depicted in Figure 6 is a single-country IOT, which is the standard type. However, the IOT used for this project covers the EU-28 (Moldavia, Serbia, and the Ukraine were added via proxy, see above), so there can be circles all over Europe, reaching from Romania to Bulgaria, Croatia, the Czech Republic, and back to Romania again. More about such special multiregional IOTs follows further down.

**Figure 6: A simplified domestic input-output table (copy of Figure 2)**

| | Good 1 | Good 2 | Good 3 | Total | Private Consumption | Public Consumption | Final Consumption | Capital Formation, Valuables | Exports | Total Final Use | Total Use |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Good 1 | 1 | 2 | 1 | 4 | 5 | 0 | 5 | 6 | 3 | 14 | 18 |
| Good 2 | 3 | 17 | 10 | 30 | 10 | 0 | 10 | 10 | 2 | 22 | 52 |
| Good 3 | 0 | 10 | 10 | 20 | 5 | 5 | 10 | 5 | 7 | 22 | 42 |
| Total | 4 | 29 | 21 | **54** | 20 | 5 | **25** | 21 | **12** | **58** | **112** |
| Use of imported products | 1 | 3 | 2 | 6 | 2 | 1 | 3 | 5 | 1 | 9 | 15 |
| Taxes less subs. on products | 1 | -2 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 5 | 6 |
| Total | 6 | 30 | 25 | 61 | 23 | 7 | 30 | 28 | 14 | 72 | 133 |
| Employees' comp. | 1 | 2 | 3 | 6 | | | | | | | |
| Cons. fixed capital | 3 | 4 | 3 | 10 | | | | | | | |
| Oth. taxes on production | 6 | 14 | 8 | 28 | | | | | | | |
| Operating surplus | 2 | 2 | 3 | 7 | | | | | | | |
| Gross Value Added | 12 | 22 | 17 | **51** | | | | | | | |
| Output | 18 | 52 | 42 | **112** | | | | | | | |

*Source: Economica.*

Note that in Figure 5 company A has a high GVA (lower row, dark orange) in relation to output (upper row). Therefore, intermediate goods necessarily amount to a comparatively small part only. Put in other words: the effects which occur within company A (direct effects) are larger than the effects within the supply network (indirect effects).

In such sectors, direct effects are large while indirect are small. Therefore, the ratio of total effects (direct plus indirect) to direct effects is smaller in such sectors. This ratio is called "GVA multiplier". The higher the multiplier, the more the rest of the economy benefits from direct demand. Inversely, small multipliers indicate weak links to other sectors. However, multipliers can also be small if a lot of intermediary goods are imported since in such cases GVA is generated abroad. This concept leads to multiregional models, following a small glance at satellite accounts below.

### *1.2.2 Satellite accounts and topic-related input-output tables*

#### 1.2.2.1 General aspects

Satellite accounts or satellite systems are extensions to the System of National Accounts (SNA) when the standard accounts (often sectors or goods) follow a categorisation different to the one needed. One has to insert a new row and a new column, fill that with the values of the analysed topic and subtract these values from the original row and column. Thus, the latter contain only purely non-topic-related data, while all the topic-related (DAREFFORT/DanubeHIS) information is in the new row and column. Doing this for every sector containing topic-related data results in an IOT for that topic as depicted in Figure 7. The new sectors are orange. They form the so called “satellite account”.

Aggregate numbers are the same as in Figure 6, but topic-related content was moved from good 1 and good 2 (now good 1’ and 2’, corresponding reduced values are in red) to good 1S and good 2S respectively. Sector 3 remained unchanged. For example, originally sector 2 sold 17 units to itself. Now there are 11 units from good 2’ to 2’, 2 units from 2’ to 2S, 3 units from 2S to 2’, and finally 1 unit from 2S to 2S, totalling again 17 units.

That enlarged IOT follows the same regulations and principles as any standard IOT. Its advantage is that topic-related economic activity is well defined in separate sectors which can be treated like any other sector. Such an enlarged IOT thus serves as a “zoom” into the details of an economy.

**Figure 7: An IOT for a special topic showing the satellite in orange. Reduced values in original sectors are red.**

| | Good 1' | Good 2' | Good 3 | Good 1S | Good 2S | Total | Private Consumption | Public Consumption | Final Consumption | Capital Formation, Valuables | Exports | Total Final Use | Total Use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Good 1' | 1 | 1 | 1 | 0 | 1 | 4 | 3 | 0 | 3 | 3 | 1 | 7 | 11 |
| Good 2' | 1 | 11 | 10 | 1 | 2 | 25 | 6 | 0 | 6 | 7 | 1 | 14 | 39 |
| Good 3 | 0 | 10 | 10 | 0 | 0 | 20 | 5 | 5 | 10 | 5 | 7 | 22 | 42 |
| Good 1S | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 3 | 2 | 7 | 7 |
| Good 2S | 0 | 3 | 0 | 1 | 1 | 5 | 4 | 0 | 4 | 3 | 1 | 8 | 13 |
| Total | 2 | 25 | 21 | 2 | 4 | 54 | 20 | 5 | 25 | 21 | 12 | 58 | 112 |
| Use of imported products | 1 | 2 | 2 | 0 | 1 | 6 | | | | | | | |
| Taxes less subs. on products | 1 | -3 | 2 | 0 | 1 | 1 | | | | | | | |
| Total | 4 | 24 | 25 | 2 | 6 | 61 | | | | | | | |
| Employees' comp. | 1 | 1 | 3 | 0 | 1 | 6 | | | | | | | |
| Cons. fixed capital | 2 | 2 | 3 | 1 | 2 | 10 | | | | | | | |
| Oth. taxes on production | 3 | 11 | 8 | 3 | 3 | 28 | | | | | | | |
| Operating surplus | 1 | 1 | 3 | 1 | 1 | 7 | | | | | | | |
| Gross Value Added | 7 | 15 | 17 | 5 | 7 | 51 | | | | | | | |
| Output | 11 | 39 | 42 | 7 | 13 | 112 | | | | | | | |

*Source: Economica.*

### *1.2.3 Multiregional input-output tables*

In order to study international production relations in the same style as domestic IOA does, it is necessary to link the single national (or more general "regional") IOTs into one multiregional IOT (MR-IOT). Obviously, foreign trade serves as link between the regions. However, usually only the aggregate import values are known, e.g. how much steel is shipped from country A to county B. What remains unknown is what the good is used for in country B. It could be an intermediate good to a company, it could be consumed by private households, it could be an investment, or it could even be exported again. Thus, calculating the links between the regions is a complex task for which several methods were proposed. The three most important ones are:

- The Interregional Input-Output Model (IRIO) by Isard (Isard (1953));
- the Balanced Regional Model by Leontief (Leontief, 1963);
- the Multiregional Input-Output Model (MRIO) by Chenery and Moses (Moses, 1955);

The major advantage of Isard's model is that it is able to cover the whole variety of effects of each sector and each region. This benefit however leads to the big disadvantage of the model: the enormous effort of data collection.

The structure of the model according to Leontief corresponds to the Isard model but due to difficult interpretation it is more complicated to apply. Its practical applicability is limited by the number of regions, sectors, and years to be used. Therefore, it is hardly used anymore.

Formally the MRIO by Chenery and Moses resembles the model of Isard, but with regard to the content it differs in that it implies a very plausible stability hypothesis which eases calculation dramatically. In fact, without Isard's IRIO is practically impossible to calculate under real-life conditions. The MRIO table suggested by Chenery and Moses is extendable to any number of regions with the complexity of the table being much lower than in Isard's model. The MRIO is set up in two steps: as a first step the intraregional tables are created (one table for each region, i.e. the national IOTs), in a second step the import and export flows are collected and inserted.

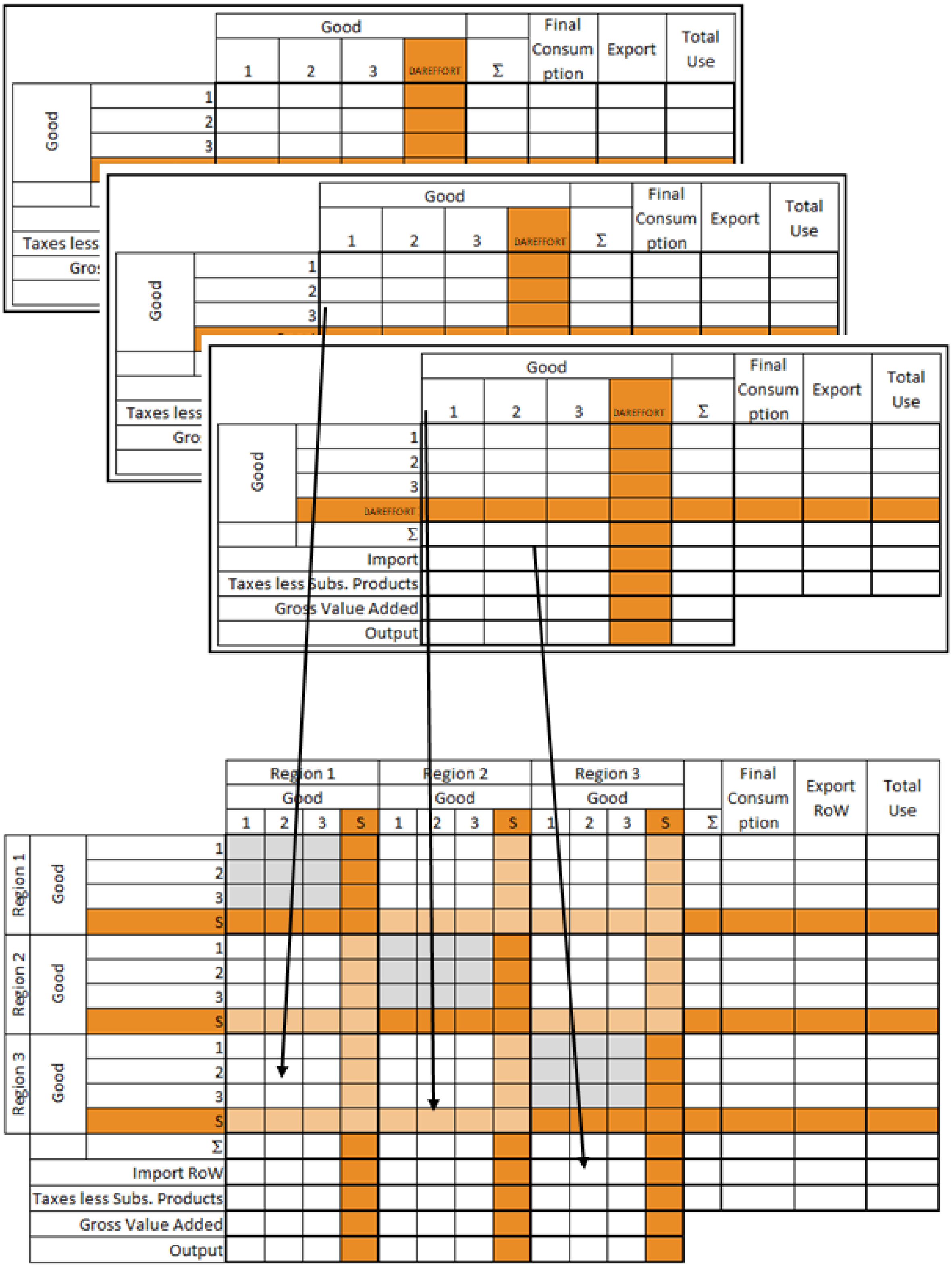
### *1.2.4 The multiregional input-output table on a specific topic*

One can chose a hybrid approach by creating a multiregional topic related IOT. In order to display the topic, topic related IOTs for every region can be created for all EU Member States. To be able to calculate EU-wide indirect effects, these enlarged IOTs were merged into a **M**ulti**R**egional **IOT** on that **T**opic (MR-IOT:T).

The principle model can be seen in Figure 2. In the upper section, one can see the national topic-related IOTs, with DAREFFORT as separate sectors in orange (only a single topic-related sector is depicted for the sake of simplicity). The MR-IOT:T below consists of the national DAREFFORT-related IOTs along the main diagonal from upper left to lower right. They are shaded a little darker than the rest. The remaining, light part of the intermediate goods matrix is foreign trade between the specific sectors of the different regions. GVA and final demand are below and to the right as usual.[4] The row and column designated "Import RoW" and "Export RoW" is residual foreign trade with the rest of the world (i.e. model-extern).

[4] Final demand is more complex than in the domestic case though, as goods for final demand in one region may come from a different region. Thus, there actually is a final demand matrix for every combination of regions and sectors.

**Figure 8: The layout of the MR-IOT:T**




*Source: Economica.*

# 2 Potential future system scenarios

The framework of the economic impact analysis is based on a document of the DAREFFORT activity A 3.2, which was elaborated under the lead of PP7 National Institute of Hydrology and Water Management Romania. It describes, in addition to the certain Scenario 0, three more potential future system scenarios. This chapter highlights the most important parts of each Scenario, which are necessary to understand the following calculations. The technical description of the said scenarios will be presented in more details in A 3.2.

## 2.1 Scenario 0 – Implementation of a common Danube River Basis *observed* data exchange platform

Scenario 0 is the certain, direct outcome of DAREFFORT. A common Danube River Basin observed[5] data software exchange platform will be implemented within the DAREFFORT project (WP4). Subsequently the exchange platform will be operated by ICPDR. The implementation phase started in June 2018 with the start of DAREFFORT and will be finished at the end of 2021, with the implementation of DanubeHIS by ICPDR. The estimated costs consist of the DAREFFORT budget plus the running costs, which are reported by the national data providers (see chapter 3.2.).

## 2.2 Scenario 1 – Implementation of a common Danube River Basin Forecasting Systems result exchange platform

The software exchange platform will have an open architecture, so that later in the process additional modules can be implemented. In Scenario 1 forecasting data[6] as a time series will be exchanged as well. The implementation phase could begin right after the implementation of Scenario 0 is completed and could be ready at the beginning of 2025. The costs for the implementation are estimated as the costs of DAREFFORT WP4 times 1.5, as the tasks are similar, but a little bit more exigent. The running costs would not be affected in comparison to Scenario 0. But there are several advantages compared to Scenario 0: 1) Improvements and standardization of data interfaces functionalities of the national systems, 2) improvements and standardization of data interfaces functionalities of the national systems, and 3) improvement of short term and medium-term hydrological forecasts and warnings.

## 2.3 Scenario 2 – Close integration between the National Flood Forecasting and Warning Systems and the existing Regional Flood Forecasting and Warning Systems: EFAS – Copernicus service, SEE-MHEWS-A, SEE-FFG, and SAVA FFWS

There are already several important supra-regional flood forecasting systems like EFAS (European Flood Awareness System), SEE-FFG (South-East Europe Flash Flood Guidance), and SAVA FFWS (Sava Flood Forecasting and Warning System) implemented within the Danube River Basin area. Another important one is currently under implementation: SEE-MHEWS-A (South-East European Multi-Hazard Early Warning Advisory System).

[5] The following data will be exchanged: precipitation, water level, temperature, discharge.
[6] Forecasted water level and discharge for selected sections.

Due to the close relation between the implementation of this scenario and the development and implementation status of different regional systems, this scenario could have two phases:

- Phase I – integration with EFAS;
- Phase II – integration with SEE-MHEWS-A, Sava FFWS, and SEE-FFG.

It should be noted that not all Danube river basin countries are represented in SEE-MHEWS-A, SEE-FFG and Sava FFWS. This is only the case for EFAS.

Depending on the needs of each country, and in correlation with the functionalities and particularities of each national flood forecasting and warning system, the integration process could include one or more of the following integration steps:

- Integration of forecasted time series and products from the regional systems together with the products generated by the national systems on a common visualization and analysis platform, in order to compare, adjust and generate final official national products.
- Integration between national flood forecasting and warning systems and/or sharing of forecasting models (e.g. based on the experience and recommendations from the pilot action implementation within DAREFFORT).

### *2.3.1 Scenario 2a – integration with EFAS*

The timeline of the implementation of Scenario 2a could be from beginning of 2022 till the end of 2023. At this point it is not possible to reliably estimate the costs for this scenario. Nevertheless, some assumptions are made:

- The costs related to EFAS upgrade and maintenance are covered by the EU.
- Some of the new functionalities added to EFAS in the last two to three years provide better options for integration with the national systems (e.g. web services for most of the products, availability of time series and grid data products). Also, the ongoing EFAS evolution activities will further improve and extend these functionalities, that could facilitate and support the integration with national systems within the Danube River Basin.
- It is required that national authorities build capacities to ingest EFAS forecast. One could even foresee that EFAS serves as a future platform for visualizing all national forecasts together with the EFAS forecasts.
- It could be considered that the costs for implementing this scenario will be consultancy costs for implementation and optimization of some standard interfaces with a maximum estimated amount equivalent to the budget and working effort of WP4 of DAREFFORT Project.

The use and maintenance costs under this scenario, can be estimated as being included in the use and maintenance costs estimated for Scenario I

Expected improvements of hydrologic forecasts and warnings products after phase I:

- Potential increase of the lead time, with the difference between the EFAS products lead time (7 or 10 days, depending on the products) and the actual lead time of each national system. This could change in the future, according to the EFAS system evolution (e.g. up to 15 days).

- Integration of new hydrologic forecast products that often are not available in national systems. This includes seasonal outlooks, flash flood nowcasting and forecasting, impact-based forecasts or the availability of river basin wide soil moisture and snow water equivalent anomalies.
- Potential improvements of forecasts accuracy, but this will depend on numerous factors. Given the recent and future planned upgrades of EFAS there will be an additional increase in forecast accuracy on the short term due to better capturing of the uncertainty by using more forecasts. Forecast accuracy for medium range forecasts is likely to increase.
- Potential significant increase of the performance of medium-term hydrological warnings and forecasts products due to the use of the rainfall-runoff simulations from EFAS as input into the routing models from the national systems, especially for the river sector with important flood control reservoirs.

