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CARE-W WP4

D9 – Development of the "Scenario Writer" software for the exploration of future utility backgrounds

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COMPUTER AIDED REHABILITATION OF WATER NETWORKS

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CARE – W

Computer Aided REhabilitation of Water networks. Decision Support Tools for Sustainable Water Network Management

WP4 - Strategic Planning and Investment

Report D9
Development of the "Scenario Writer" software for the exploration of future utility backgrounds

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1 Introduction

The CARE-W project is funded by the European Community and aims to develop methods and software that will enable engineers of the water undertakings to establish and maintain an effective management of their water supply networks, rehabilitating the right pipes at the right time. The results shall be disseminated as a manual on Best Management Practice (BMP) for water network rehabilitation.

This project is organised in the following Working Packages (WP):

- WP1: Construction of a control panel of performance indicators for rehabilitation;
- WP2: Description and validation of technical tools;
- WP3: Elaboration of a decision support system for annual rehabilitation programmes;
- WP4: Elaboration of a decision support system for long-term strategic planning and investment;
- WP5: Elaboration of CARE-W prototype;
- WP6: Testing and validation of CARE-W prototype;
- WP7: Dissemination;
- WP8: Project management.

TUD is responsible for WP4, which is divided in three tasks, each one with its specific objective, schedule, deliverables and methodology.

Task 1:

A software platform for developing consistent scenarios, the **Scenario Writer**, supporting the creation of future background scenarios for any particular Water Supply Company and opening its "window of opportunities". This software allows to create consistent paths into the future. Five points on the time axis cover a time span from yesterday into the far future. Three paths – containing context information for network rehab policies, key factors influencing rehab policy for each point in time – open up a funnel into the future.

Task 2:

The **Rehab Strategy Manager** based on the *KANEW* software allowing the simulation of long term effects of specific rehab options and alternative programmes. This tool starts from a data base containing information on pipelines, previous failures and rehab activities. With specified rehab activities in the medium (programme) term for types of pipelines, parts of the network or the entire network, their effects on network performance indicators, determined in WP1, are simulated on the long run and transformed into monetary terms (Euro), as far as possible.

Task 3:

A software platform **Rehab Strategy Evaluator** allowing the evaluation of rehab strategy output from the Rehab Strategy Manager and taking into account the background scenarios written by support of the scenario writer. Multiple criteria decision support is provided in order to find "the best and most robust" rehab strategy.

All software packages are stand-alone applications with capabilities of interacting as shown in Figure 1 on one hand and with the encompassing CARE-W prototype on the other.

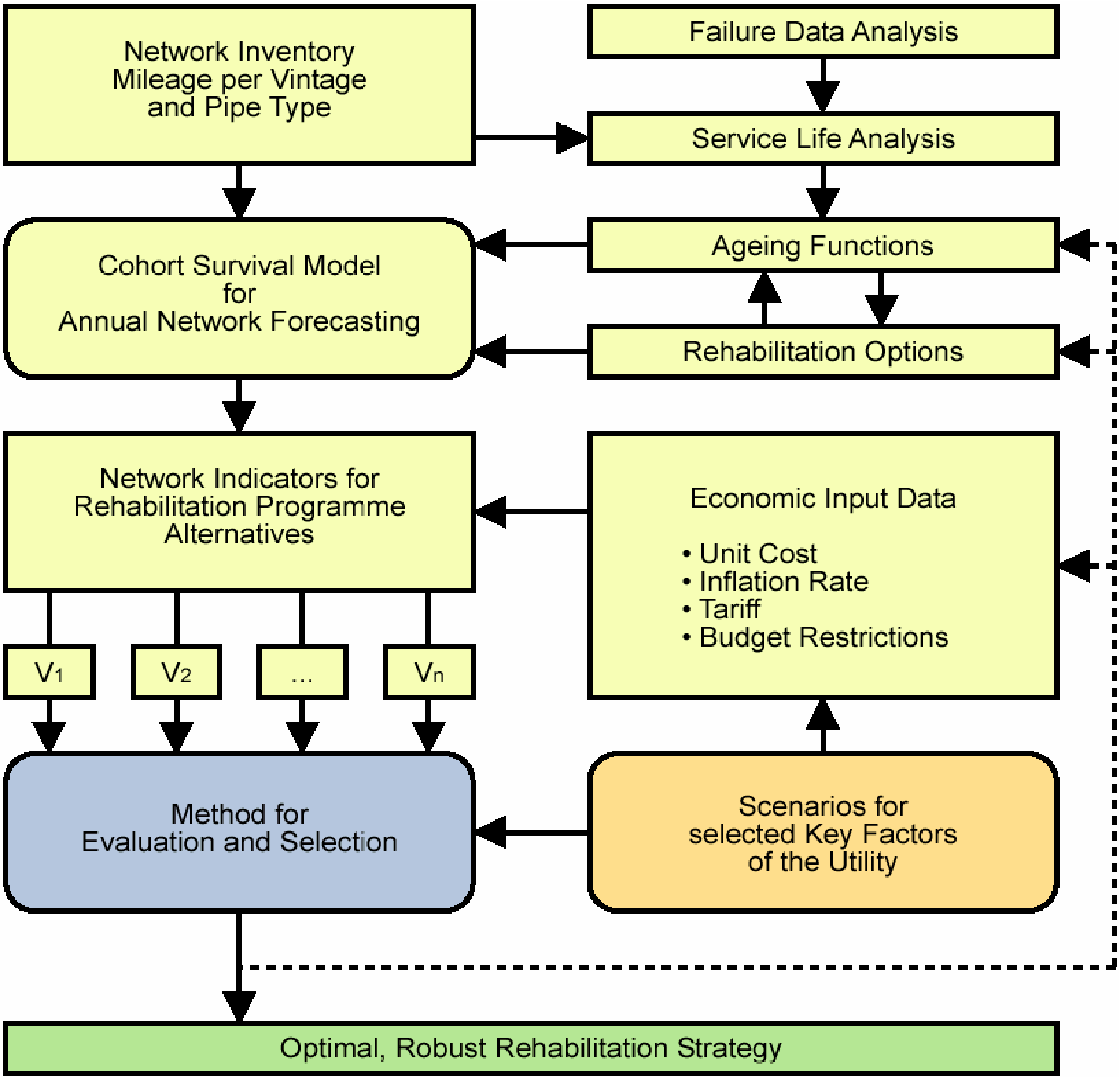

Figure 1: Extended *KANEW* Framework

This extended *KANEW* framework includes the "Scenario Writer" for utility background scenarios and the "Rehab Strategy Evaluator" for the evaluation of rehab strategies. The *KANEW* approach is recommended by the German Association of Gas and Water Works (DVGW) guidelines G401 / W401 as a method for long term forecast of rehabilitation needs of gas and water supply networks.