### *2.3.2 Scenario 2b – integration with SEE-MHEWS-A, Sava FFWS, and SEE-FFG*

Timeline: 2022 – 2025 (medium term), could change in function of the implementation period and planning of the activities within SEE-MHEWS-A and SEE-FFG.

Sava FFWS is already operational, the countries within Sava River Basin have already integrated flood forecasting systems, there could be potential benefits from integrating Sava FFWS with other National FFWS.

Expected NWP improvements within SEE-MHEWS-A:
Three new high-resolution NWP models are under implementation, at different resolutions: 2,5km for Aladin, 4km for COSMO, and possibly 2 or 4km for NMM-B, and with a lead time of 48 – 72 hours. The actual experimental computation domain covers the entire Danube River Basin.

Expected improvements of hydrologic forecasts and warnings products after phase II (referring mainly to the integration with SEE-MHEWS-A):

- Significant increase in the performance of short-term hydrological warnings and forecasts products due to the use of the high-resolution NWP models from the regional SEE-MHEWS-A system.
- Implementation of the SEE-MHEWS-A Project, could include also other integrations steps between national flood forecasting and warning systems and/or sharing of forecasting models (e.g. based on the experience and recommendations from the pilot action implementation within DAREFFORT), with a potential benefit on the performance and lead time of several hydrological forecasts and warning products.
- According to the implementation plan of the SEE-MHEWS-A, this project will improve also the performance of the SEE-FFG System.
- Depending on the implementations of the SEE-MHEWS-A project, this scenario could bring the same level of improvements as Scenario III, or for short term products the benefits could even exceeds Scenario III, due to the high-resolution NWP.

## 2.4 Scenario 3 – implementation of a common Danube River Basin Forecasting Platform

The implementation of a common Danube River Basin Forecasting Platform would be similar to the common Sava FFWS, which has been implemented recently. This is the most complex and uncertain Scenario in this document. It would need a two-year design phase followed by at least seven years of implementation. It would use the meteorological products generated by the regional systems, based on observations and forecasts, as input into the hydrological models from the national systems.

The expected improvements could be the following:

- Maximum possible increase of the lead time, limited only by the uncertainty’s thresholds impose by the limitations of the NWP models.
- As a first estimation of the increase of the lead time, this will be at least as much as the lead time offered by EFAS system products.
- Maximum possible increase of the forecast’s accuracy, up to the limits related to the hydrological and meteorological models’ accuracy, and quality of historical hydrological and meteorological data used for the calibration of the hydrological forecasting models.
- Achieving the best hydrological forecasts and warnings accuracy and/or performance as the most advanced existing national systems, within the Danube River Basin, specific for different hydrological forecast products categories.

Main advantages:

- It is possible that this scenario brings the maximum possible increase on performance and lead time.

Potential expected problems / issues:

- High costs, long implementation period, vulnerable to multiple delays.
- Significant duplication of efforts for similar activities and results with the existing regional systems, could not be avoided.
- Could be more difficult to operate, maintained and upgraded than Scenario I + Scenario II.

## 2.5 Timeline overview of the potential future system scenarios

**Figure 9: Timeline potential future system scenarios, 2018-2060**

<table>
<tr><th></th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>2027</th><th>2028</th><th>2029</th><th>2030-2060</th></tr>
<tr><td>Scenario 0</td><td colspan="4">Implemention</td><td colspan="9">Operating Phase</td></tr>
<tr><td>Scenario 1</td><td colspan="4"></td><td colspan="3">Implementation</td><td colspan="6">Operating Phase</td></tr>
<tr><td>Scenario 2a</td><td colspan="4"></td><td colspan="2">Implementation</td><td colspan="7">Operating Phase</td></tr>
<tr><td>Scenario 2b</td><td colspan="4"></td><td colspan="4">Implementation</td><td colspan="5">Operating Phase</td></tr>
<tr><td>Scenario 3</td><td colspan="4"></td><td colspan="2">Design phase</td><td colspan="6">Implementation</td><td>Operating Phase</td></tr>
</table>

*Source: DAREFFORT.*

# 3 Data

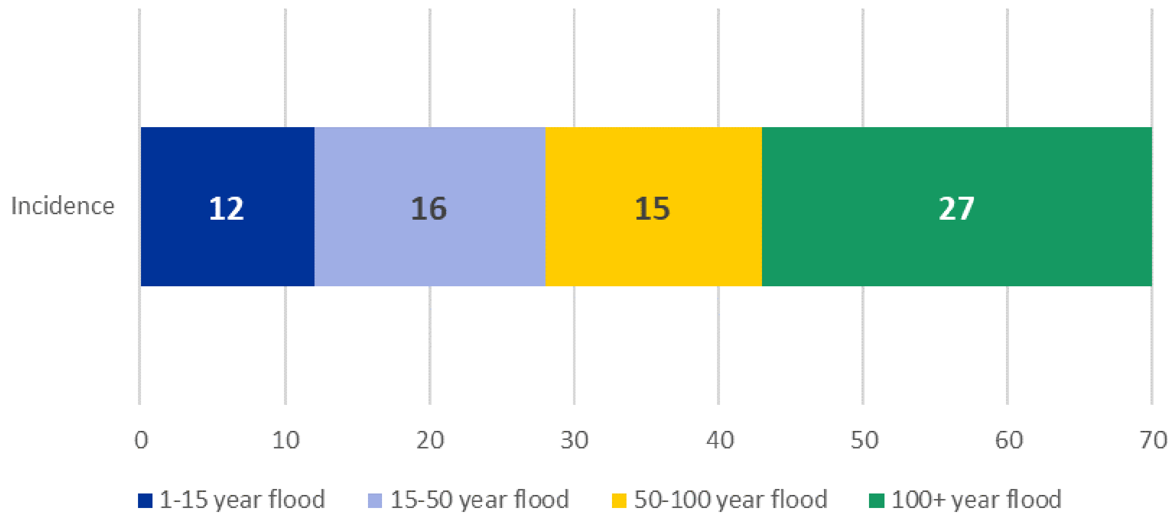
The data for the quantitative impact analysis derives from the DAREFFORT project partners in each partner country. A data request file[7] from Economica was sent to each project partner on 28th of November 2019. The project partners were asked to contribute in two ways 1) researching effects of previous flood events in their respective home country in terms of flood related damages per affected economic activity (agriculture, manufactured products, constructions above ground, constructions below ground, transportation, and other) marked by the corresponding return period, and 2) making an estimation of the expected staff and material costs which will occur after DAREFFORT in DanubeHIS.

## 3.1 Historic flood events

72 data points exist in the data set concerning historic flood events. In this data all 10 riparian states are included. The Czech Republic and Slovenia, which contain tributaries that flow into the Danube, are also part of the data set. Floods were divided into categories, depending on their severity (by return period: 1-15 year flood, 15-50 year flood, 50-100 year flood, and 100+ year flood).

The earliest available information is a flood in 1954 in Germany, while the most recent recorded event was in Slovakia 2019. Within the time range, there are 28 years that contain at least one substantial flood event. Figure 10 shows the distribution of flood events by their severity. It is instantly visible that more extreme floods are especially overrepresented in the data set. 100+ year floods make up over a third of the data while 1-15-year floods make up less than a fifth of all recorded floods. This is because weaker floods are less likely to be recorded or measurable than the strong floods. Thus, the data is somewhat biased towards more extreme flood occurrences. This issue will be tackled later, when the observed data is adjusted by the corresponding probabilities of the incidences.

**Figure 10: Distribution of flood events by return period, all countries (1954-2019)**

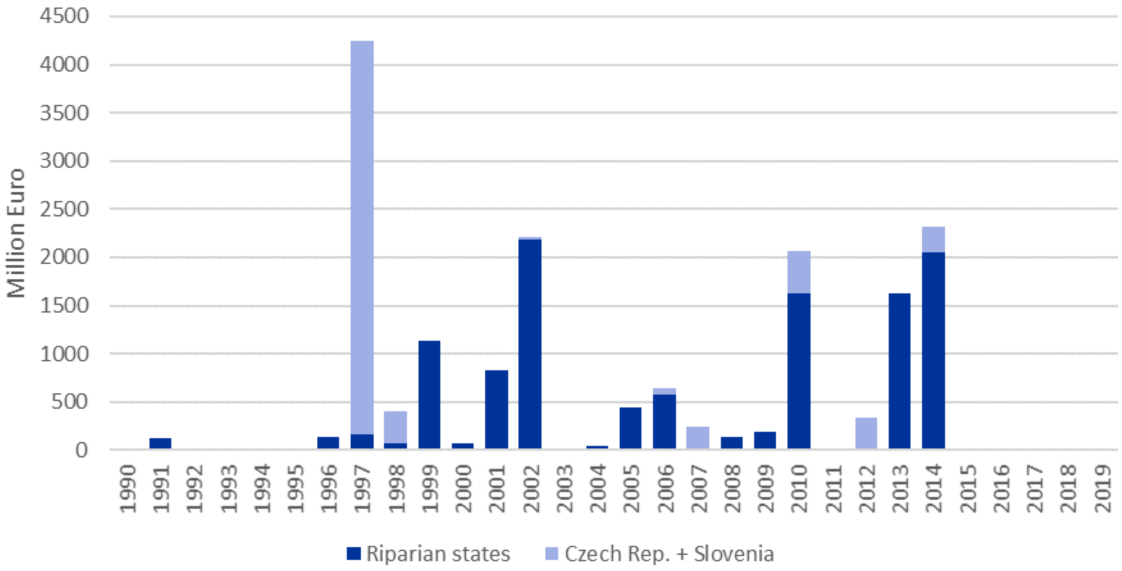



*Source: DAREFFORT.*

[7] See Annex 7.1 and 7.2.

Figure 11 shows the flood damage losses per year between 1990 and 2019 for all 12 countries in the data. There is no clear trend or cyclicity in the floods or the damage caused by them. Between the years 1990-1995 there was almost no damage caused by floods and between 2015-2019 no significant flood occurred. In the years between 1996 and 2014 the picture is a different one. The years 1997, 2002, 2010 and 2014 all saw floods that caused damages in excess of 2 billion Euro, with 1997 being an extreme occurrence that caused over 4 billion Euro of damage. It is evident that extreme floods can occur at any time and long periods of calmness are not indicative of future flood behaviour.

**Figure 11: Flood damage losses per year, all countries (1990-2019), price level 2019**

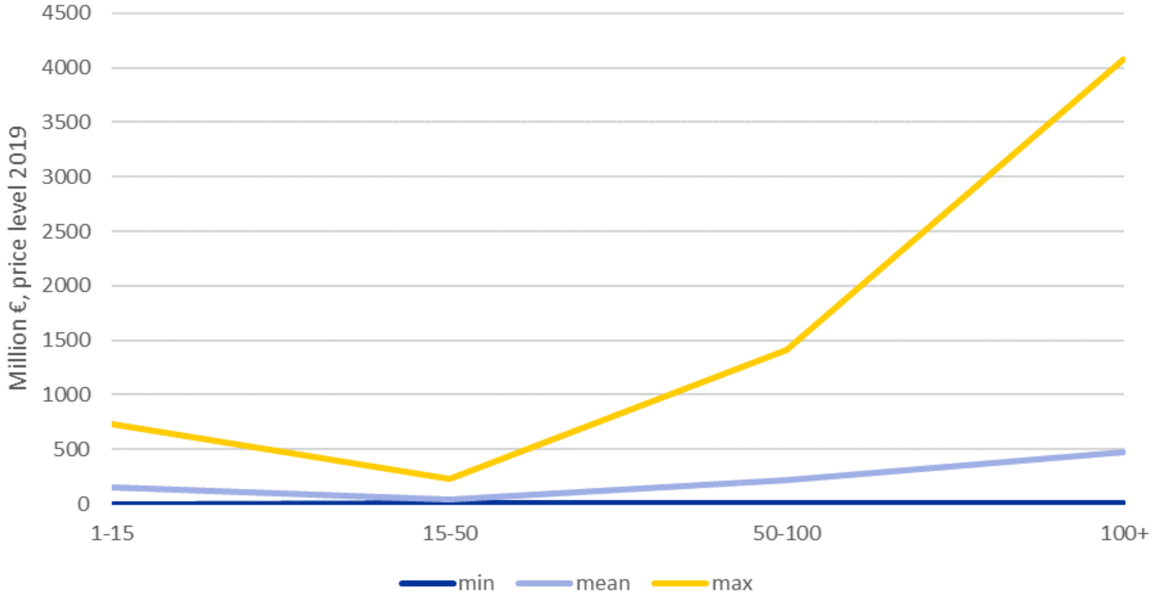



*Source: DAREFFORT.*

The damage caused by these floods is extremely heterogenous and ranges from zero to 4 billion Euro (all values adapted to the 2019 price level). There is also no clear picture that a flood with a lower probability of occurrence automatically leads to higher damages. This is by no means surprising, as not only the level of the flood is crucial, but also where does the flood occur, and how fast and which countermeasures have been set. So, it is possible that a flood which is marked as a 100+ flood leads to lesser damages than a flood which is marked as a 15-50-year or even a 1-15-year flood. In general, however, the data shows that the highest damages where caused by floods with a return period of less than 100 years.

Figure 12 shows the damage function over all the data points for three different characteristics, which represent the damage range of the flood events. The dark blue line stands for the minimum damage caused by a flood in each category. In the category of a 1-15-year flood, there was one flood event reported, which didn't lead to an economic damage. In the next category, 15-50-year flood, the lowest damage was caused by a flood in Serbia in 2013 with losses of 320,000 Euro (in prices 2019). In the category of 50-100-year floods, the minimum damage was 9.5 million Euro and in the category of 100+ year floods, the lowest damage was 3.0 million Euros. The yellow line represents the highest damages caused by floods in each category. In the total sample these highest damages were 728 million (1-15), 233 million (15-50), 1.4 billion (50-100), and 4.0 billion Euro (100+). Both, the yellow and the dark blue lines represent the range of economic losses caused by the floods in this sample. As this corridor is very broad, a third line in light blue, the mean, is introduced.

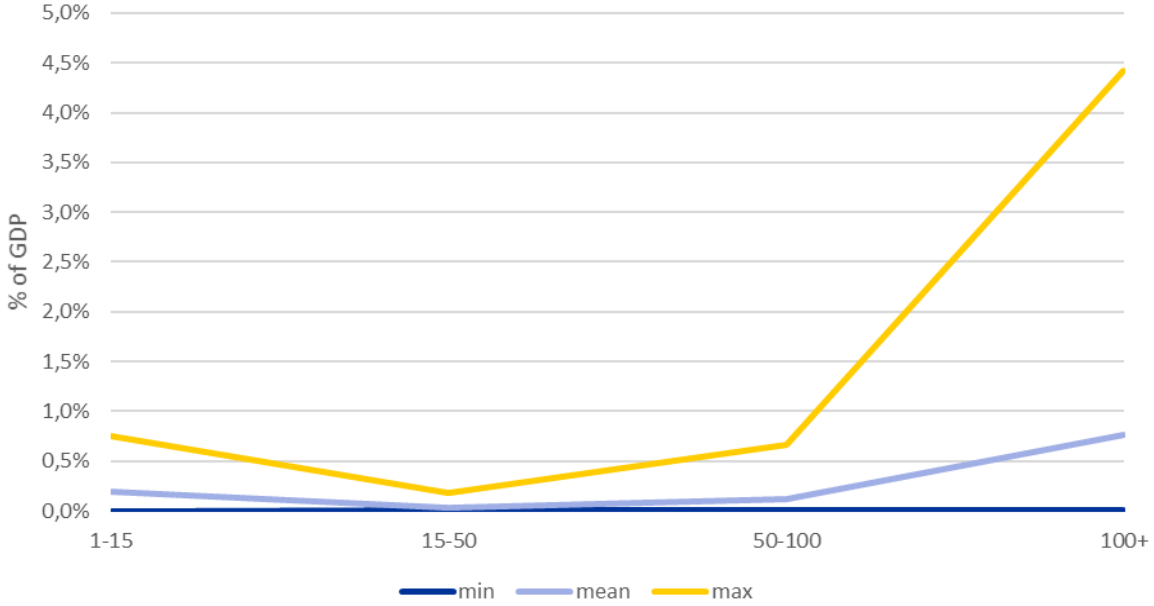
**Figure 12: Damage function, all countries, price level 2019**




*Source: DAREFFORT.*

The damage function in terms of losses in percent of the GDP shows a similar picture, as Figure 13 illustrates.