As long-term network rehab strategies cannot be developed in isolation from the wider context of the utility's economic background, there is a need for establishing several future scenarios describing potential changes for the water supply system in general, and the system assets in particular.

The scenario method, a "soft" forecasting technique, appears to be most appropriate for this problem. Scenarios are intended to open a "window of opportunities" rather than to forecast the most probable future development. They help to explore in a systematic and consistent way a whole range of complex future states, including paths of future developments which are rather unlikely to occur, but exclude those which definitely won't take place because they are utopian.

2 Methodology and Analysis

2.1 The Scenario Method

The scenario technique shall show realistic possibilities or developments in the more or less far future, especially under large uncertainties on future boundary conditions. The method is widely used on long term future analysis where quantitative methods fail and where there are too many uncertainties for simulations. The scenario method concentrates on determining and describing the interactions of factors of influence rather than producing a quantitative forecast with highest precision and probability of occurrence.

Scenario writing is a technique used for compiling enfolded images of the future from isolated perceptions of variances of development factors. There are two main aims of these images of the future. They should have some probability of occurrence and neither be impossible nor implausible. They should be internally consistent and transparent so they would be easy to communicate. Therefore, scenarios are neither prognoses based on quantitative information from the past and present extrapolated into the future nor are they escapist fantasies.

The method originally comes from futurology and is not geared for planning. It was developed in the fifties in the USA and used as a soft forecasting method for nonlinear processes and unpredictable incidents. Later on it turned into a decision support tool.

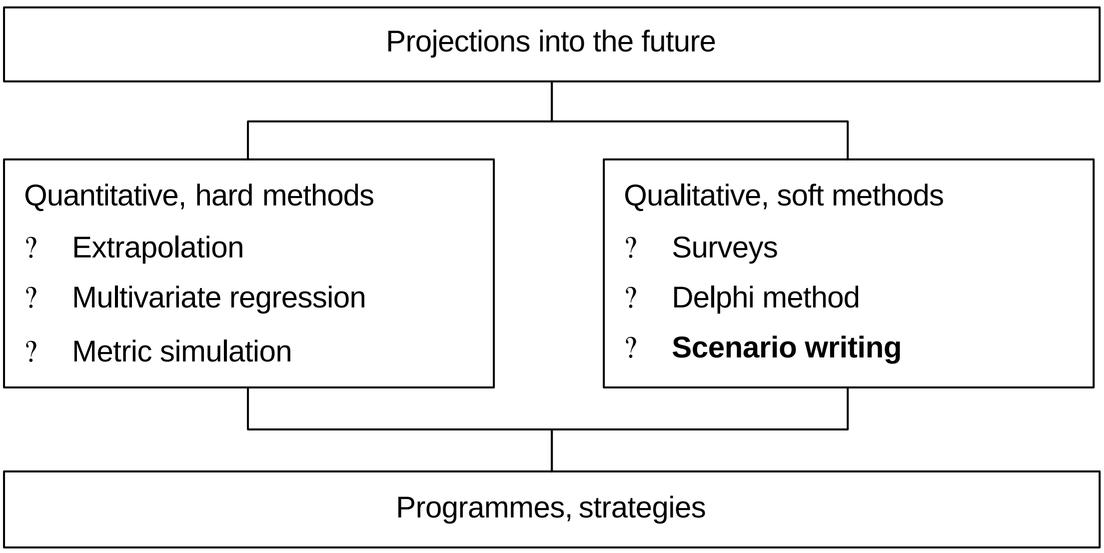

Figure 2: Scenario writing as method for future projections

The scenario technique links quantitative data with qualitative information, evaluations and views to develop detailed and holistic descriptions of possible futures. Normally there are three scenarios to be created:

? The best case scenario – the positive extreme scenario, describing the most beneficial future development

? The worst case scenario – the negative extreme scenario, describing the most evil future development

? The trend scenario – the most probable scenario, describing the future development following more closely the recent trends.

Scenarios start from the present situation. The two extreme developments that are projected define the shape of a funnel opening up into the far future and containing possible future states. These future states are characterized by a set of consistent values of variables that are closely interrelated. As time goes by, the funnel moves forwards.

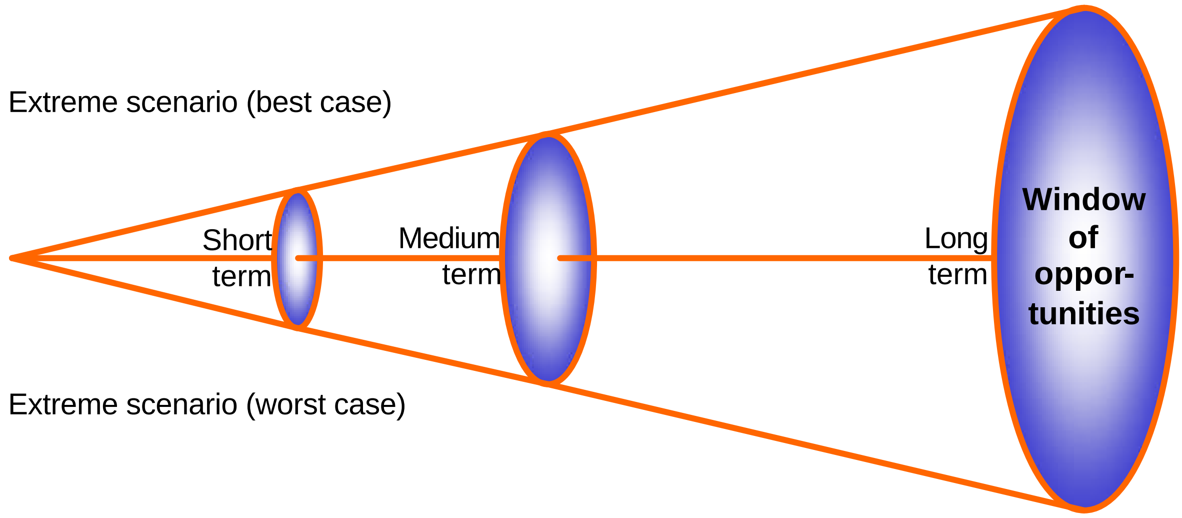

Figure 3: Scenario method – funnel into the future "window of opportunities"

The development of scenarios is ruled by a fixed scheme:

1. Problem/ system analysis

   Starting points of each scenario are different problems which have to be solved and where controversial solutions or views exist. The first step is to define and delimit the system in its factual, spatial and time dimension.