**Figure 13: Damage function, all countries, in % of GDP**



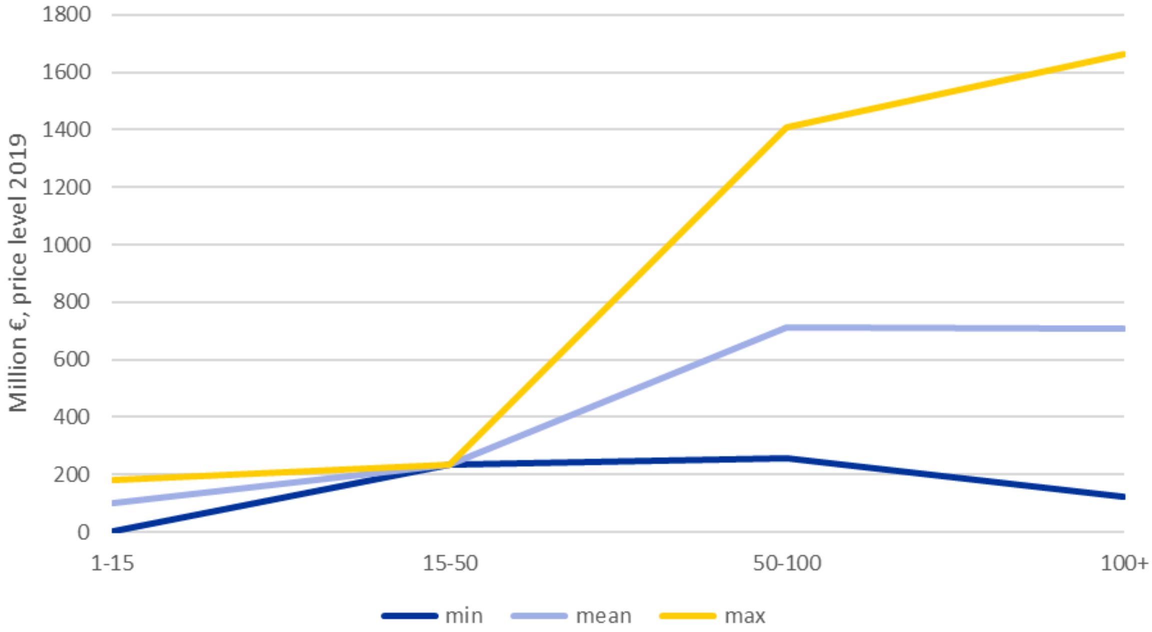

Source: DAREFFORT

In order to deal with the different economic circumstances alongside the Danube river, the countries were divided into three groups, depending on total GDP. The groups are as follows:

A) Germany and Austria
B) Slovakia, Hungary, Romania, Czech Republic, and Ukraine
C) Slovenia, Croatia, Serbia, Bulgaria, and the Republic of Moldova

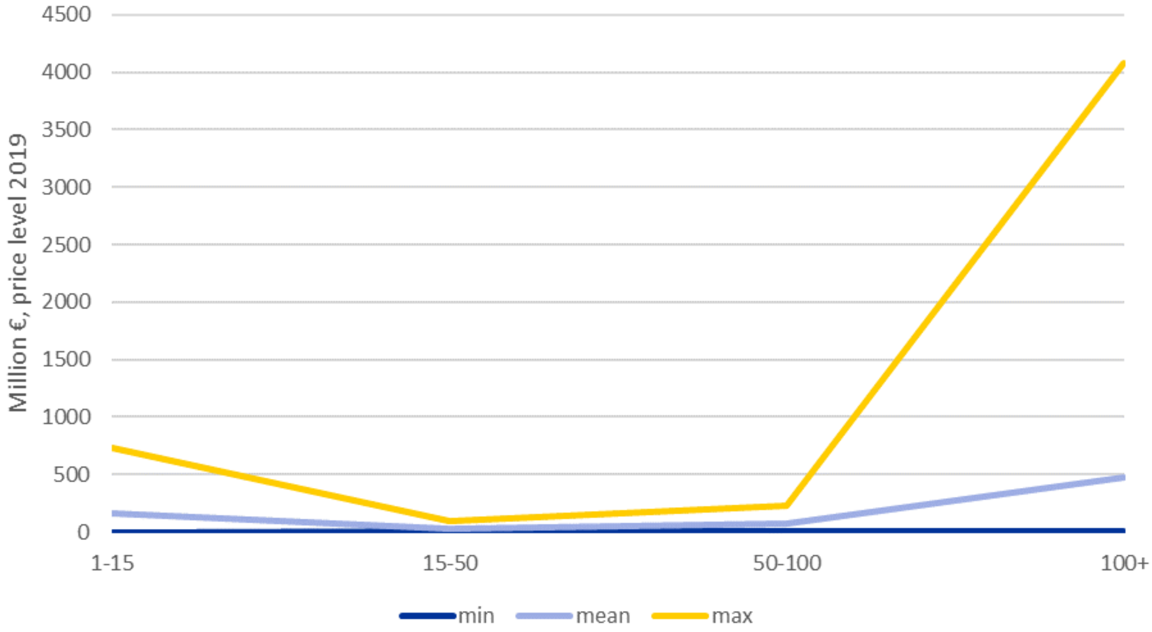
The damage functions for these three country groups are illustrated in Figure 14, Figure 15, and Figure 16.

**Figure 14: Damage function, Germany + Austria**



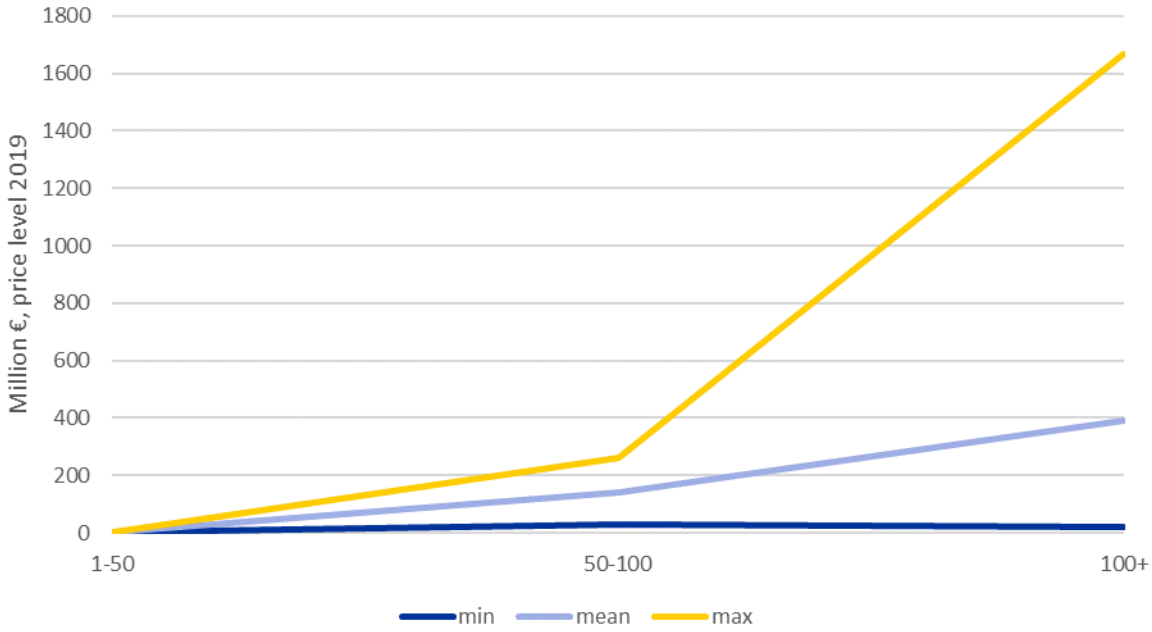

*Source: DAREFFORT.*

**Figure 15: Damage function, Slovakia + Hungary + Romania + Czech Republic + Ukraine**




*Source: DAREFFORT*

**Figure 16: Damage function, Croatia, Bulgaria, Republic of Moldova, Serbia, Slovenia**



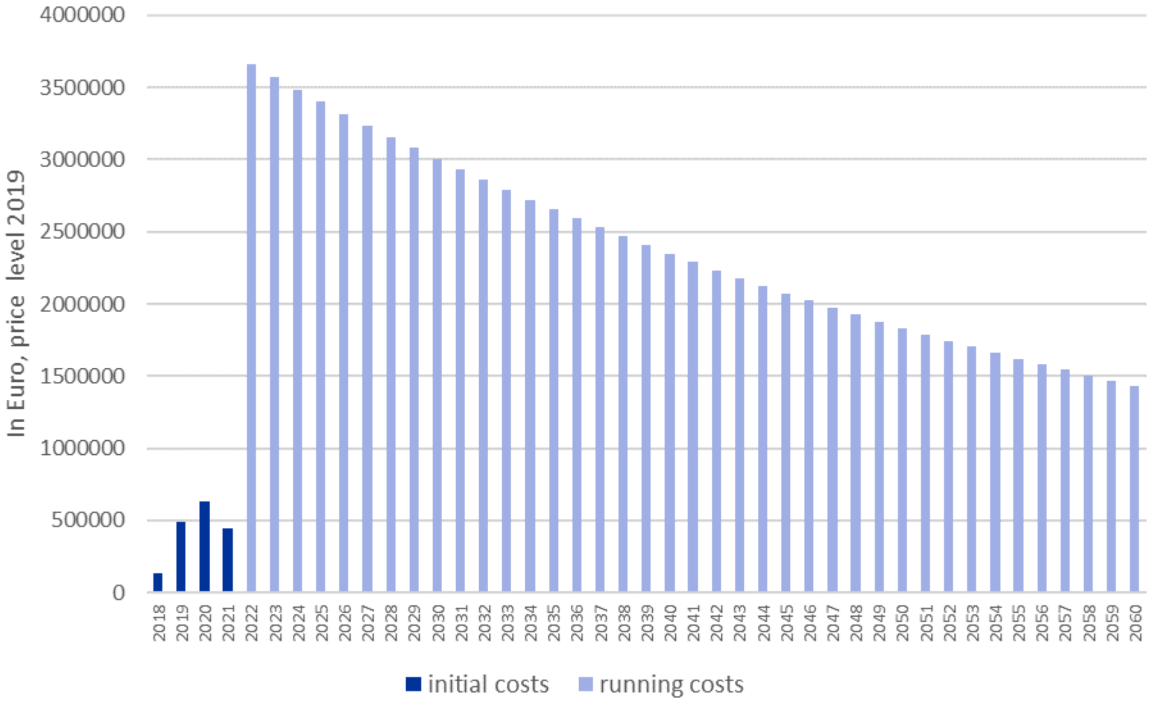

*Source: DAREFFORT.*

### 3.2 Relevant costs

All the national data providers were asked to indicate their expected costs which can be linked directly to DAREFFORT/DanubeHIS. Both personnel and material/maintenance costs were inquired. In total, 190,000 Euro staff costs and 10,000 Euro material costs per year were reported. Material costs consists of expenses for additional servers, and staff costs accrue, mainly, for process monitoring of the data exchange. However, it would not be sufficient, to base the CBA on this data only. The data (precipitation, water level, temperature, and discharge), which will be exchanged in DanubeHIS, first needs to be collected and processed. Although these processes are already done by the national data providers, and no additional costs arise, these costs have to be taken into account proportionately. Otherwise, in the end the cost- benefit-ratio would be misleading. Therefore, costs in the “background” also are considered. These costs amount to 3.5 million Euro per year (3.1 million staff costs and 0.4 million material costs). These costs would also accrue without DAREFFORT/DanubeHIS, and are already covered in the data providers budgets.

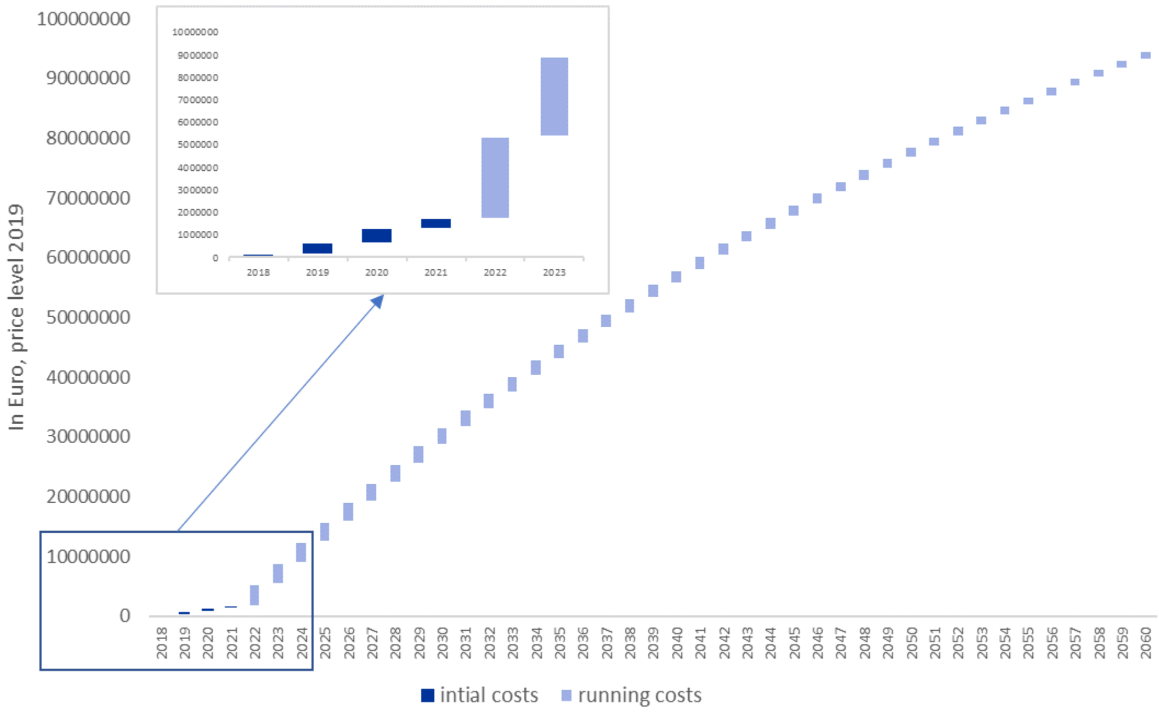
Figure 17 shows the total costs per year for all countries from 2018 till 2060 in Scenario 0. Initial costs are mostly the DAREFFORT project costs and some necessary investments in the Ukraine. The operating costs are discounted with a yearly rate of 2.5 percent. In Figure 18 the costs have been accumulated in each year.

**Figure 17: Cost function Scenario 0, all countries, per year**




*Source: DAREFFORT.*

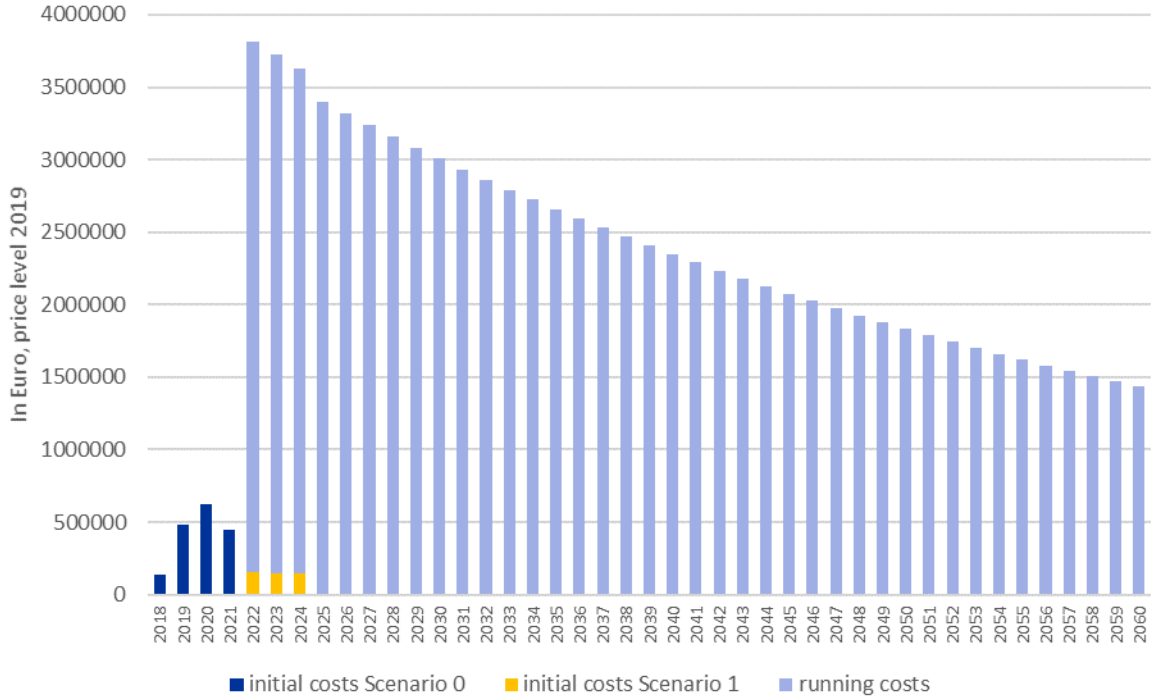
**Figure 18: Cost function Scenario 0, all countries, accumulated**




*Source: DAREFFORT.*

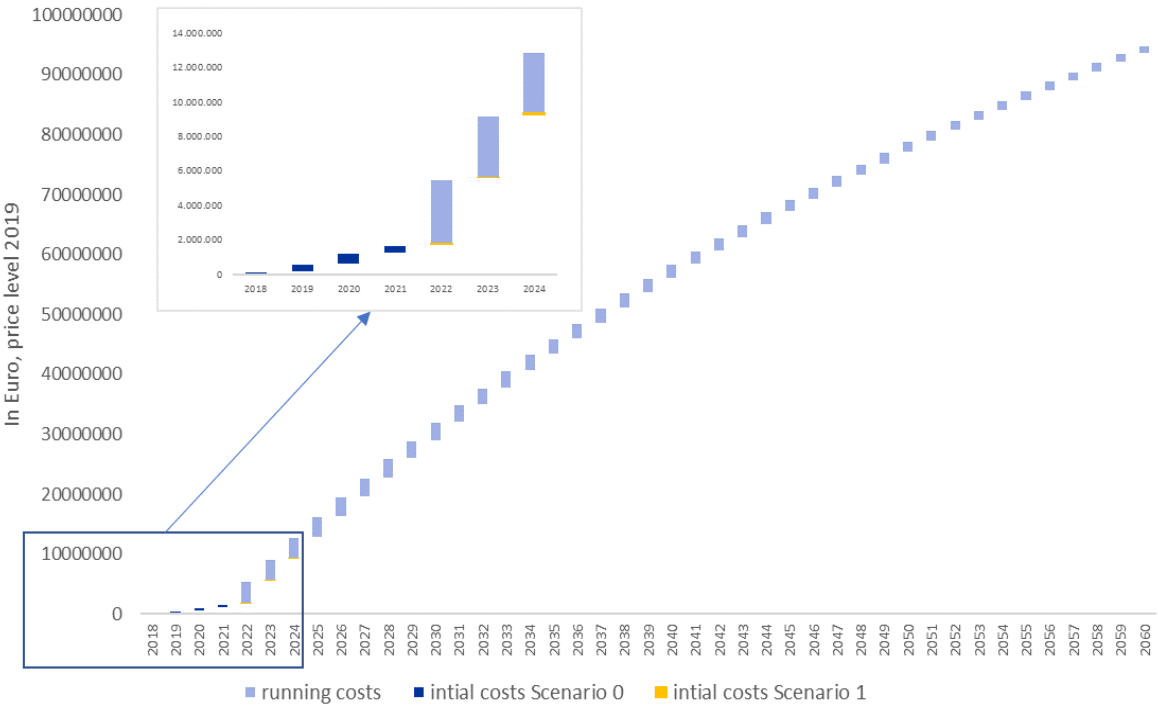
Scenario 1 adds one module to the in Scenario 0 existing data exchange platform. In a three-year implementation phase, also national forecasting data will be exchanged between the national data providers. For this implementation, a budget 1.5 times of the expenses in budget WP4 of DAREFFORT are assumed. As the running costs in Scenario 1 are not affected and are equal to the costs in Scenario 0 (no additional costs in the operating phase), just the initial costs have an impact on the cost structure. These costs are marked yellow in Figure 19 and Figure 20. It appears, that the additional initial costs in Scenario 1 do not have a substantial impact on the overall costs structure.