2. Impact analysis and key factor determination

   The next step is to identify all impact spheres which are related to the problem in any way. These impact spheres are scanned in detail in order to find impact factors affecting the problem. Furthermore, measurement rules for these factors have to be defined either in quantitative (m^3/km•day) or qualitative (good, bad) terms. From all the factors affecting the problem, the most important ones have to be identified. By limiting the number of these so called key factors to about a dozen factors, the subsequent analysis still is manageable.

3. Key factor impact analysis

   All key factors are analysed in pairs in order to determine dependencies, interactions and relations between them. Impact matrices are used for keeping this difficult process transparent and manageable. These impact matrices must be internally consistent.

   The impact matrix presented in Figure 4 is an example. It shows the direction and intensity of relations between 9 key factors. In this case, there are 36 relationships, including zero-relations (0), in general there are n(n-1)/2. The arrows are pointing from the affecting key factor to the affected one. In case of an interaction, the cell contains two opposite arrows. Bold arrows indicate strong impacts. By counting the number of arrows pointing to or from key factors, active and passive key factors can be identified. Another useful category is whether relationships are proportional or inverse. This would normally be presented in separate matrix.

	KF1	KF2	KF3	KF4	KF5	KF6	KF7	KF8	KF9
KF1									
KF2	✍								
KF3	✍	✍							
KF4	✍	✍	0						
KF5	✍	✍	✍	✍					
KF6	✍	✍	0	✍	✍				
KF7	0	✍ ✍	✍	✍	0	✍			
KF8	✍	✍	✍	0	✍	✍	0		
KF9	✍	0	0	✍	✍	0	✍ ✍	✍	

Figure 4: Example of impact matrix

4. Projections of key factors into the future

   The development of each single key factor, as defined by its measurement rule, has to be projected into the future for the best, worst and most probable case, on different time horizons (short term, medium term and long term). These projections of alternative future states have to be consistent and transparent. The consistency of these presumptions is validated by reference to the impact matrices.

5. Scenario development and interpretation

   This part – the so called scenario writing – is the summit of the scenario technique. The consistent future projections of the key factors are now used to compile holistic future images illustrating in a vivid and evident manner possible future developments and their consequences.

6. Conclusions, activity analysis and options of interaction

   This final phase is connecting the problem analysis of the first step with the scenarios in order to develop strategies and to analyse the scope of activities needed to support favourable scenarios and prevent unwanted ones to occur. The main objective is to define a strategy that is robust with respect to potential future developments and to set up a catalogue of measures to be taken in the short and medium term.

2.2 The „Scenario Method“ within CARE-W, WP4

2.2.1 Problem and system analysis

The object of CARE-W is the rehabilitation of drinking water distribution networks. However, the distribution system has to be seen in the wider context of future conditions under which the water utility will operate. They will largely determine the network rehabilitation policy because the utility also has to react to customer needs, sales and external developments like inflation and technological innovation. Some of these factors are clearly out of a utility's sphere of influence. But they do affect the financial situation of a company. Thus the exploration of such future utility background variables will be useful for evaluating network rehabilitation planning and strategies.

2.2.2 Impact analysis and key factor determination

In order to determine the key factors of impact on the future development of the utility and, indirectly, affecting the rehabilitation policy, an initial list of factors was sent to all project partners and end users. The factors were grouped into three impact spheres:

1. Water supply
2. Economy
3. Technology.

There was an intensive feedback on the first draft of key factors (see appendix 1). All of the key factors were commented and a lot of additional key factors were suggested. After discussing the pros and cons of inclusion, as shown below, a final list of 13 key factors was established and, later on, complemented by three additional key factors which are directly related to network rehabilitation issues and simulated more in detail in the "Rehab Strategy Manager" tool.

Scenarios are intended, as stated before, to open the "window of opportunities" rather than to forecast the most probable future development. They are an instrument for exploring in a rather systematic and consistent way a whole range of complex future states, including paths of future developments which may be quite a bit away from the expected ones, but certainly not including those which definitely won't take place because they are utopian. Thus the scenarios set the stage for a more detailed analysis and evaluation of rehabilitation strategies, which will be based on further long-term simulation, particularly for some key network performance indicators which have a more technical character and depend on specific rehabilitation programmes.

Key factors for the exploration of long-term strategies have to refer to the total system or a few distinctive subsystems. They cannot refer to very specific local situations. Furthermore, key factors must be presentable on the Scenario Writer screen along the time axis. If this is not possible, because the factor is too difficult either to quantify, to qualify or to forecast, it could not be included into the final list. Within a limited set of key factors that can be handled in a formal procedure to support the writing of scenarios, the most important and suitable factors had to be chosen.

Another group of suggested factors was very closely related to local conditions within the network, such as soil conditions or backfill quality. Although these factors certainly have an influence on the service life of pipes, they are not really predictable at the network level, or may not change over time.

After pre-selecting the suggested key factors along these lines, the remaining key factors were analysed for cross-references, practicability, redundancy and plausibility. It was checked whether or not the factors were related to other working packages of the CARE-W project. Practicability was considered with respect to the ability of the user to handle the requirements of a particular factor, and whether it appeared to be feasible to include such a factor into the scenario writing software. The difficulty of forecasting a factor by a water utility was another argument for rather not to include it into the scenario writing procedure. Another reason for eliminating a suggested key factor was redundancy with other key factors on the list. Finally all remaining factors were checked with respect to their interaction with other key factors.

To keep the scenario model manageable, only a limited number of key factors could be on the final list, preferably not more than a dozen. It was finally decided to chose thirteen key factors for describing potential long-term developments, seven for the water supply system (W1 – W7) and six for the economic context (E1 – E6). These key factors are listed in appendix 2 together with their definition and dimension of measurement, reference to WP1 performance indicators and context information, and words of justification as well as caveats.

From the former three impact spheres the technology-sphere was dropped, the main reason being difficulties to predict such very specific key factors. However, for the user of the Scenario Writer tool, there is the option to define up to four additional key factors on their own.

2.2.3 Key factor impact analysis

The main objective of this step is to identify the interrelationship between the key factors determined before. The method employed was qualitative impact matrices. Every key factor was compared with each other one, with respect to the intensity and direction of the relationship between the pair of factors. Verbal descriptions would have lead to an unstructured amount of data which would not be manageable within this context. Therefore, predefined symbols were assigned to each pair of key factors. The use of two different impact matrices did ease the process. The intensity and direction of the relationships were explored with matrix A, whereas matrix B identified the proportionality of factors.

The following example on matrix A and B shall illustrate the method.

Comparison of key factor W1 (population supplied) with key factor W6 (network extension):

> In matrix A, it is assumed that the population supplied (W1) has a strong influence on the network extension (W6), whereas there is no influence from W6 on W1. Key factor W6 remains passive here, while key factor W1 takes the active part.
>
> In matrix B, the development of W6 is supposed to be directly proportional to the development of W1. This means that if the population supplied rises, the network extension will also rise (but not necessarily at the same rate).

Another example is the key factor pair E1 (domestic water tariff) and E4 (inflation rate).

> Matrix A shows that the inflation rate (E4) is assumed to have a strong influence on the domestic tariff (E1), whereas the water tariff has no significant influence on the general inflation.
>
> In this pair, there seem to be very similar trends between E1 and E4. Domestic water tariff will grow almost at the same pace as the general inflation rate. Therefore, the symbol = is filled into the cell for this pair of key factors in matrix B.

(Note: these are just examples)

All cells of the two matrices A and B had to be filled with one of the pre-defined symbols. The impact analysis was done by all project partners and was discussed with end users as well. Although the results of the analysis were primarily represented by the two different impact matrices, most of the decisions made by the partners were commented in detail explaining the reason and background of each single decision.

Appendix 3 shows the very intense feedback on the two different impact matrices. The justifications of the various fillings were very different in some key factor pairs, in other cases there was unanimous agreement. This indicated the enormous bandwidth of viewpoints on the various relationships, interactions and impacts between the paired key factors. This huge amount of possible interactions and relations – 702 at matrix A and 312 at matrix B – inevitably lead to different predications.

The verbal justification of the numerous decisions did ease the preparation of the final impact matrices because the decisions were made transparent. Nevertheless, the discussions on some contradictory assignments of the paired key factors were very intense. All decisions made on the final versions are explained in detail – see Appendix 4.

Table 1: Impact matrix A – example fill for interactions between pairs of key factors

Key factors	(W6) Annual network extension	(E4) Inflation rate
(W1) Population supplied	✍	O
(W3) Residential per capita consumption	?	O
(E1) Domestic water tariff	?	✍

✍	Key factor to the left has a **strong influence on** key factor above
✍	Key factor to the left is **strongly influenced by** key factor above
✍	Both key factors **interact strongly** with each other
?	Key factor to the left has **some influence on** key factor above
?	Key factor to the left is **somewhat influenced by** key factor above
?	Both key factors **interact** with each other
O	There is **no interaction** between the two key factors
✍?	Key factor to the left has a **strong influence on** key factor above and is **somewhat influenced by** key factor above
? ✍	Key factor left has **some influence on** key factor above and is **strongly influenced by** key factor above

Table 2: Impact matrix B – example fill for proportionality of development

Key factors	(W6) Annual network extension	(E4) inflation rate
(W1) Population supplied	~	O
(W3) Residential per capita consumption	~	O
(E1) Domestic water tariff	~	=

=	Key factor to the left develops **parallel** to key factor above
~	Key factor to the left develops **similarly** to key factor above
?	Key factor to the left develops **reversely** to key factor above
O	Key factor to the left may develop **independently** from key factor above

From the information given in Matrix A, the key factors can be classified according to their degree of activeness and importance within this system of interactions. Some key factors are affecting others more often than being affected by others and vice versa, and some key factors show very strong effects, whereas others have relatively few and week effects. This Distinction is important as the scenario writer should concentrate on the most active and important key factors.

A simple counting rule was applied to identify different degrees of activeness and importance: Impacts were summed up with double weight given to strong impacts. For measurement of activeness, active impacts have a positive, whereas passive impacts have a negative sign.

The rating scale is shown at Table 3. These categories are used in the Scenario Writer program to eliminate, in an efficient way, inconsistencies of key factor projections within the different scenarios. Thus the iterative process of creating consistent scenarios is shortened.

Table 3: Classification scale of activeness and importance (for 13 key factors)

Activeness		Importance	
X > 4	very active	X > 11	very important
4 => X > 0	active	11 >= X > 6	important
0	balanced	6 >= X > 0	less important
0 > X >= -4	passive	X = number of counts in impact matrix	
X < -4	very passive		

Table 4: Activeness and importance of key factors

Key factor	Activeness		Importance		Active impacts	Passive impacts
W1 ***Population supplied***	very active	6	important	8	W2 / W5 / W6 / W7 / E1 / E3	E5
W2 ***Total per capita consumption***	passive	-2	very important	14	W4 / W5 / E1 / E2 / E3	W1 / W3 / E1 /E2 / E4 / E5 / E6
W3 ***Residential per capita consumption***	balanced	0	very important	12	W2 / W4 / W5 / E1 / E3	E1 / E4 / E5 / E6
W4 ***Percentage of revenue water***	passive	-3	important	9	E1 / E2 / E3	W3 / W6 / W7 / E3 / E5 / E6
W5 ***Yearly water production capacity***	passive	-4	important	10	E1 / E2 / E3	W1 / W2 / W3 / W6 / E5
W6 ***Annual network extension***	balanced	0	important	8	W4 / W5 / W7 / E3	W1 / E4 / E5
W7 ***Pipe length per capita***	balanced	0	important	8	W4 / E1 / E2 / E3	W1 / W6 / E5 / E6
E1 ***Domestic water tariff***	very passive	-6	very important	16	W2 / W3 / E2 / E3	W1 / W2 / W3 / W4 / W5 / W7 / E2 / E4 / E5 / E6
E2 ***Industrial water tariff***	passive	-4	important	10	W2 / E1 / E3	W2 / W4 / W5 / W7 / E1 / E4

Key factor	Activeness		Importance		Active impacts	Passive impacts
E3 ***Percentage of running costs***	**very passive**	-9	important	11	W4	W1 / W2 / W3 / W4 / W5 / W6 / W7 / E1 / E2 / E4
E4 ***Inflation rate***	**very active**	8	**very important**	12	W2 / W3 / W6 / E1 / E2 / E3 / E5	E5
E5 ***Average per capita income***	**very active**	9	**very important**	13	W1 / W2 / W3 / W4 / W5 / W6 / W7 / E1 / E4 / E6	E4
E6 ***Average number of persons per household***	**active**	4	**less important**	6	W2 / W3 / W4 / W7 / E1	E5

Impact matrices must be consistent in a logical and mathematical sense. Otherwise they cannot be used for improving the consistency of key factor projections within scenarios. Therefore, the impact matrix (A and B) had to be checked with respect to logical inconsistencies such as circular references (in Matrix A) and equality errors (in Matrix B).