**Figure 19: Cost function Scenario 1, all countries, per year**




*Source: DAREFFORT.*

**Figure 20: Cost function Scenario 1, all countries, accumulated**




*Source: DAREFFORT.*

# 4 Cost-benefit analysis

Based on the data described in chapter 3.1 "potential annual average flood losses" are calculated for each country cluster. This is done by multiplying the damages in each category with its probability of occurrence. In Germany and Austria, the annual expected value of flood damages is between 15.7 million and 78.2 million Euro. In the country group B, consisting of Slovakia, Hungary, Romania, Czech Republic, and the Ukraine, the annual expected flood losses range between 0.3 million and 146.3 million Euro. In country group C (Slovenia, Croatia, Serbia, Bulgaria, and the Republic of Moldova) the expected annual losses are between 0.8 million and 22.0 million Euro.

**Table 1: Potential annual average flood losses, in million Euro**

| Country Group | Country | min | mean | max |
|---|---|---|---|---|
| A | Germany | 15.7 | 44.1 | 78.2 |
| | Austria | 15.7 | 44.1 | 78.2 |
| B | Slovakia | 0.3 | 29.1 | 146.3 |
| | Hungary | 0.3 | 29.1 | 146.3 |
| | Romania | 0.3 | 29.1 | 146.3 |
| | Czech Republic | 0.3 | 29.1 | 146.3 |
| | Ukraine | 0.3 | 29.1 | 146.3 |
| C | Slovenia | 0.8 | 6.7 | 22.0 |
| | Croatia | 0.8 | 6.7 | 22.0 |
| | Serbia | 0.8 | 6.7 | 22.0 |
| | Bulgaria | 0.8 | 6.7 | 22.0 |
| | Republic of Moldova | 0.8 | 6.7 | 22.0 |

*Source: DAREFFORT.*

Now, just one more crucial information is missing before the CBA can be undertaken: To what extent can DanubeHIS contribute to reduce flood related damages in the Danube region? The exchanged data affects the national forecasts in two different ways. It can 1) increase the lead time and 2) improve the accuracy. Various studies show that a longer lead time can decrease flood damages substantially (ICPR, 2002; Carsell et al., 2004; Tunstall et al., 2005; Steinführer and Kuhlicke, 2007). On the other hand, the accuracy of the forecasts is elementary, because false alarms tend to reduce responses of the population for future alerts, (ICPR, 2002; Roulston and Smith, 2004; Parker and Priest, 2012; Lopez et al., 2017).

The DanubeHIS-data-provider where asked about their assumptions, whether, and if so, to what extent the forecasts were improving. In Scenario 0, Croatia, Romania, Bulgaria, Serbia, and the Ukraine reported anticipated improvements in terms of an extended lead time, Slovakia and Hungary expect at least a higher accuracy due to the data exchange between all countries. Germany, Austria, the Republic of Moldova, Czech Republic and Slovenia do not expect any improvements of their national forecasts. This is not surprising, as Germany and Austria are upstream countries with an ongoing bilateral data exchange, and data from downstream countries do not affect their forecasts. Water in the Czech Republic significantly depends on the precipitation amount, as there are no significant tributaries to the country. Moreover, the Czech Republic and Austria have bilateral agreements, so there is no expected improvement for the Czech Republic resulting of DAREFFORT. Same applies to Slovenia. The Republic of Moldova shares just 430 meters with the Danube river at its southern extremity.

In Scenario 1 Germany, Austria and the Republic of Moldova, still do not expect any improvements in terms of a longer lead time or a forecast quality improvement. Slovakia, Croatia, Romania, Bulgaria, Serbia, Czech Republic, Slovenia, and the Ukraine expect improvements of both, lead time and accuracy.

An overview of the improvements in Scenario 0 and Scenario 1 compared to the status quo can be found in Table 2.

**Table 2: Expected improvements compared to status quo**

| Country | Improvements compared to status quo | | | |
|---|---|---|---|---|
| | Scenario 0 | | Scenario 1 | |
| | lead time | accuracy | lead time | accuracy |
| Germany | x | x | x | x |
| Austria | x | x | x | x |
| Slovakia | x | ✓ | ✓ | ✓ |
| Hungary | x | ✓ | x | ✓ |
| Croatia | ✓ | ✓ | ✓ | ✓ |
| Romania | ✓ | ✓ | ✓ | ✓ |
| Bulgaria | ✓ | ✓ | ✓ | ✓ |
| Republic of Moldova | x | x | x | x |
| Serbia | ✓ | ✓ | ✓ | ✓ |
| Czech Republic | x | x | ✓ | ✓ |
| Slovenia | x | x | ✓ | ✓ |
| Ukraine | ✓ | ✓ | ✓ | ✓ |

*Source: DAREFFORT.*

An extensive literature review[8] was used to determine percentages of reduction in potential flood damages in each affected economic activity, (agriculture, manufactured products, constructions above ground, constructions below ground, transportation, and other), that can be attributed to a longer lead time or a higher accuracy of the forecasts. A conservative estimate of reduction in the flood damage costs are as follows: agriculture (-20%), manufactured products (-8%), constructions above ground (-6%), constructions below ground (-6%), transportation (-10%), private economy (-10%), public infrastructure (-5%), others (-20%) overall mean (-10.6%).

These values represent the status quo (so the observed flood damage costs are already reduced by 10.6 percent). Thielen-del Pozo et al. (2015), assume, "flood early warning systems in Europe have the

[8] Numerous studies were considered in this section: Day, 1970; Chatterton and Farrell, 1977; Smith, 1981; Wind, 1999; ICPR, 2002; Reese, 2003; Carsell et al., 2004; Kreibich et al., 2005, 2007, 2008; Parker, 1991; Parker et al., 2005, 2007; Thieken et al., 2005, 2007; Tunstall et al., 2005; Steinführer and Kuhlicke, 2007; Priest et al., 2011; Penning-Rowsell et al., 2013.

potential of reducing the costs of flood damages by about 25%, saving an estimated 30,000 million EUR over the next 20 years." From this information, we derive the assumption, that in Scenario 1 we will reach the 25 percent and in Scenario 0 the mean between 25 percent and 10,6 percent.

Without existing flood warnings, the potential damages would be higher by the factors we identified in our literature research. So, first, in the CBA we add the current reduction to arrive at the "natural damage costs without any warning systems", and then subtract the new values for Scenario 0 and Scenario 1. This results in the new expected flood damage costs after DAREFFORT in each Scenario.

Then, we compare the potential damage costs in the status quo, with the potential damage costs in Scenario 0 and 1. We also add the DAREFFORT/DanubeHIS costs here. If the damage costs and DAREFFORT/DanubeHIS costs are lower than the potential costs in the status quo, the system would be beneficial from an economic point of view.

These results are presented in the following chapter.

# 5 Results

## 5.1 Quantitative results of the economic impact evaluation

### *5.1.1 Quantitative results of the cost-benefit analysis*

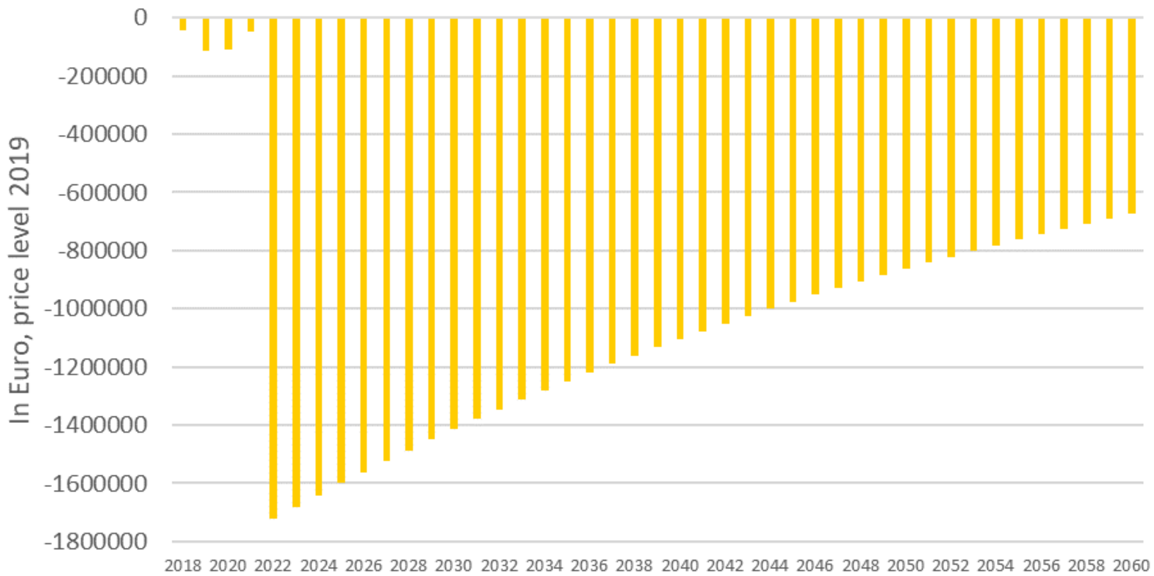
#### 5.1.1.1 Scenario 0

The core feature in Scenario 0 would be the implementation of the Danube Hydrological Information System (DanubeHIS), which allows the sharing of four key data points between the participants. The four variables would be precipitation, water level, discharge and temperature data. The implementation period has been ongoing since 2018 and is expected to be completed in 2021. Following this, the operating phase will begin. For the following calculations, the operating phase will run at least till 2060. As mentioned in the data section, flood damage can be very heterogenous, which is why there are three separate damage functions. As such, the potential benefit from reduced flood damages depends on the three damage functions (min, mean, and max).

The following figures (Figure 21-Figure 34) show the results of the cost-benefit analysis for all country groups in each damage function in a net perspective. The bars represent the differences between costs and benefits in each year. Net costs are displayed as negative values, net benefits as positive. Additionally, if the costs exceed the benefits, the bars are coloured orange, if the benefits outweigh the costs, the bars are coloured green.

The country group consisting of Germany and Austria does not expect any benefits from DanubeHIS as these nations already have advanced data exchange systems in place. Thus, these countries only face costs, but no additional benefits from DAREFFORT/DanubeHIS. This is shown in Figure 21.

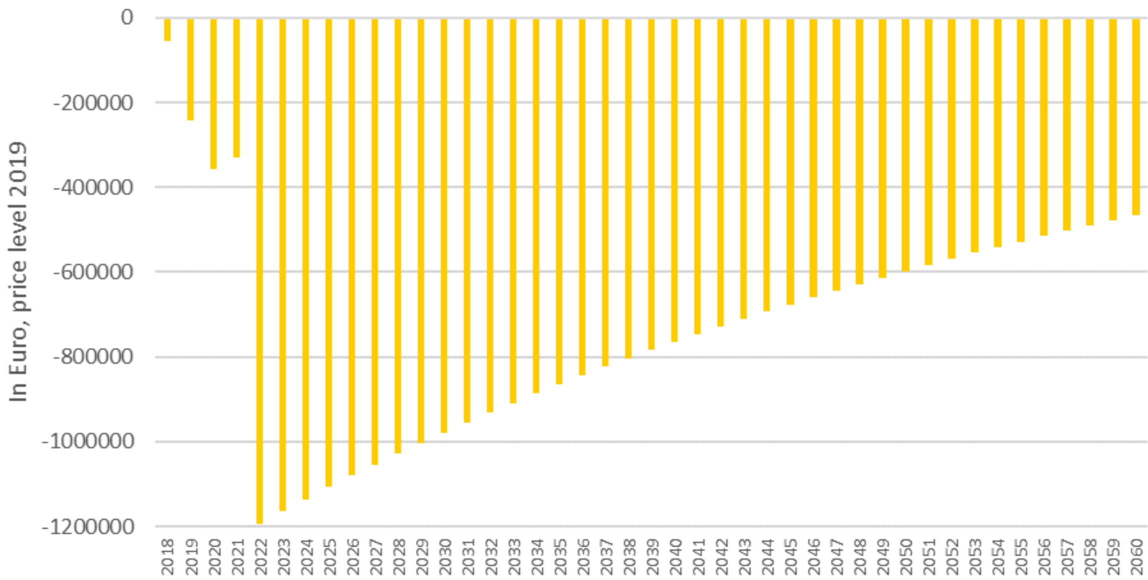
**Figure 21: CBA results (min, mean, and max): GER + AUT**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economia.*

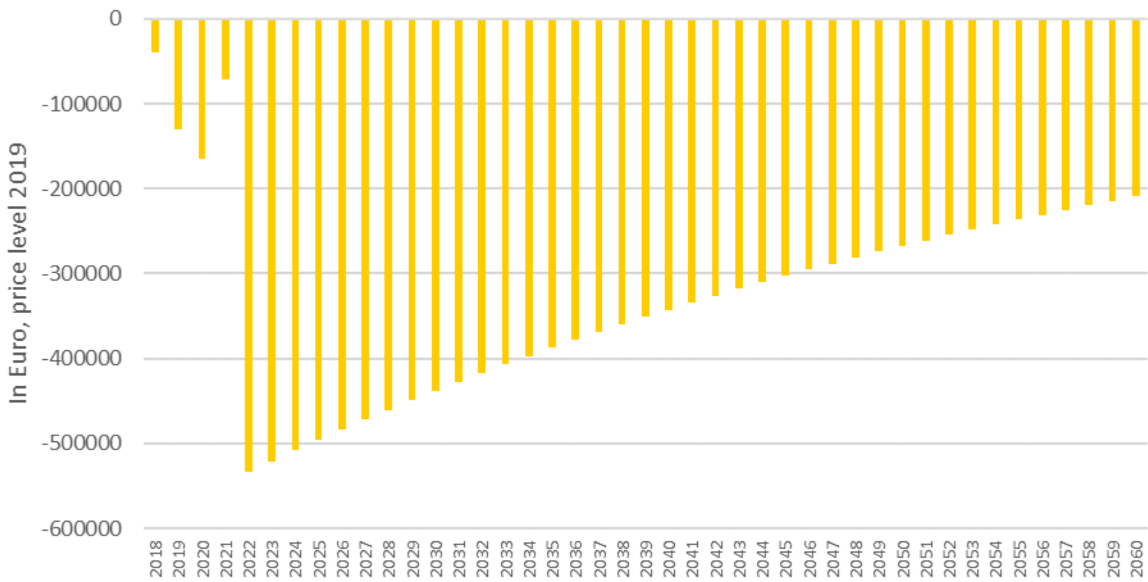
Figure 22 and Figure 23 show that under a minimum flood damage function, there would be no actual benefits accrued as the implementation and operating of the DanubeHIS would cost more than any potential benefits gained from lower flood damage. This is true for both country groups and doesn't change throughout the lifetime of this project. Given that many smaller floods tend to cause only very minimal amount of damage, this result isn't too surprising.

**Figure 22: CBA results (min): SVK + HUN + ROU + CZE + UKR**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

**Figure 23: CBA results (min): HRV + BGR + MDA + SRB + SLO**



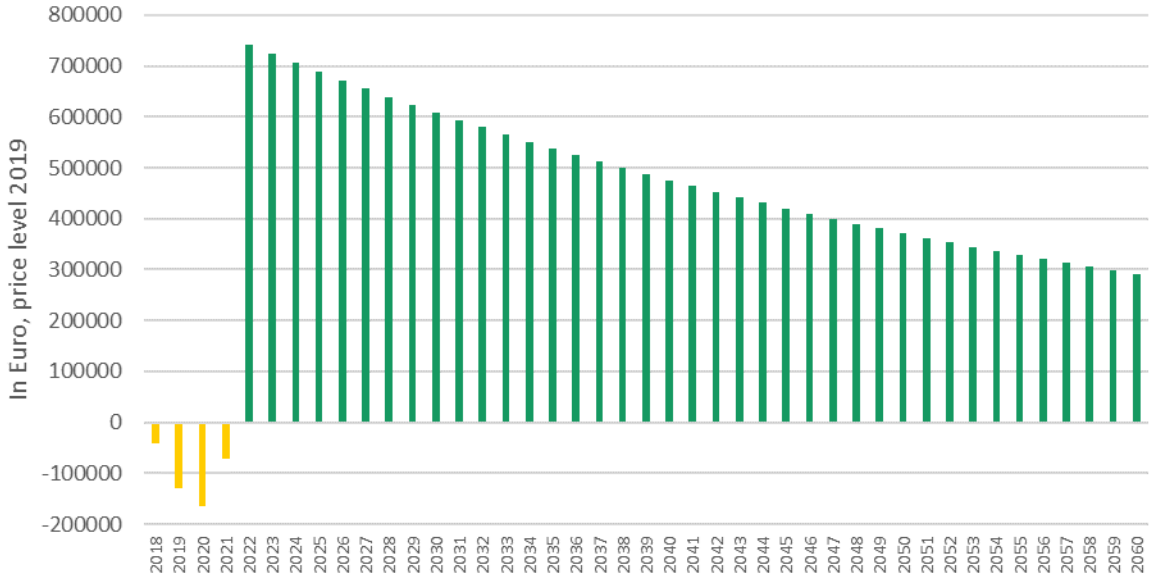

*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

Under a mean damage function, displayed in Figure 24 and Figure 25, the story begins to change. Immediately with the launch of the operational phase, the benefits for the two country groups outweigh any costs occurred. For the group consisting of Slovakia, Hungary, Romania, Czech Republic and Ukraine, the benefits are as high as 3.8 million Euro in 2022. For the second country group (consisting of Croatia, Bulgaria, Moldova, Serbia and Slovenia) the potential benefits are estimated to be around 750,000 Euro in 2022. Due to discounting, these values will fall to 1.5 million Euro and 290,000 respectively by 2060. Over the course of this project, the potential combined benefits of both groups are approximated to save over 114 million Euro due to lower flood damages.

**Figure 24: CBA results (mean): SVK + HUN + ROU + CZE + UKR**


*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

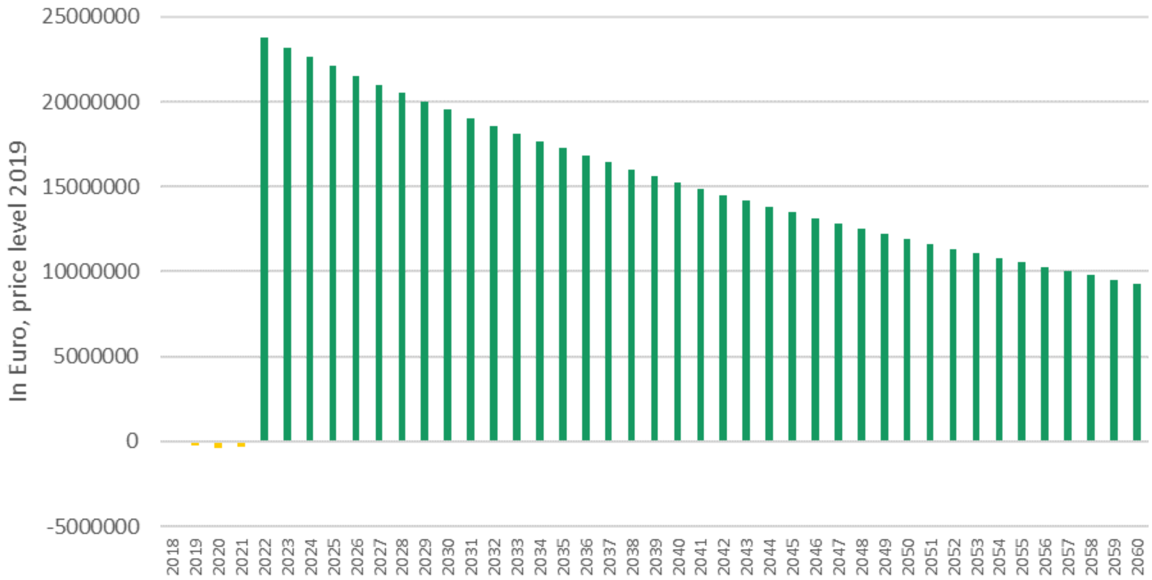
**Figure 25: CBA results (mean): HRV + BGR + MDA + SRB + SLO**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

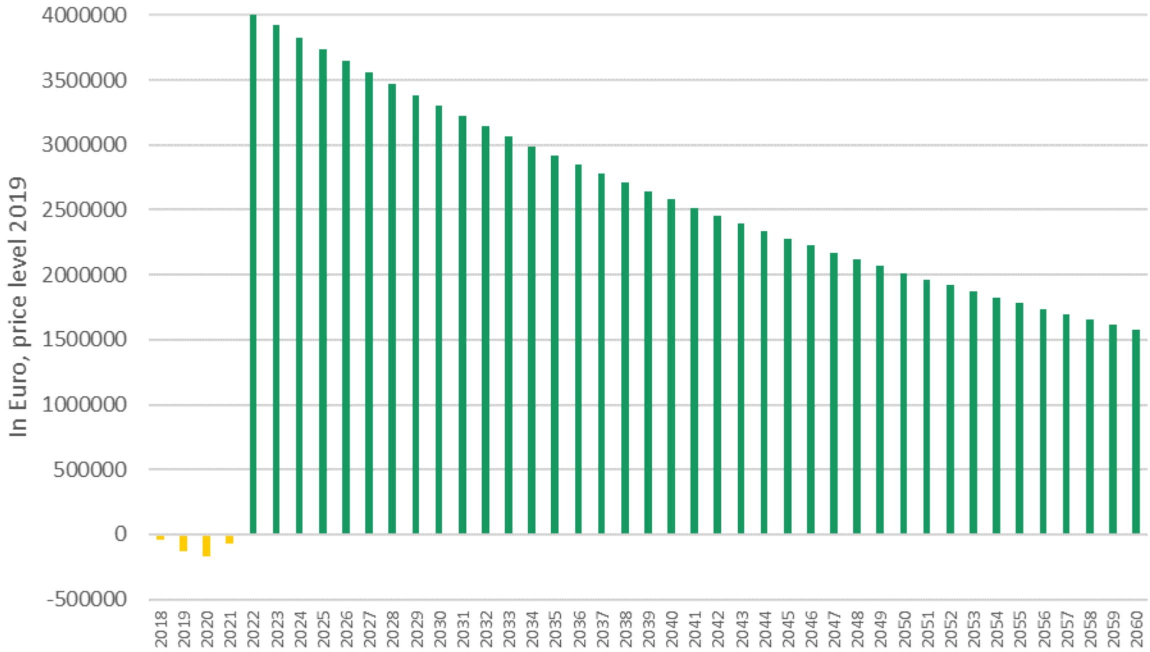
Concentrating on the maximum flood damage costs DanubeHIS has the potential of creating substantial benefits. In Figure 26 and Figure 27 it becomes clear just how large these benefits can be. For the country group of Slovakia, Hungary, Romania, Czech Republic and Ukraine the potential benefits are estimated to be a total over 600 million Euro during the 2022-2060 timespan. For Croatia, Bulgaria, Moldova, Serbia and Slovenia the total benefits would add up to over 100 million Euro.

**Figure 26: CBA results (max): SVK + HUN + ROU + CZE + UKR**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

**Figure 27: CBA results (max): HRV + BGR + MDA + SRB + SLO**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

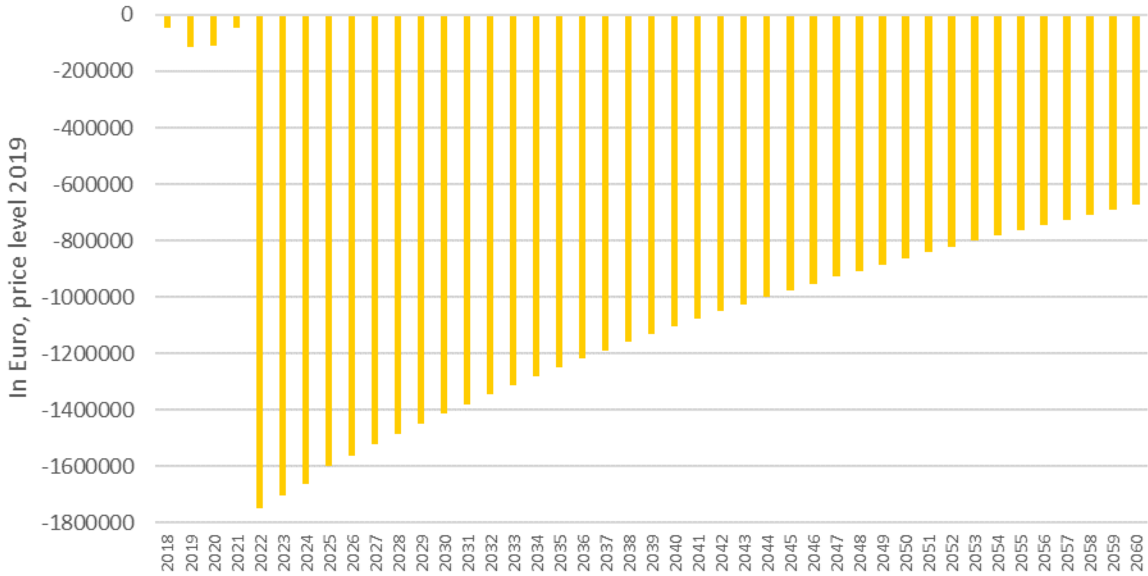
The stark difference between the three dimensions just highlights how heterogenous floods and flood damage are. Countries effected by weaker floods will see only minor benefits. However, in mean or maximum dimensions, the benefits of this project will clearly offset any operational costs.

#### 5.1.1.2 Scenario 1

Scenario 1 will incorporate the entirety of Scenario 0 with the added benefit of a platform that will allow for forecast data to be exchanged between the member states. The implementation period will be slightly longer and will last until 2024. The costs will be slightly higher due to the added implementation costs for this new platform.

As before in Scenario 0, the country group of Germany and Austria has only reported costs and no additional benefits. The total sum of implementation and operative costs for Germany and Austria is 44 million Euro.

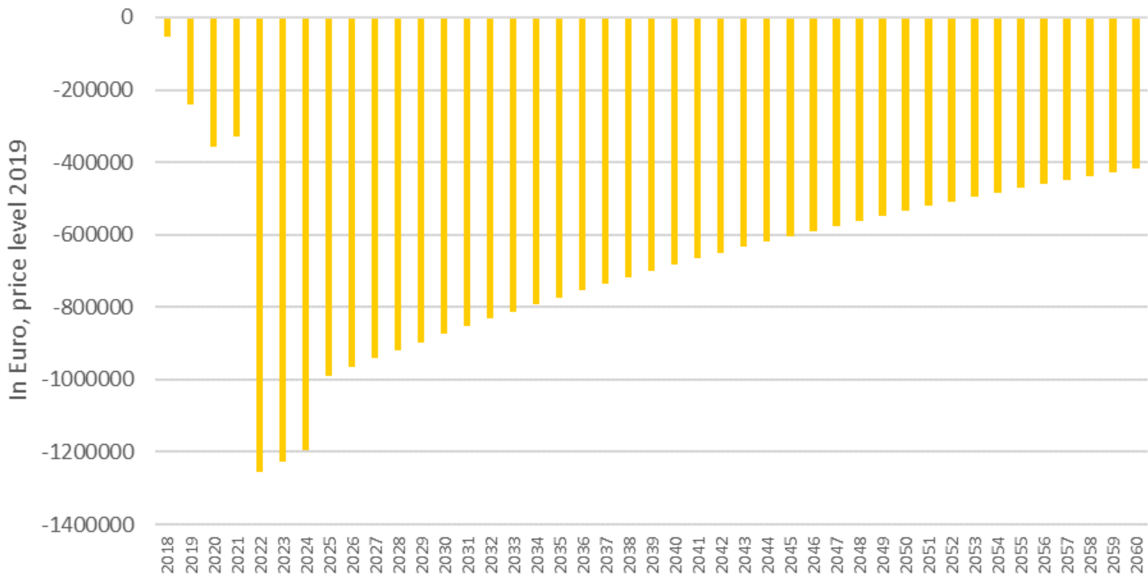
**Figure 28: CBA results (min, mean, and max): GER + AUT**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

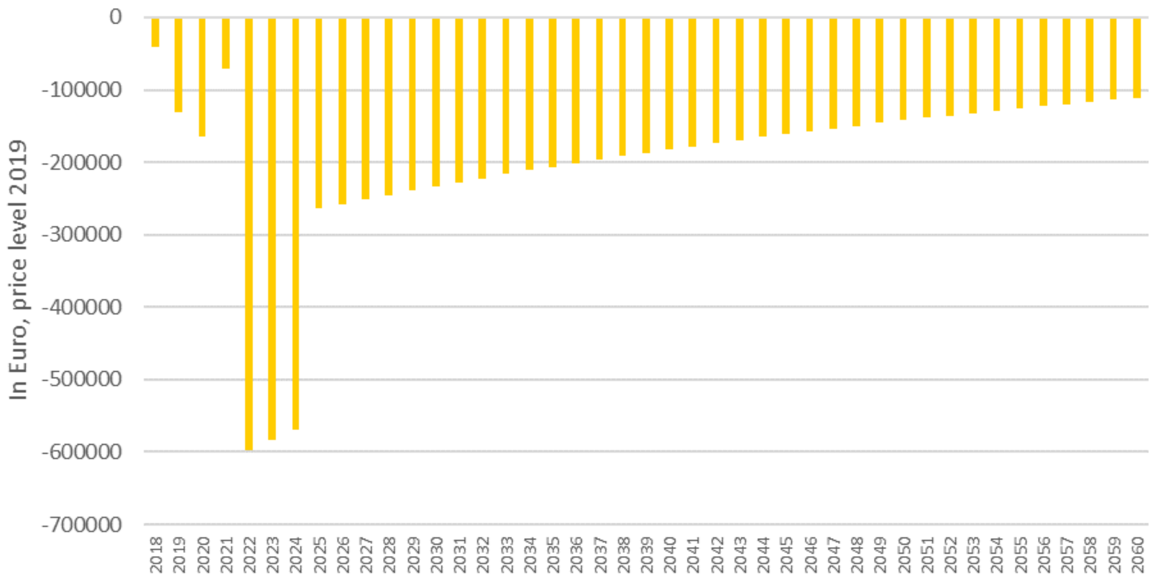
Figure 29 and Figure 30 show the country groups and the potential costs and benefits from Scenario 1 under a minimal damage function. Like Scenario 0, the costs outweigh the benefits for every year. For Slovakia, Hungary, Romania, Czech Republic and Ukraine the total costs are totalled at 28.5 million Euro, for Croatia, Bulgaria, Moldova, Serbia and Slovenia this figure is 8.5 million Euro.

**Figure 29: CBA results (min): SVK + HUN + ROU + CZE + UKR**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

**Figure 30: CBA results (min): HRV + BGR + MDA + SRB + SLO**



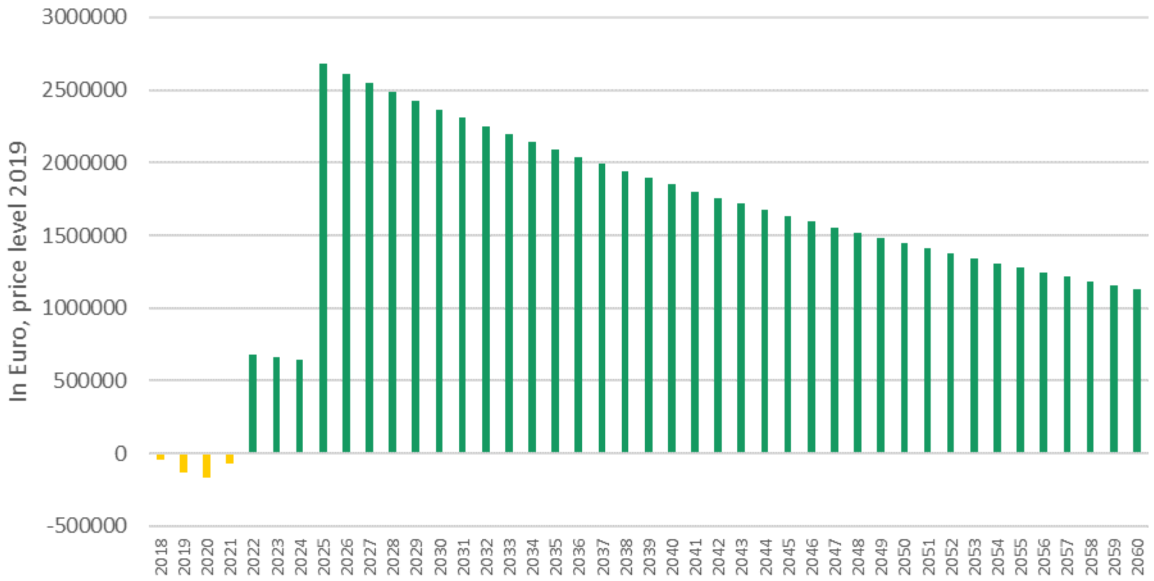

*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

The amount of flood damage that can be reduced, should a flood be somewhat stronger, is shown in Figure 31 and Figure 32. In this scenario, under a mean damage function, there is a significant amount of costs that can be saved. For Slovakia, Hungary, Romania, Czech Republic and Ukraine, the difference between the status quo and the implementation of Scenario 1 could save up to 404 million Euro till 2060. For Croatia, Bulgaria, Moldova, Serbia and Slovenia the amount of money saved would be around 66 million Euro. The difference between Scenario 0 and Scenario 1 is visible in the graphs. Up until 2024, only Scenario 0 is active, Scenario 1 begins after its implementation stage, with the first year being 2025. Between 2024 and 2025 there is a noticeable increase in the potential flood damage related costs that can be saved.