Even though the finalisation of the impact matrices was processed with intense discussions, it proved not to be consistent. This will be understandable by looking at the huge number of combinations between the factors of an impact matrix that can be calculated from the following formula:

$$\sum_{k=3}^{n}\binom{n}{k}\left(\frac{k^2}{2}-\frac{k}{2}\right)=\sum_{k=3}^{n}\frac{n!}{k!(n-k)!}\left(\frac{k^2}{2}-\frac{k}{2}\right)$$

There are 159 666 combinations in a matrix of 13 key factors. If the number of key factors is increased, as foreseen in the Scenario Writer by adding 3 rehabilitation factors and up to 4 user-defined factors, the number of combinations is approaching 40 Millions.

Therefore, an algorithm detecting logical inconsistencies had to be programmed and implemented into the scenario writer tool. Some changes had to be made to the matrices documented in Appendix 4 as they had resulted from discussions among WP 4 members.

Several WP 4 partners suggested that key factors referring more directly to network rehabilitation should be added to the matrix. Although such network performance indicators will be subsequently simulated by the Rehab Strategy Manager tool in more detail as a function of the existing stock and of future rehab options, the Dresden team decided to complement the utility background factors be the following key rehab factors:

R1 failure rate (number of failures per km and year)

R2 rehabilitation rate (km of water mains rehabilitated per year in relation to the total length of water mains in km)

R3 leakage rate (m^3 of water losses (or non-revenue water) in relation to the total length of water mains in km)

The inclusion of these factors into the soft forecasting tool of the Scenario Writer allows to cross check the output from the cohort survival model with respect to plausibility, desirability and feasibility. Furthermore, it renders important factors to the Scenario Writer when used as a standalone tool. The definitions of the three added key factors and the finally implemented matrices checked by the software may be found at appendix 5.

2.2.4 Key factor projections, scenario development and conclusions

As the target of this part of WP 4 was the provision of software support for scenario writing, there were no scenarios developed apart from test scenarios during software development. All previous work was aimed to integrate expert revised target definitions, key factors and impact matrices into a software tool in order to release the user from the first three steps of scenario development. Thus user of this tool can concentrate on the last steps of the scenario development, key factor projections, analysis and scenario development, supported by the output of this software tool. The scenario writing itself still has to be done by hand and brain.

3 Software Development

3.1 Development system analysis

Before starting the software development, the development system had to be chosen. As there are various systems with different programming languages available, it was necessary to set up a list of general features of the future software to evaluate the development systems. The following reasons finally led to the decision in favour to *Borland Delphi*:

? Applications designed with *Borland Delphi* are compiled into executable files. Therefore, code execution is far faster than in systems using code interpreters.

? Applications designed with *Borland Delphi* are standalone and do not need additional software for execution. This prevents trouble in software usage and maintenance if the additional software is updated. This ensures the usability of the software regardless of software packages and software versions that are installed in parallel. Furthermore, the requirements for the user are kept on a modest level.

? The source code of *Borland Delphi* is, with minor changes, compatible to *Borland Kylix,* which is a development system for Linux. This eases cross platform development and permits the development of Linux versions of the software if there is a need for it.

? *Borland Delphi* includes the mighty relational client-server database system *Interbase* which can be run as a desktop system as well. *Interbase* is available as an open source and causes almost no costs in software acquisition.

? *Borland Delphi* is already the system chosen for the development of *KANEW* which will be enhanced within WP4 task 2.

3.2 Workflow model and graphical user interface (GUI)

The workflow model of the software has been developed according to the working steps of the scenario method. All steps documented in the structure chart were designed with separate forms to keep as close as possible to the steps of the scenario method. The graphical user interface itself was designed according to guidelines for windows based software using menus and button–bars as main navigation instruments. The intention was to keep the interface as familiar as possible to quasi-standard software like MS-Office. Additional elements like project navigation tree were added to ease the first steps of the software usage. As CARE-W is a multi-national research project, it was decided to develop multilingual software with capabilities of language customisation by the user themselves. This eases the usage of the software, especially for future end users who didn't participate in the project and are not familiar with the research work behind the software.