**Figure 31: CBA results (mean): SVK + HUN + ROU + CZE + UKR**


*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

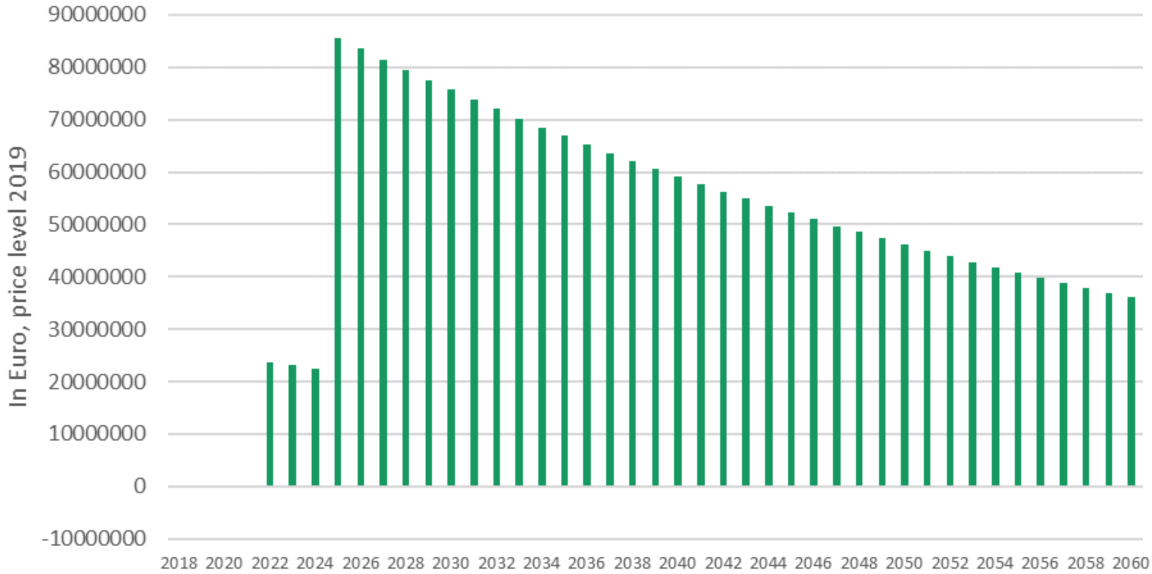
**Figure 32: CBA results (mean): HRV + BGR + MDA + SRB + SLO**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

In a worst-case regime (in the sense of high flood damages), the potential benefits from Scenario 1 are extraordinarily large. The country group of Slovakia, Hungary, Romania, Czech Republic and Ukraine could save up to 2.1 billion Euro once Scenario 1 is implemented. For Croatia, Bulgaria, Moldova, Serbia and Slovenia this figure is around 259 million Euro.

**Figure 33: CBA results (max): SVK + HUN + ROU + CZE + UKR**




*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

**Figure 34: CBA results (max): HRV + BGR + MDA + SRB + SLO**


*Annual differences between costs and benefits. Yellow: net costs; green: net benefits.*
*Source: Economica.*

The three damage functions and their widely different cost/benefit-ratio highlights just how heterogenous and complicated the topic of flood damages are. In good years the project will yield more costs than benefits. However, in any situation where a medium to large scale flood event occurs, the benefits from reduced damages strongly outweigh any additional costs occurred by this project. In a minimum damage function, the combined costs of all three country groups add up to 81 million Euro. In a mean damage function, 426 million Euros could be saved. Lastly, under a maximum damage function, it is estimated that the benefits outweigh the additional costs by around 2.4 billion Euro.

### *5.1.2 Quantitative results of the input-output analysis in Scenario 0*

The economic footprint[9] of DAREFFORT/DanubeHIS will be calculated in two different dimensions. The first dimension is derived from the national expenses for staff and maintenance. The second dimension is based on the results of the CBA.

Natural disasters actually have a positive effect on future value added. This might sound counterintuitive at first, but becomes clear on closer inspection, as reconstructions stimulate the economy. This is a well know problem in evaluating natural disasters in an economic way. Of course, for the affected people in the endangered areas, these events mean dramatic economic cuts. From another perspective, one can say, that these kind of reconstruction investments are not beneficial. If no damage had occurred, the money could have been used more sensibly. Therefore, the results of the input-output analysis in the second dimension are to be interpreted, as “vacated capacities” that would have been reserved for the sole purpose of restoring the status quo and now can be used for beneficial investments.

#### 5.1.2.1 Running costs – gross value added

Running costs (expenses for staff and material/maintenance), paid by the national hydrological and meteorological institutes, stimulate the economy. One part of these expenditures stimulates the domestic economy, the other part goes abroad via imports.

The highest expenses were reported in Austria and Germany. These expenses are transformed to a direct annual gross value added of 633,402 Euro in Austria and 547,417 Euro in Germany. In Romania, the direct GVA resulting from the running costs is 405,916 Euro, followed by Slovenia with 198,066 Euro. The other countries range between 102,522 Euro in Hungary and 29,033 Euro in the Ukraine.

Due to purchases of intermediate goods, the direct GVA increases by the so-called indirect effect generated in the supply network. This indirect effect amounts to 218,956 Euro in Germany, 196,557 Euro in Austria, 180,007 Euro in Romania, 80,606 in Hungary, 74,881 in Slovakia, 61,876 in Slovenia, 41,807 in Serbia, 29,903 in Croatia, 29,029 in Bulgaria, 14,380 in the Republic of Moldova, 10,847 in the Ukraine, and 7,936 in the Czech Republic.

Aggregating direct and indirect effect equals the total GVA effect. The multiplier indicates, by how much the total effect exceeds the direct effect. A multiplier of 1.8 means, that for every Euro originally paid for the running costs, an additional GVA of 80 cent can be generated within the supply network.

The results are displayed in Table 3 and Figure 35.

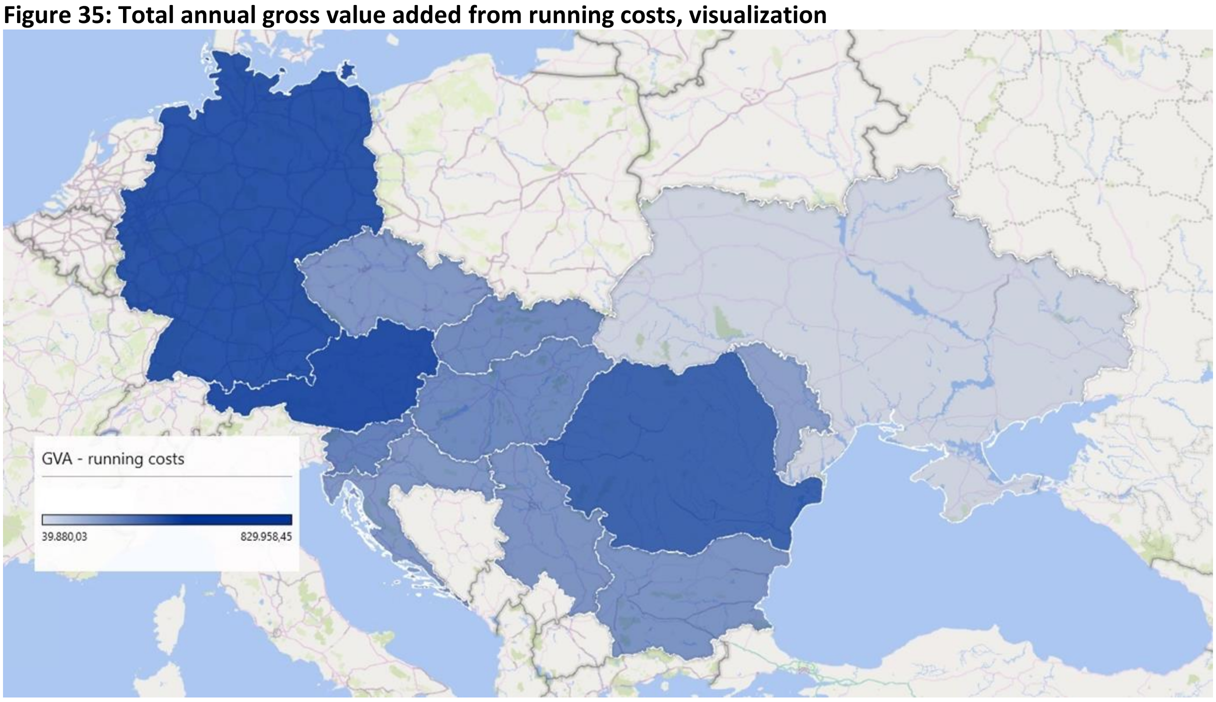
[9] The “Economic footprint” is a method to quantify economic impacts of companies, sectors or systems, designed by Economica. Economica holds a trademark protection for the German term “ökonomischer Fußabdruck”.

**Table 3: Annual GVA effects generated from running costs**

| Country | Direct effect in € | Indirect effect in € | Total effect in € | Multiplier |
|---|---|---|---|---|
| Germany | 547,417 | 218,956 | 766,372 | 1.4 |
| Austria | 633,402 | 196,557 | 829,958 | 1.3 |
| Slovakia | 92,449 | 74,881 | 167,330 | 1.8 |
| Hungary | 102,522 | 80,606 | 183,128 | 1.8 |
| Croatia | 44,097 | 29,903 | 74,000 | 1.7 |
| Romania | 405,916 | 180,007 | 585,923 | 1.4 |
| Bulgaria | 67,094 | 29,029 | 96,123 | 1.4 |
| Republic of Moldova | 31,322 | 14,380 | 45,702 | 1.5 |
| Serbia | 51,414 | 41,807 | 93,221 | 1.8 |
| Czech Republic | 65,750 | 7,936 | 73,685 | 1.1 |
| Slovenia | 198,066 | 61,876 | 259,942 | 1.3 |
| Ukraine | 29,033 | 10,847 | 39,880 | 1.4 |

*Source: Economica.*

**Figure 35: Total annual gross value added from running costs, visualization**




*Source: Economica.*

#### 5.1.2.2 Running costs – employment

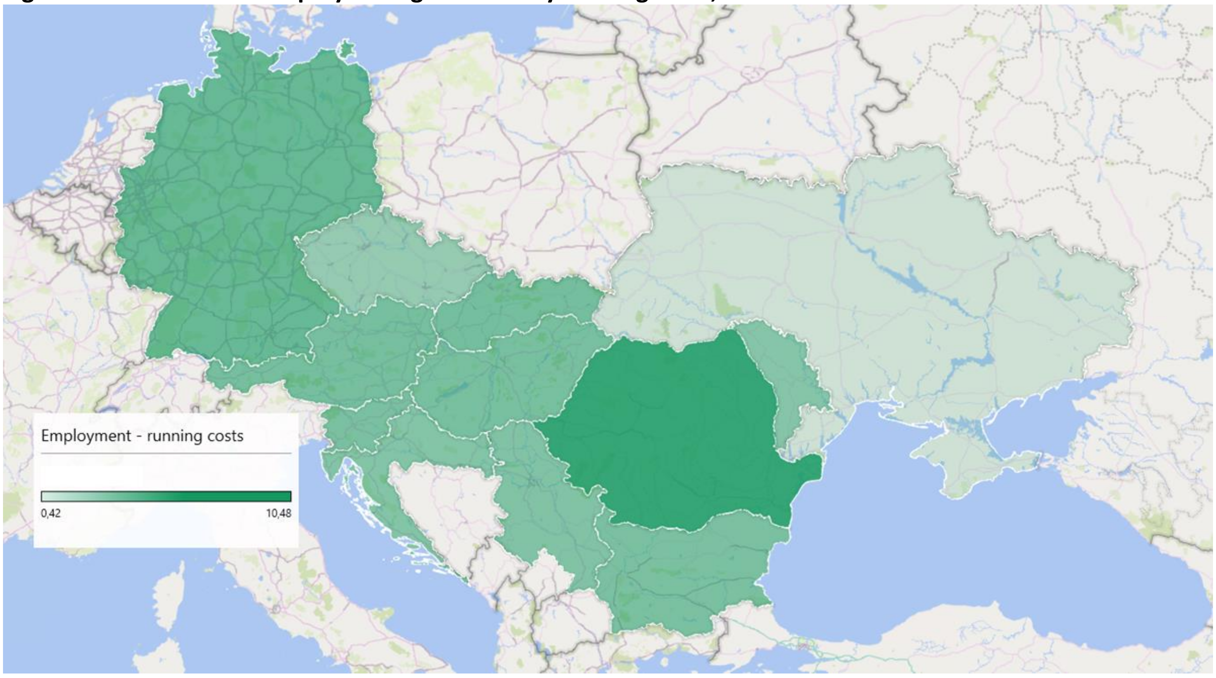
The effects on the employment resulting from the running costs are shown in Table 4 and Figure 36. The highest total effect can be observed in Romania, where 10.5 jobs can be created or secured. The highest employment multiplier can be observed in Austria, where 1 workplace in DanubeHIS creates or secures 1.8 workplaces in the supply network.

**Table 4: Annual employment effects generated by running costs**

| Country | Direct effect in person | Indirect effect in person | Total effect in person | Multiplier |
|---|---|---|---|---|
| Germany | 1.8 | 2.5 | 4.3 | 2.4 |
| Austria | 0.9 | 1.7 | 2.7 | 2.8 |
| Slovakia | 1.4 | 1.3 | 2.7 | 2.0 |
| Hungary | 1.0 | 1.3 | 2.4 | 2.3 |
| Croatia | 0.7 | 0.6 | 1.3 | 1.8 |
| Romania | 6.2 | 4.3 | 10.5 | 1.7 |
| Bulgaria | 1.4 | 0.8 | 2.2 | 1.6 |
| Republic of Moldova | 0.7 | 0.4 | 1.1 | 1.6 |
| Serbia | 0.8 | 0.7 | 1.5 | 1.8 |
| Czech Republic | 0.4 | 0.1 | 0.5 | 1.3 |
| Slovenia | 1.2 | 0.9 | 2.2 | 1.8 |
| Ukraine | 0.2 | 0.2 | 0.4 | 1.7 |

*Source: Economica.*

**Figure 36: Total annual employment generated by running costs, visualization**




*Source: Economica.*

#### 5.1.2.3 CBA – gross value added

This section presents the effects on the gross value added, that result from the cost savings, that where determined in the CBA. One has to bear in mind that the system of national accounts, and thus gross value added, gross domestic product, employment, and all other indicators as we currently know and use them, need special interpretation when it comes to the prevention of negative effects. All catastrophes, but also accidents treated in hospitals and the like, generate economic activity. In the case discussed here, a flood destroys e.g. infrastructure. The reconstruction of it requires investments and thus generates GVA and employment. Using these standard measures therefore leads to the well-known problem that catastrophes in fact increase (!) economic indicators. Such events are thus hard to detect in economic time-series. It thus seems counter-intuitive to apply the same methods here as for the case without a disaster. However, the same reasoning can be used for the treatment of the victims of accidents or ill persons. It seems strange though to exclude nurses and doctors from the economy. One must also not forget that the persons employed in the process of removing the destruction of the flood and reconstructing everything are better off having that job than without it. On the other hand, the society would have spent the money in a different, most likely more useful way. These arguments must be considered when reading and interpreting the economic results on damage done and damage prevented.

As for the countries, Germany, Austria, Republic of Moldova, Czech Republic and Slovenia no cost savings are expected, no GVA effects will be experienced.

Table 5, Table 6 and Table 7 showcase the amount of gross value added dependent on the damage function applied. Under a minimum damage function only a small amount of GVA will be generated. This is to be expected as hardly any flood damage is prevented. In the mean and maximum function, this changes. Here, certain countries, such as Romania and Ukraine, see significant GVA effects through the avoidance of flood damage. Romania, which saw less than 20,000 GVA produced in a minimum damage function, can create 9,305,118 GVA in a maximum damage function. That’s because here are two kind of impulses working, that reinforce each other. In Romania, DanubeHIS potentially lead to high improvements, thus high cost savings. In addition, these savings can create a lot of employment, as labour is comparatively cheap in Romania.

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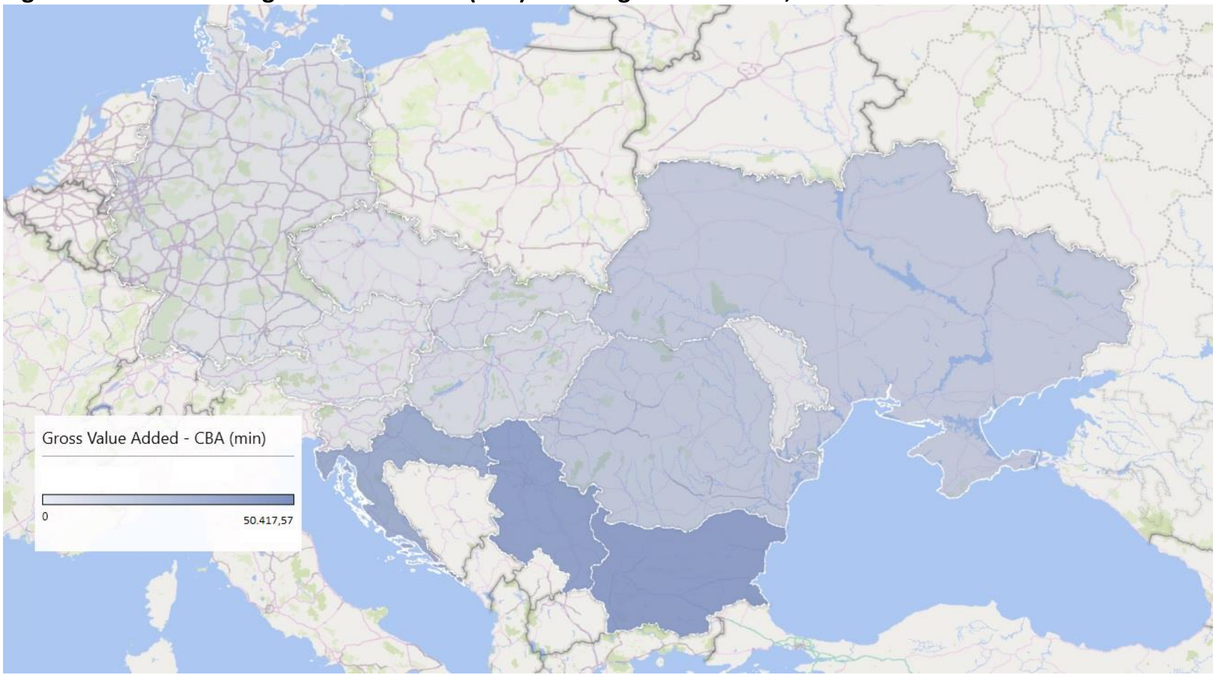
**Table 5: Gross value added resulting from the CBA in the minimum damage function**

| Country | Direct effect in € | Indirect effect in € | Total effect in € | Multiplier |
|---|---|---|---|---|
| Germany | - | - | - | |
| Austria | - | - | - | |
| Slovakia | 1,204 | 1,586 | 2.789 | 2,3 |
| Hungary | 1,175 | 1,548 | 2.723 | 2,3 |
| Croatia | 18,327 | 22,649 | 40.977 | 2,2 |
| Romania | 7,305 | 9,869 | 17.175 | 2,4 |
| Bulgaria | 17,826 | 30,406 | 48.232 | 2,7 |
| Republic of Moldova | - | - | - | |
| Serbia | 21,755 | 28,663 | 50.418 | 2,3 |
| Czech Republic | - | - | - | |
| Slovenia | - | - | - | |
| Ukraine | 6,485 | 8,705 | 15.190 | 2,3 |

*Source: Economica.*

**Figure 37: Total annual gross value added (min) resulting from the CBA, visualization**



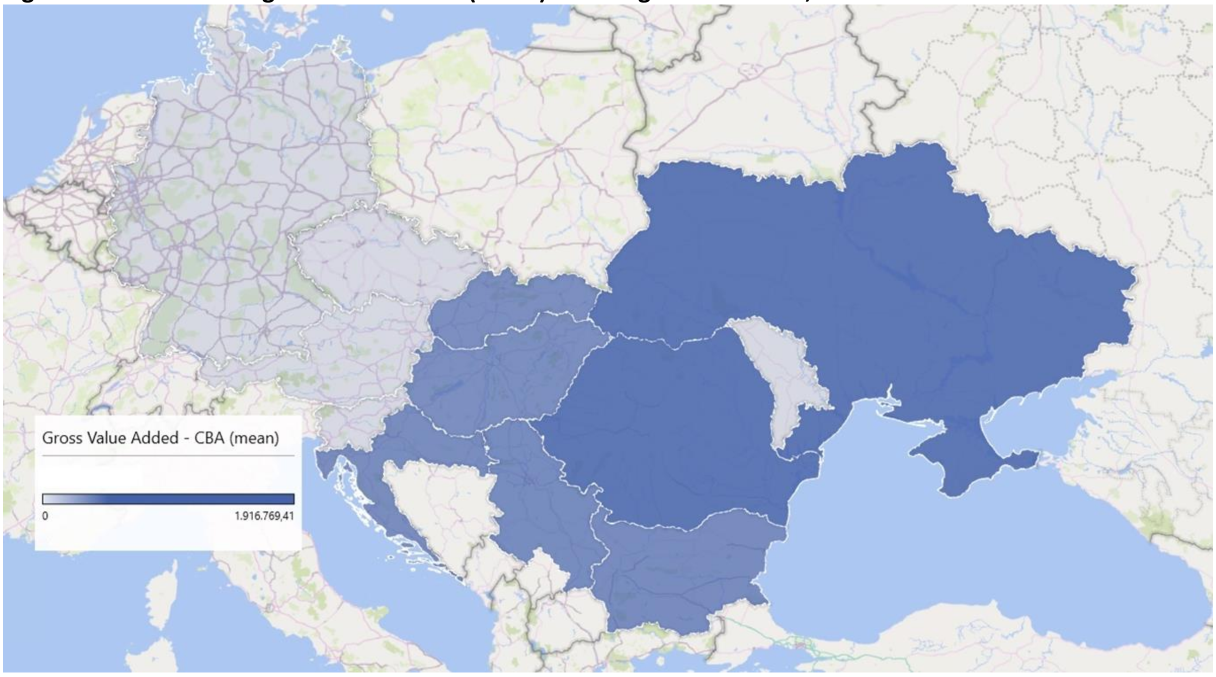

*Source: Economica.*

**Table 6: Gross value added resulting from the CBA in the mean damage function**

| Country | Direct effect in € | Indirect effect in € | Total effect in € | Multiplier |
|---|---|---|---|---|
| Germany | - | - | - | |
| Austria | - | - | - | |
| Slovakia | 127,140 | 174,114 | 301,254 | 2.4 |
| Hungary | 126,316 | 170,626 | 296,942 | 2.4 |
| Croatia | 157,196 | 192,949 | 350,145 | 2.2 |
| Romania | 806,930 | 1,065,086 | 1,872,015 | 2.3 |
| Bulgaria | 154,791 | 261,948 | 416,739 | 2.7 |
| Republic of Moldova | - | - | - | |
| Serbia | 185,016 | 244,806 | 429,822 | 2.3 |
| Czech Republic | - | - | - | |
| Slovenia | - | - | - | |
| Ukraine | 812,424 | 1,104,346 | 1,916,769 | 2.4 |

*Source: Economica.*

**Figure 38: Total annual gross value added (mean) resulting from the CBA, visualization**



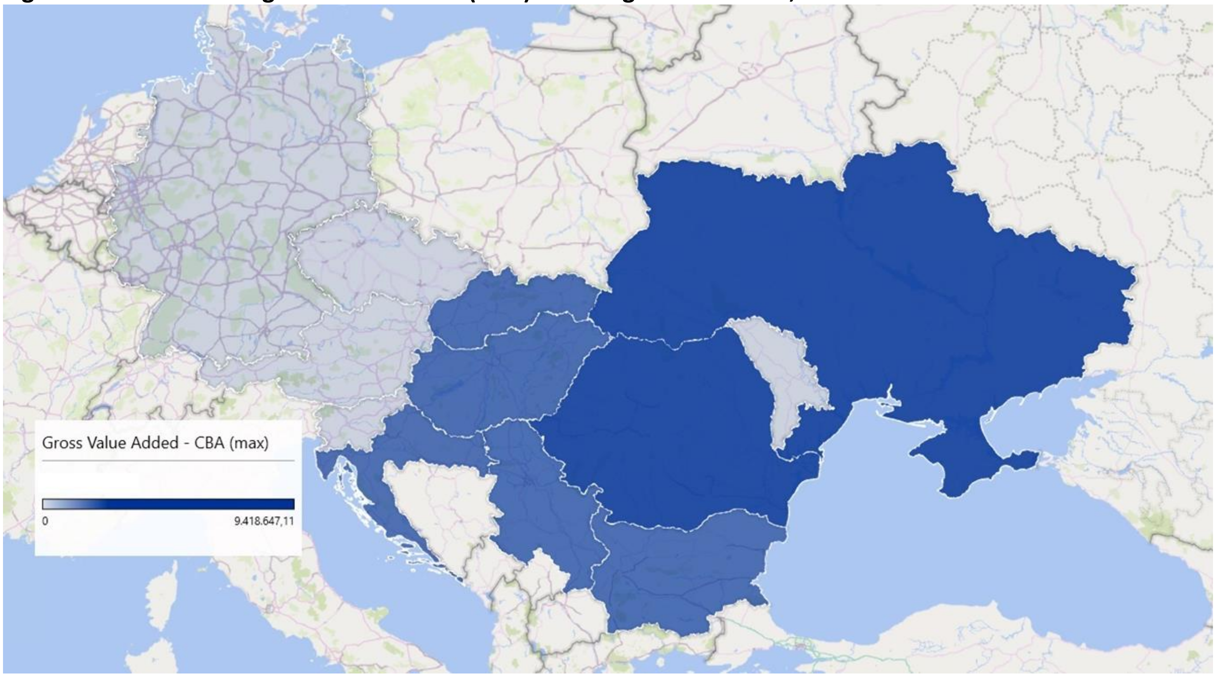

*Source: Economica.*

**Table 7: Gross value added resulting from the CBA in the maximum damage function**

| Country | Direct effect in € | Indirect effect in € | Total effect in € | Multiplier |
|---|---|---|---|---|
| Germany | - | - | - | |
| Austria | - | - | - | |
| Slovakia | 640,723 | 871,970 | 1,512,693 | 2.4 |
| Hungary | 634,856 | 853,709 | 1,488,566 | 2.3 |
| Croatia | 515,320 | 629,972 | 1,145,291 | 2.2 |
| Romania | 4,001,434 | 5,303,685 | 9,305,118 | 2.3 |
| Bulgaria | 511,747 | 862,549 | 1,374,296 | 2.7 |
| Republic of Moldova | - | - | - | |
| Serbia | 603,442 | 800,564 | 1,404,006 | 2.3 |
| Czech Republic | - | - | - | |
| Slovenia | - | - | - | |
| Ukraine | 3,995,706 | 5,422,941 | 9,418,647 | 2.4 |

*Source: Economica.*

**Figure 39: Total annual gross value added (max) resulting from the CBA, visualization**




*Source: Economica.*

#### 5.1.2.4 CBA – employment

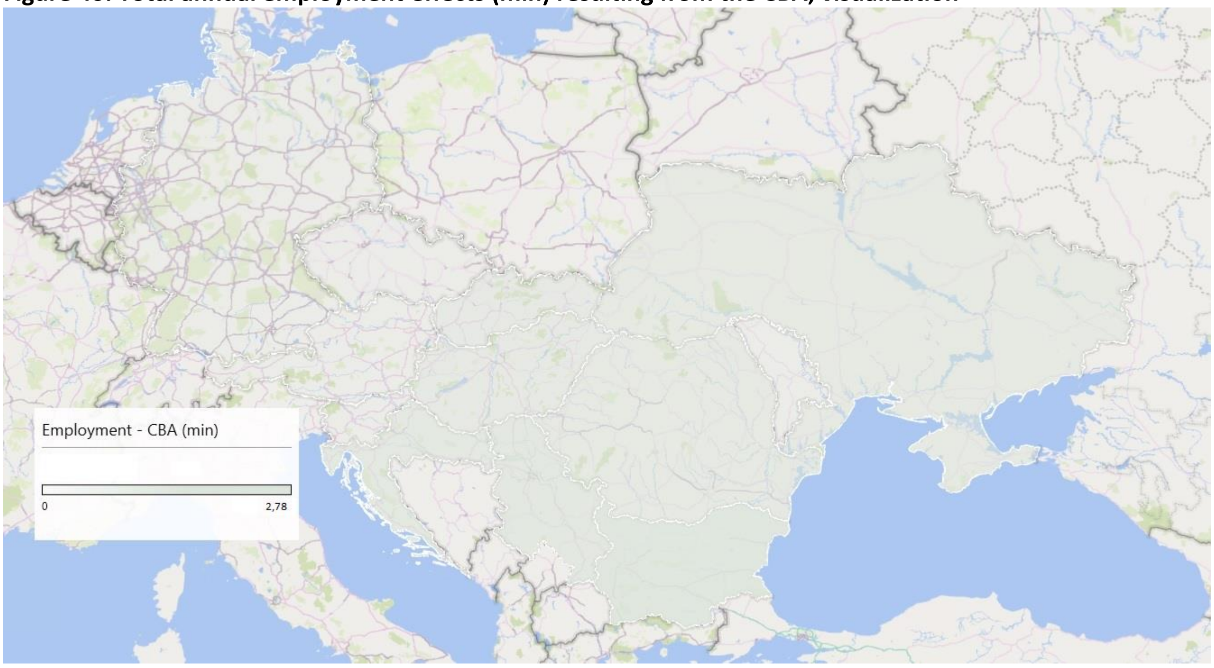
Similar to GVA, employment effects in the minimum damage function visible in Table 8 are rather small, creating or securing a total of only 7.4 work places. In comparison, employment effects in the mean and maximum damage function are significantly higher. In a mean damage function, the total employment effect would be 205.7. In a maximum damage function this number rises to 932,8. Again, Romania faces the highest effects, as high savings are expected, and labour is relatively cheap.

**Table 8: Employment effect resulting from the CBA in the minimum damage function**

| Country | Direct effect in person | Indirect effect in person | Total effect in person | Multiplier |
|---|---|---|---|---|
| Germany | - | - | - | |
| Austria | - | - | - | |
| Slovakia | 0,0 | 0,0 | 0,1 | 1,8 |
| Hungary | 0,1 | 0,0 | 0,1 | 1,6 |
| Croatia | 0,8 | 0,6 | 1,3 | 1,7 |
| Romania | 0,4 | 0,3 | 0,7 | 1,6 |
| Bulgaria | 1,5 | 1,3 | 2,8 | 1,8 |
| Republic of Moldova | - | - | - | |
| Serbia | 1,2 | 0,7 | 1,9 | 1,6 |
| Czech Republic | - | - | - | |
| Slovenia | - | - | - | |
| Ukraine | 0,3 | 0,2 | 0,5 | 1,9 |

*Source: Economica.*

**Figure 40: Total annual employment effects (min) resulting from the CBA, visualization**



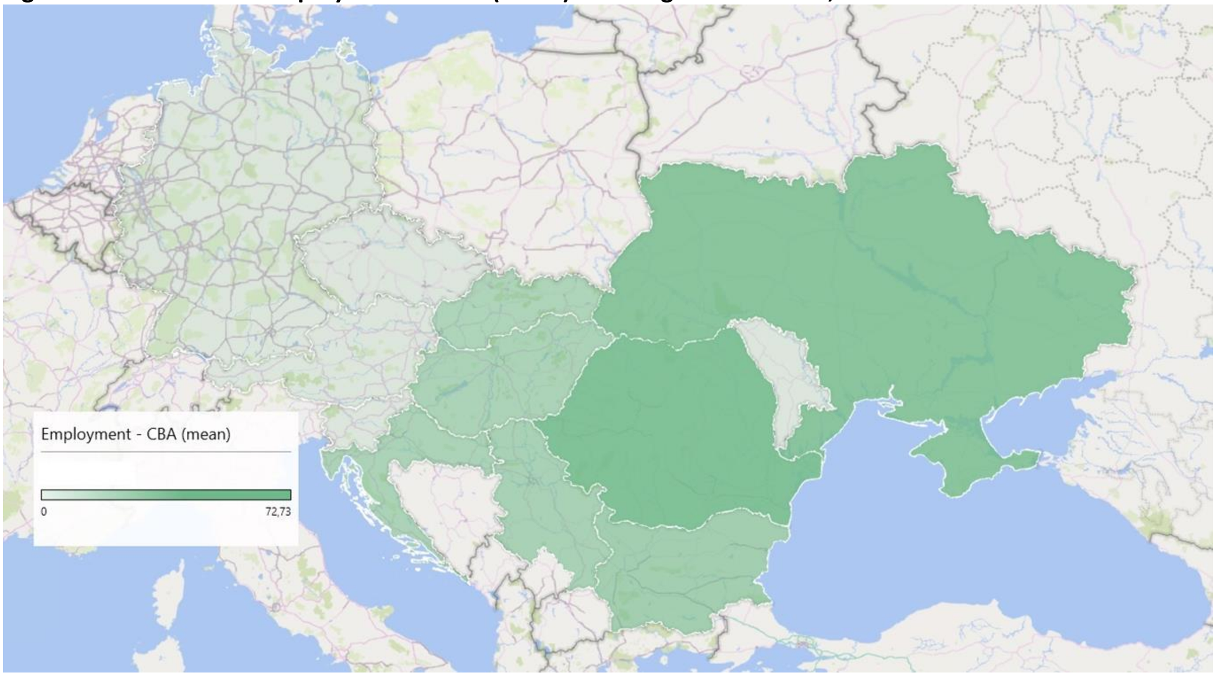

*Source: Economica.*

**Table 9: Employment effect resulting from the CBA in the mean damage function**

| Country | Direct effect in person | Indirect effect in person | Total effect in person | Multiplier |
|---|---|---|---|---|
| Germany | - | - | - | |
| Austria | - | - | - | |
| Slovakia | 4,8 | 3,8 | 8,6 | 1,8 |
| Hungary | 7,0 | 4,2 | 11,2 | 1,6 |
| Croatia | 6,8 | 4,8 | 11,6 | 1,7 |
| Romania | 43,9 | 28,8 | 72,7 | 1,7 |
| Bulgaria | 13,3 | 10,8 | 24,2 | 1,8 |
| Republic of Moldova | - | - | - | |
| Serbia | 9,8 | 6,1 | 15,8 | 1,6 |
| Czech Republic | - | - | - | |
| Slovenia | - | - | - | |
| Ukraine | 33,2 | 28,4 | 61,6 | 1,9 |