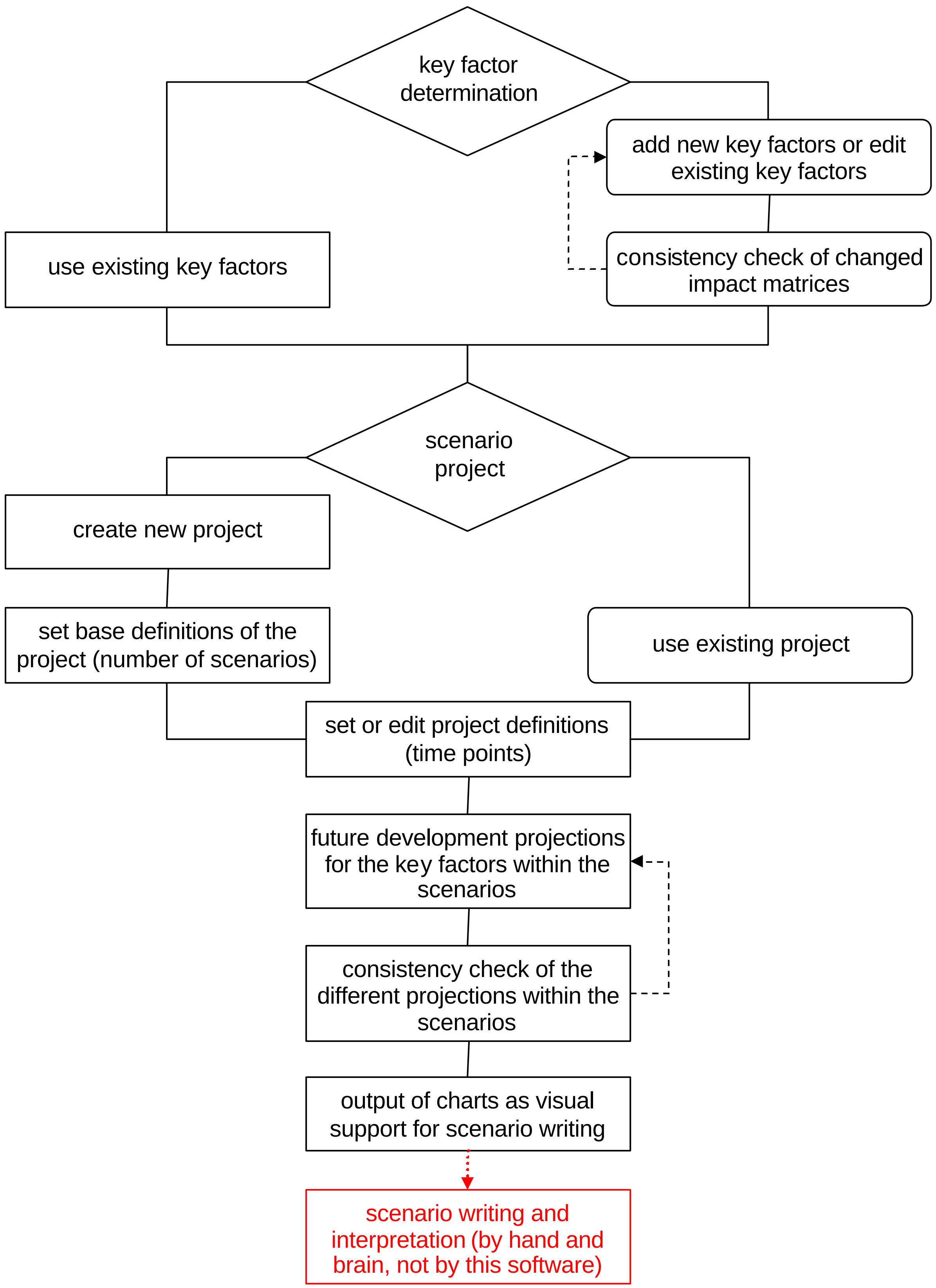

Figure 5: workflow structure chart

3.3 Improvement of the "Scenario Writer" software

The evaluation of first draw of the Scenario Writer software – the beta testing phase – brought up questions and hints concerning misunderstandings, improvements of Graphical User Interface GUI, errors and bugs of the Scenario Writer. The main issues were the GUI and the connection of the software to the CARE-W prototype. All other comments referred to various minor items and were mainly caused by misunderstandings of the method behind the software.

3.3.1 Interface with CARE-W prototype

The CARE-W prototype has to connect the various tools of CARE-W and to handle the numerous data outputs and data requests of these tools. Therefore, most of the tools are designed as standalone applications with no direct data connection. The advantage of this procedure is the independence of all software developers of CARE-W once the interfaces between the different software tools are defined.

The data exchange via plain text files was selected as technique of the choice. Each developing team had to define their data requests and data outputs in a structured plain text import/ export file. All further development towards the connections between tools relies on these set definitions. The Scenario Writer software exports complete projects as long as they are completed and can re-import this type of data. As the structure of the export file is defined, the CARE-W prototype can assemble new data exchange files for other tools if the required data provided from the Scenario Writer.

3.3.2 Redesign of graphical user interface (GUI)

The beta testing feedback made it obvious that keeping the GUI very close to the single steps of the scenario method is causing various problems of understanding because of the complexity of the GUI. The main target of the redesign of the GUI was, therefore, the simplification of the GUI. This was reached by integrating the different steps of the scenario process into two main forms, one responsible for key factor operation and another one for the scenario projects themselves. These project forms are capable of multiple instances, hence it is possible to open more then one project at the same time, which is useful if there is a need in comparing different projects. Automated error logging was added to ease reporting of bugs and hints to the author.

3.4 Improving future projections of scenarios by software consistency support

All of the steps described in chapter 2.2 are the basis for implementing the user guidance and software algorithms checking the consistency of key factor projections within the scenarios. Support is given for preventing input errors and inconsistent data and for guiding the user towards consistent scenarios.

3.4.1 Input data control

The first group – input control sanctions – identifies threshold input errors, data type errors, logical data errors and data redundancy errors.

Threshold errors occur if predefined threshold values are surpassed. These thresholds are defined together with the key factors and can be customised by the user. There are two types of thresholds, hard ones that must and soft ones that should be respected. Hard thresholds such as the smallest and the biggest possible value of a key factor can not be bypassed. Soft thresholds generate user information in case of being bypassed, but can be neglected by a user. Annual rates of change belong to this group of soft thresholds. They inform the user when the annual rate of change of a key factor is beyond a defined value. They can be customised by the user too. There are three threshold categories with increasing importance: an informing threshold, a warning threshold and an error threshold. Ignoring these thresholds has different consequences on the consistency of the scenarios.

Data type errors emerge if input data of a different type is assigned to specific input fields, e.g. text strings instead of numerical expressions. Leaving this unchanged would cause software exceptions under certain circumstances. Therefore, all input fields are checked whether the assigned values have the correct data type.

Logical data errors occur if the user puts wrong data into dependent input fields, e.g. the date of *today* is later than the date of *short term future*. Leaving this unchanged would cause software exceptions under certain circumstances. Therefore, all input fields are checked whether the input values are logically correct.

Data redundancy errors emerge if the user inserts data which can appear only once, e.g. scenarios with the same name within the same project, or different projects with the same name. Therefore, all input fields are checked whether the inserted values do already exist.

3.4.2 Consistency control

The second group – consistency proofing algorithms – identifies consistency errors within the key factors matrices and within scenarios.