*Source: Economica.*

**Figure 41: Total annual employment effects (mean) resulting from the CBA, visualization**



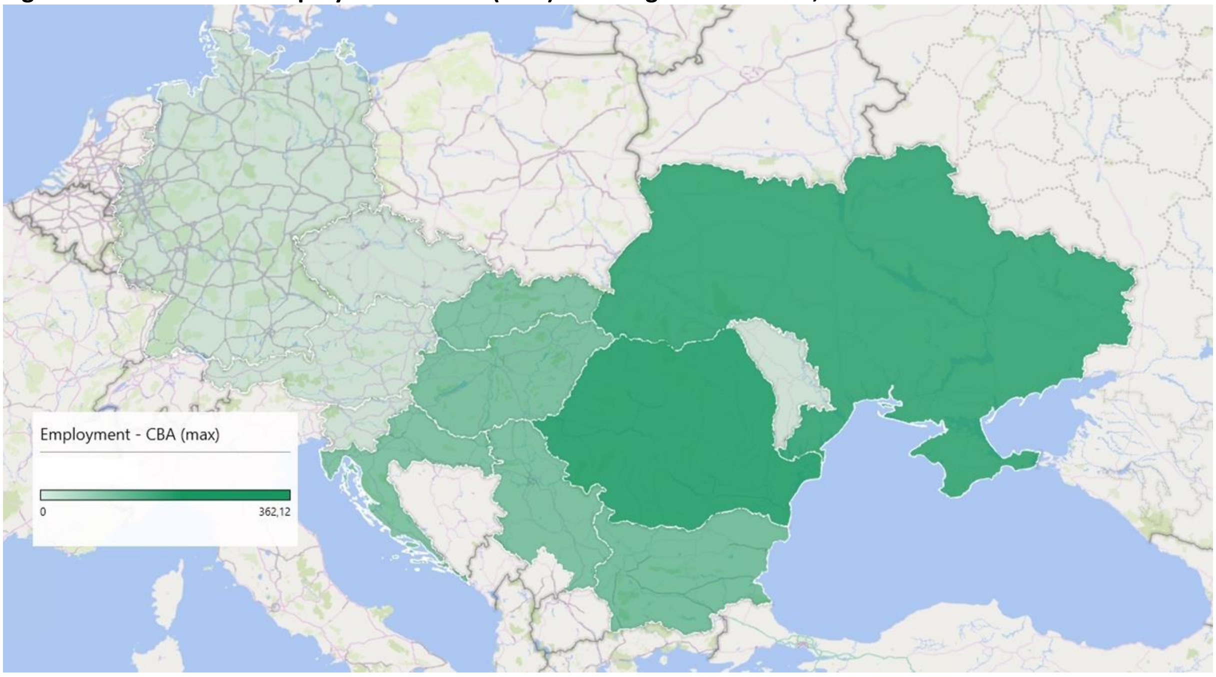

*Source: Economica.*

**Table 10: Employment effect resulting from the CBA in the maximum damage function**

| Country | Direct effect in person | Indirect effect in person | Total effect in person | Multiplier |
|---|---|---|---|---|
| Germany | - | - | - | |
| Austria | - | - | - | |
| Slovakia | 24.0 | 19.2 | 43.2 | 1.8 |
| Hungary | 35.2 | 21.0 | 56.2 | 1.6 |
| Croatia | 22.5 | 15.5 | 38.1 | 1.7 |
| Romania | 218.6 | 143.5 | 362.1 | 1.7 |
| Bulgaria | 44.6 | 35.6 | 80.1 | 1.8 |
| Republic of Moldova | - | - | - | |
| Serbia | 31.6 | 19.8 | 51.3 | 1.6 |
| Czech Republic | - | - | - | |
| Slovenia | - | - | - | |
| Ukraine | 162.4 | 139.4 | 301.8 | 1.9 |

*Source: Economica.*

**Figure 42: Total annual employment effects (max) resulting from the CBA, visualization**




*Source: Economica.*

## 5.2 Qualitative remarks on Scenario 2 and 3

### *5.2.1 Scenario 2*

Scenario 2, marked by a close integration with supra-regional flood warning systems like EFAS, Copernicus service, South-East European Multi-Hazard Early Warning Advisory System (SEE-MHEWS-A); South East Europe Flash Flood Guidance (SEE-FFG), Sava Flood Forecasting and Warning System (Sava FFWS) would add another potentially beneficial dimension to DanubeHIS. Phase I (integration with EFAS) seems to be the most “trouble-free” phase, as all the DAREFFORT/DanuebHIS partner countries already are part of EFAS. In contrast, not all the partners are members in the cooperation of Phase II, and it is not sure, if this integration step would be welcomed by all the missing partner countries.

It should be noted that, a quantitative assessment is not possible at this stage. Too many uncertainties make it impossible for any quantitative analysis of a high calibre to be performed. Many key assumptions are yet to be determined making it unclear how the actual costs will be, and by how much the forecasts will improve. Although, no quantitative analysis is possible here, the possible consequences in Scenario 2 will be discussed. A higher regional integration could potentially improve the lead time in some countries. As we have seen in Scenario 1, adding one more variable (national forecasting data) to the data exchange server, leads to substantially higher benefits when compared to Scenario 0. This could also be the case here. A point worthy of studying, might be the increased quality of forecasting. Nations that now follow the EFAS standards could experience an increase in their ability to produce high quality forecasts, which could have various effects for those nations. Especially, the potential significant increase of the performance of medium-term hydrological warnings and forecast products due to the use of rainfall-runoff simulations from EFAS as an input to the routing models from the national system could contribute to an improvement. The corresponding costs could be covered by the EU resulting on no additional costs for the national data providers. Nevertheless, these costs would have to be included in a future analysis.

### *5.2.2 Scenario 3*

Scenario 3, as it is described in chapter 2.4, would be the most inclusive, but also the most complex potential future system scenario. It is the most uncertain scenario as well. A reliable assessment of the economic consequences is therefore not possible at this time. At this stage, too many factors on the exact framework and implementation of Scenario 3 remain unclear to perform any type of quantitative analysis. A quantitative impact analysis can be considered at a later date, when DanubeHIS is fully implemented and the data provider have made their first experiences with the system. This could eliminate some of the uncertainties, allowing making evidence-based assumptions on potential future costs and forecast improvements.

# 6 Conclusions

This study showed the potential economic impacts of DAREFFORT/Danube HIS in two different Scenarios each with three dimensions. Due to the heterogeneous economic characteristics of the participating countries, three groups where formed:

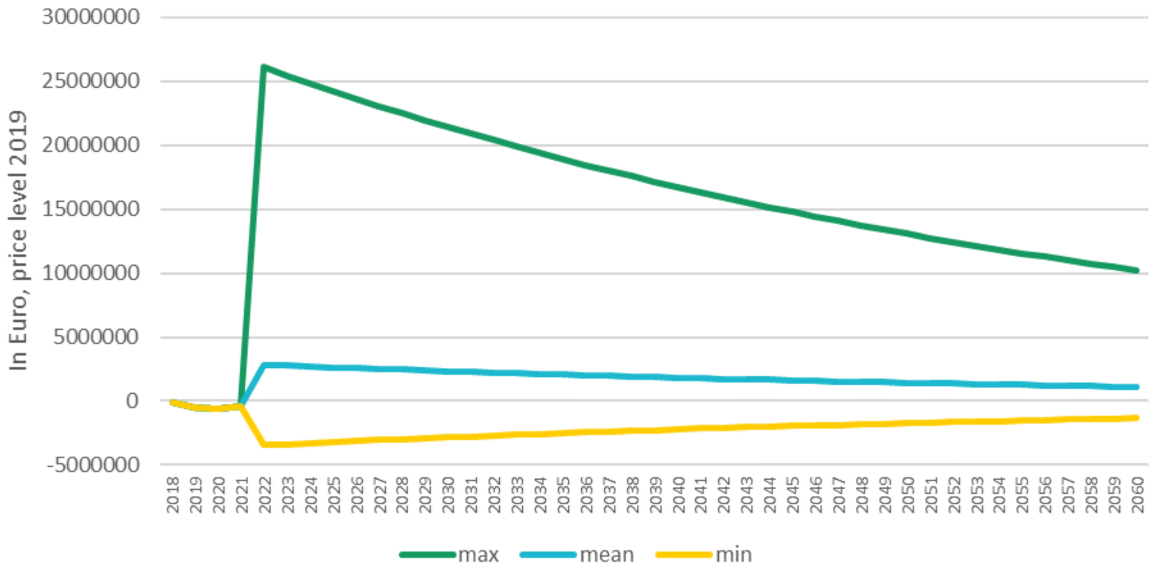
Germany, and Austria,
Slovakia, Hungary, Romania, Czech Republic, and Ukraine
Croatia, Bulgaria, Republic of Moldova, Serbia, and Slovenia

Upstream countries like Germany and Austria, and the Republic of Moldova with just a minor common part with the Danube river, do not expect any improvements of their national flood forecasting systems. All the other countries, at least in Scenario 1, however, expect improvements. These improvements have been assessed in a cost-benefit analysis and in an input-output analysis.

The results of the CBA are displayed in Figure 43 (annually) and Figure 44 (accumulated). The yellow line represents the effects from a minimal damage perspective, the green line from a maximum damage perspective. Depending on the severity of the future flood events, the costs or benefits will lie between those lines. If just – what is unfortunately not very likely – minor damages accrue, the system will be more expensive than it can save potentially. Already in the mean DAREFFORT/DanubeHIS has the potential to save a total of around 3 million Euros per year, or accumulated 70 million Euro till 2060. These savings could grow up to 26 million Euro annually, or 660 million Euro accumulated till 2060 under a maximum perspective.

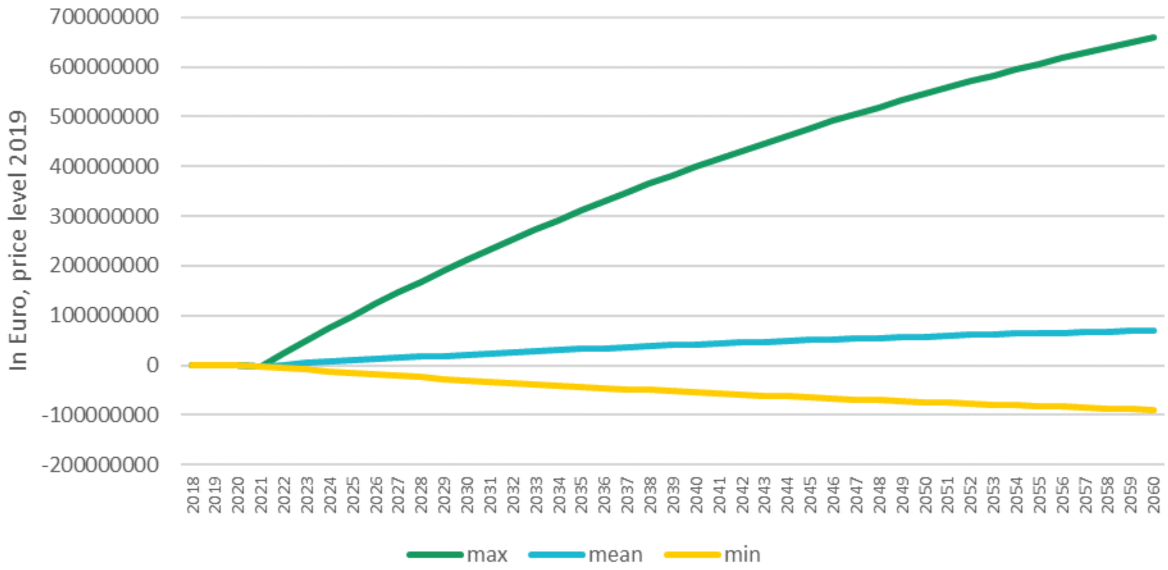
In other words, with 1 Euro invested DAREFFORT/DanubeHIS in Scenario 0 has the potential to save -6.98 Euro till 2060.

**Figure 43: Total annual results of the CBA, Scenario 0**




*Source: Economica.*

**Figure 44: Total accumulated effects of the CBA, Scenario 0**




*Source: Economica.*

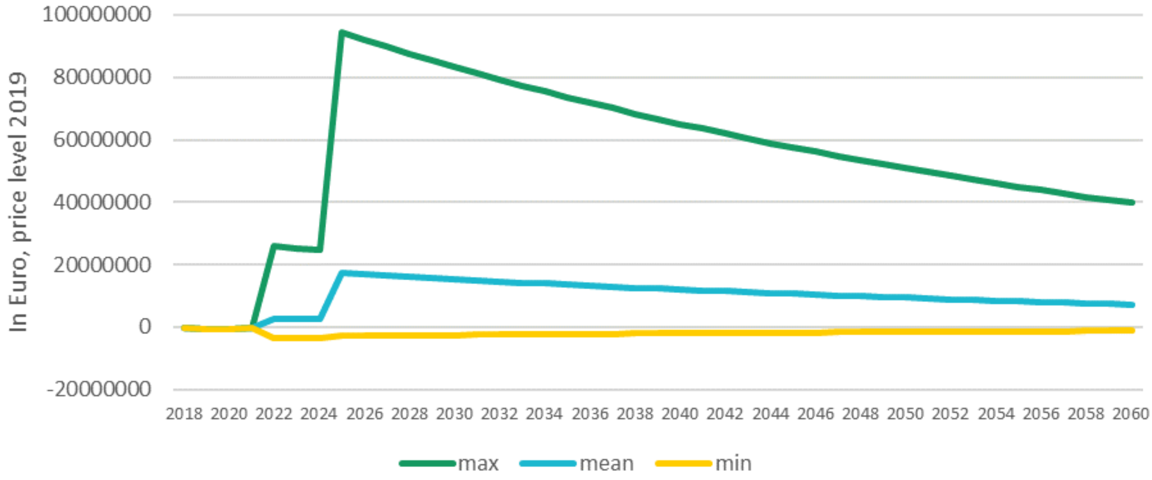
The economic footprint transforms the results from the cost-benefit analysis into an input-output analysis and adds the economic effects from the running costs as well.

In total (for all countries), the annual gross value added effect amounts from 3.4 million Euro (min) up to 28.8 million Euro (max).

In Scenario 1 even higher effects are expected. The annual difference with the status quo ranges between higher costs of 3.6 million Euro and benefits of 26,0 million Euro. Accumulated, the effects range between higher costs of 81 million Euros to savings of 2,4 billion Euro till 2060. In the mean – the most likely state – DAREFFORT/DanubeHIS would save up to 426,4 million Euro till 2060.

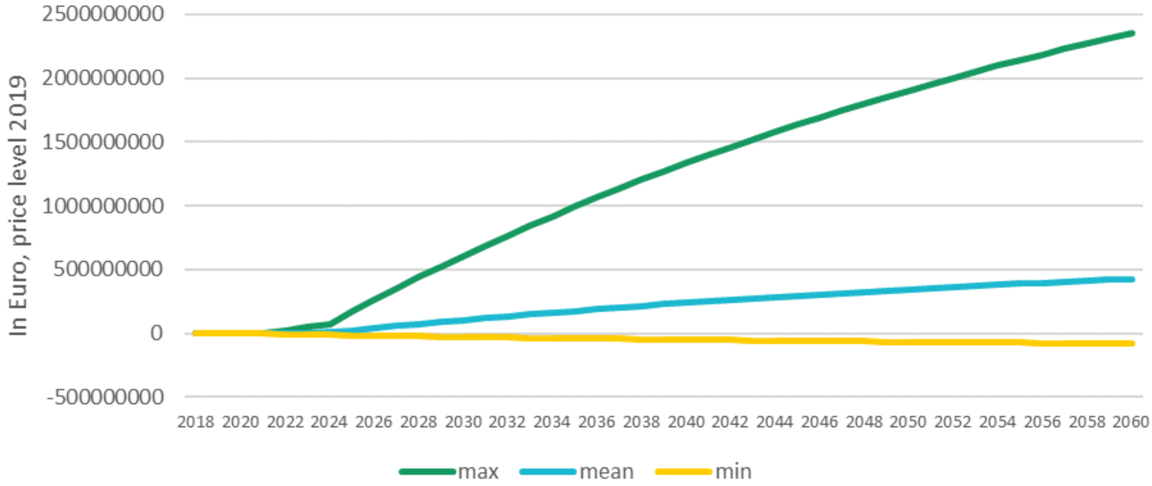
In other words, with 1 Euro invested DAREFFORT/DanubeHIS in Scenario 1 has the potential to save 24,75 Euro till 2060.

**Figure 45: Total annual results of the CBA, Scenario 1**




*Source: Economica.*

**Figure 46: Total accumulated effects of the CBA, Scenario 1**




*Source: Economica.*

These findings lead to the conclusion, that from an economic point of view, DAREFFORT/DanubeHIS will be beneficial in a maximum and mean perspective. Only if just minor flood damages accrue, the costs exceed the benefits. Also, we could recommend implementation of Scenario 1 as well, as the costs just rise slightly, but the potential benefits increase substantially. However, only economic aspects are not enough for answering the question if a flood warning system should be implemented or not. Social and ethical aspects should be taken into account, as flood warnings not only save property, but also lives.

# 7 Annex

## 7.1 Data request file – historic flood events

**Data about previous flood damages**

**(5) Danube related flood damage costs (in Euro)**

| | | | | | |
|---|---|---|---|---|---|
| Year | | | | | |
| Classification (frequency: e.g. 1-year flood, 30-year flood, 100-year flood) | | | | | |
| Source | | | | | |
| **Category** | | | | | |
| Agriculture, Forestry and Fishing (crop failure, dead livestock...) | | | | | |
| Manufactured Products | | | | | |
| Constructions above ground (buildings, | | | | | |
| Constructions below ground (streets, bridges) | | | | | |
| Transportation (Vehicles, Ships...) | | | | | |
| Other (please specify):__________ | | | | | |
| Other (please specify):__________ | | | | | |
| Other (please specify):__________ | | | | | |
| Other (please specify):__________ | | | | | |
| **TOTAL COSTS** | - | - | - | - | - |
| **Death toll** | | | | | |

**If more columns (more flood related cost data is available) are needed, please add more**
**The more data we get, the better will be the quality of our calculatoins!**
**Data about >5 floods would be great!**

## 7.2 Data request file – expected DAREFFORT/DanubeHIS related costs

**Data about maintenance costs DAREFFORT/DanubeHIS**

*The DAREFFORT project will serve as the basis for a future DanubeHIS. How many people are expected to deal with the maintenance of DAREFFORT/DanubeHIS related data directly? How many people are invovled in general hydrological and meteorological tasks in your institution?*

| | |
|---|---|
| (2) Institution | |

| **(3) Expenditures (in Euro)** | 2019 | 2020 | | 2022 | 2023 |
|---|---|---|---|---|---|
| **TOTAL** | DATA covered through DAREFFORT | | | | |
| PERSONNEL COSTS (incl. non-wage labour costs) | DATA covered through DAREFFORT | | | | |
| thereof: DAREFFORT/DanubeHIS | DATA covered through DAREFFORT | | | | |
| thereof: general | DATA covered through DAREFFORT | | | | |
| MATERIAL COSTS (server, needed equipment) | DATA covered through DAREFFORT | | | | |

| **(4) Employees** | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|
| DAREFFORT/DanubeHIS related (per capita) | | | | | |
| general (per capita) | | | | | |
| DAREFFORT/DanubeHIS related (full-time equivalent) | | | | | |
| general (full-time equivalent FTE) | | | | | |

## Table of figures

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