As the key factor matrices are used to check the scenarios for consistency, they must be logically consistent in the first place. Otherwise the scenario proofing algorithm will fail. Since matrices describe the relations between the key factors, the algorithm checks whether the relations are logically correct, e.g. if the development tendency between KF1 and KF2 is defined to be similar (this means if KF1 increases, KF2 increases too) and the development tendency between KF1 and KF3 is similar, then the development tendency between KF2 and KF3 has to be similar as well because, otherwise, there would be a logical inconsistency. This kind of consistency proof has to be performed on all possible combinations. The predefined matrices of 16 key factors are consistent (see Appendix 5). For additional user-defined key factors, both matrices have to be checked again.

Inconsistencies have to be eliminated in an iterative procedure by changing values step by step, since changing one value will impact the whole network of key factors. There is no alternative to this process. At the beginning, consistency errors will be numerous, however, the change of one value, particularly of an important active key factor, will normally eliminate more than one inconsistency warning because all the key factors are linked within the matrices.

The proofing algorithm of the scenarios is neither that complex nor that time consuming as the matrix proofing algorithm. It compares the consistent impact matrices and checks whether the relations described in the matrices are equal to the relations described by the scenario data. Unless the relations are found to be identical, consistency errors emerge and will be listed, describing in detail the severity of and the reason for each error.

There are several possibilities of eliminating inconsistencies within scenarios. The most common way is to change the particular key factor value within the scenario, which is the recommended operation. Another option is to allow exceptions, which will exclude these values from the consistency check. This may be necessary if certain unusual boundary conditions justify such exclusion, e.g. the enormous caesura caused by the reunification of Germany, which may have caused an extraordinary development of some key factors and their impacts.

3.4.3 User guidance

The third group – user guidance – helps the user to eliminate consistency errors within the scenarios. Since all key factors are linked in many ways, changing one value within the scenario will always impact the whole scenario. Therefore, the user may want to know which key factor, when changed, is causing the most or the fewest impacts to others. Furthermore, the magnitude of the impacts may be useful to know. This information is provided by the activeness and importance of key factors as explained in detail in chapter 2.2.3.

4 Summary

The scenario writer software was developed as an intuitive support tool for the scenario writing. Yet the scenario writing has to be done manually, it just eases the creation of consistent scenarios by giving consistency proofed visual support to the user. Furthermore it integrates into the extended *KANEW* framework and expands the long term strategy abilities of this framework in a convincing way. The complex field of the scenario method is kept away from the user; only the details necessary are passed on to the user.

A description of the scenario writer software is available as handbook – together with the software. All working steps are explained in detail to ease the applications first usage. The handbook is included in the software package and will be available in the Acrobat-PDF-format.

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6 Appendices

6.1 Appendix 1 – Results of key factors questionnaire

Water supply factors

Service population Total population (permanent residents) served by the utility	Changes in service population dictate necessary changes in the service infrastructure
LNEC	We suggest adopting "Population supplied", expressed in "No. of persons", defined as "Resident population served by the water undertaking". This key factor was proposed as an "Utility Information" in the WP1.1 report and corresponds to the IWA PI variable F1. Note that significant changes in service population are not expected in Europe, where those figures are in general very stable.
SINTEF	High priority
BRNO	Important
BOLOGNA	An important comment is that usually only permanent residents are used to evaluate the service population; as a consequence, an increase in residential population implies an extension of the network. However the key factor evaluated in such a way does not take into account that inhabitants tend to move from the city center to the suburbs. This happened for instance in the historic part of Bologna, but also in several other cities within Regione Emilia-Romagna. While the number of residents dwindled, the total extension of the distribution network remained unchanged; therefore the ratio network length/inhabitants increased. The decrease of population living in historic areas of these cities is due to the combination of the following factors: Several apartments/residential units remain empty for most of the year; The inhabited area /number of inhabitants ratio tends to increase as older people remain in their original home as children leave to form their own family; Commercial and touristic activities increase in the city center.

Per capita consumption annual average consumption of households and industry divided by the service population [m³ / person · a]	Changes in per capita consumption dictate necessary changes in service operation in order to satisfy user demand
LNEC	We suggest adopting "Total per inhabitant consumption", expressed in "l per inhabitant/day", calculated as "(Daily average input - exported water)/ population served / 365". This key factor was proposed as an "Utility Information" in the WP1.1 report and corresponds to an IWA CI. Note that significant changes in per capita consumption are not expected in Europe, where those figures are in general very stable.
SINTEF	High priority
BRNO	Important
BOLOGNA	It is important to note that up to now changes in per capita consumption are taken to be with the plus sign, i.e. the per capita consumption is taken to increase with time. This, in turn, dictates changes in service operations. However, there is a growing tendency in Italy (and in other countries, we believe) towards policies meant to reduce per capita consumption; this tendency is also reflected in recent new legislation. Specific examples could be the following ones: i) in new buildings, reuse of rainwater for uses not needing high quality (potable) water (gardening, car washing, toilet flushing); ii) adoption of toilets with a double flushing system, allowing for discharge of a limited amount of water when heavy flushing is not needed. Success in adopting these policies will bring about a decrease in per capita consumption.

Percentage of domestic/ industrial consumption ratio between domestic and industrial consumption	Changes affect the amount of drinking water to be distributed, and the revenue gained through different tariffs
LNEC	We suggest adopting "Residential per inhabitant consumption", expressed in "l per inhabitant/day", calculated as "Residential consumption during the year / population served / 365". This key factor was proposed as an "Utility Information" in the WP1.1 report and corresponds to an IWA CI. Note that the difference to the "Total per inhabitant consumption" represents not only industrial but also commercial, public or institutional consumption and losses.
SINTEF	High priority
BRNO	Useful The tariffs for domestic and industry consumers are same in the Czech Republic since 2001.
BOLOGNA	The ratio between domestic and industrial consumption is important; however it does not take fully into account that, in turn, domestic water consumption is made up of two parts: usage by residents and usage by other "services" (schools, hospitals, and the like). As far as industrial consumption is concerned, it would be good to have a set of specific factors per unit of good produced (for instance water consumption/year/ton of steel produced), or, at least, for categories and number of employees (water consumption/year/employee, category: heavy industry).

Network extension Average annual extension length of the service network [km / a]	Network extension requires part of the investment budget and creates further long term rehab needs. Performance indicators are related to the updated length of the network
LNEC	We agree adopting “Network extension”, expressed in “km/year”, but calculated as “Average annual extension of transmission and distribution mains length over the last 5 years (service connections excluded)”. This key factor was proposed as “Utility Information” in the WP1.1 report and corresponds to the IWA PI variable C6.
SINTEF	OK
BRNO	Important
BOLOGNA	It is correct to update yearly the network extension so that the renewal percentage is derived. This should be done by material, and, possibly, distinguishing between different pipe laying techniques and required time. This key factor is connected with key factor #1, service population. In fact we propose to create a new factor: network extension per inhabitant. We found this to be on average 4 to 6 meters per inhabitant in urban water distribution network in Emilia-Romagna. In Codigoro where several small/medium communities are connected the ratio is much higher (about 15 meters per inhabitant. At a higher level of detail, a set of new factors could be devised for industrial consumption (see also #3), i.e. network extension per unit of good produced or per employee in each category.

Annual water production capacity	Ability to react to changes of the key factors mentioned above
LNEC	We suggest adopting "Yearly abstraction capacity", expressed in "m^3/year", calculated as "Maximum yearly allowance of water abstraction for water supply, based on the availability of water resources". This key factor was proposed as an "Utility Information" in the WP1.1 report and corresponds to the IWA PI variable A1.
SINTEF	High priority. Also important regarding leakage
BRNO	Useful
BOLOGNA	Definition of the production capacity must take the following into account: quantity of raw water used; quantity of water treated; quantity of water input into the network; quantity of water metered (and paid by users). All of these must be related to the previous key factors (#1-4). A serious problem in defining the different quantities in the water balance, at least in Italy, is the lack of any metering in public services such as schools and hospitals.

New key factors suggested as water supply factors

Resources availability ratio ***LNEC***	We suggest to add the "Resources availability ratio", expressed in "%", calculated as "[Authorised consumption (including exported water) + water losses] / total yearly abstraction capacity and imported water allowance x 100". A value of 100% for this indicator means that all available resources are being used. Although this indicator is sometimes difficult to assess, and is not easily auditable, its used is encouraged as a management tool, particularly in rapid growing areas or areas subject to scarcity problems. Each water undertaking should estimate the yearly abstraction capacity and imported water allowance according to its own guaranteed schemes, drought management and operation procedures. This key factor was proposed as a "Performance Indicator" in the WP1.1 report (WR2).
Inefficiency of use of water resources ***LNEC***	We suggest to add the "Inefficiency of use of water resources", expressed in "%", calculated as "Real losses / water abstracted and imported water x 100". This key factor was proposed as a "Performance Indicator" in the WP1.1 report (WR1).
Average mains age ***LNEC***	We suggest adding the "Average mains age", expressed in "years", calculated as "Average mains age for the global supply system based on the age of each mains and its length". This key factor was proposed as an "Utility Information" in the WP1.1 report.
Mains rehabilitation ***LNEC***	We suggest to add the "Mains rehabilitation", expressed in "%/year", calculated as "Length of transmission and distribution mains rehabilitated during the year / total mains length x 100". This key factor was proposed as a "Performance Indicator" in the WP1.1 report (Op15).
Mains failures ***LNEC***	We suggest to add the "Mains failures", expressed in "No./100 km/year", calculated as "Number of mains failures during the year, including failures of valves and fittings and excluding service connection insertion point failures / total mains length x 100". This key factor was proposed as a "Performance Indicator" in the WP1.1 report (Op26).

Water interruptions ***LNEC***	We suggest to add the "Water interruptions", expressed in "%", calculated as "? (Population subject to a water interruption x duration of the interruption in hours) / (population served x 24 x 365) x 100". This key factor was proposed as a "Performance Indicator" in the WP1.1 report (QS11). Since, for many water undertakings, the information required for this indicator is neither available nor feasible to be collected in a near future, QS12 is alternatively proposed (see WP1.1 report).
Service complaints ***LNEC***	We suggest adding the "Service complaints", expressed in "No. complaints/connection/year", calculated as "Number of complaints of quality of service during the year / number of service connections". This key factor was proposed as a "Performance Indicator" in the WP1.1 report (QS22).
Real Water Losses [m3/km.year] ***BRNO***	Important
Structure of pipe materials [%] ***BRNO***	The percentages of pipe materials in the network (steel, ductile iron, cast iron, PVC, PE, GRP, others)
Age of pipe materials [years] ***BRNO***	Average age of each pipe material in the network

Economic factors

Domestic / industrial tariff price per unit [€ / m³]	Indicates (combined with consumption) the cash flow of the water utility. One important impact on the limits of the investment budget available.
LNEC	We agree adopting this key factor with the name “Average water charges for direct consumption”, expressed in “€/m³”, expressed as “Annual water sales revenue from residential, commercial, industrial, public, institutional and other customers (exported water excluded; public water taxes excluded) / (total annual authorised - exported water)”. This key factor was proposed as a “Performance Indicator” in the WP1.1 report (Fi21).
SINTEF	Future price if new water sources has to be included
BRNO	important
BOLOGNA	At a fundamental level, one could ask the question: is it good to have different tariffs between domestic and industrial consumption ? Or is it better to favor industries willing to implement water-saving tools ? One could also imagine building dedicated networks for industrial activities, taking into account the level of water quality required by each activity.

Percentage of variable costs in water production	Indicates the potential for cost reduction within the process of water production and supply, indicator for marginal cost of leakage reduction
LNEC	We agree adopting this key factor with the name "Unit running costs", expressed in "€/m3", expressed as "Annual running costs / authorised consumption (including exported water)". This key factor was proposed as a "Performance Indicator" in the WP1.1 report (Fi2).
SINTEF	Even more important if close to water source capacity
BRNO	important
BOLOGNA	We deem this factor to be very important; leakage reduction needs to be cost-effective !

Inflation rate [% p.a.]	Affects rehab and running costs as well as fixed costs. Required for the calculation of the rehab date at optimal costs
LNEC	We agree adopting "Inflation rate", expressed in "%/year", expressed as "Official annual inflation rate at the end of the year in the country". This key factor was proposed as "Context Information" in the WP1.1 report.
SINTEF	OK
BRNO	important
BOLOGNA	This factor is also very important; beside it, and in a similar way, one could also imagine to break down the tariff in all components, and determine the annual rate of increase for each of these components. This would help in pinpointing the component(s) which had the highest rates of increase in the last year(s); these are likely candidates for intervention (if applicable). In summary if we could agree on the components of the tariff, we could propose several new separate indicators: rate of increase of cost of component x in year y.

New key factors suggested as economic factors

Annual investments for new and upgrading assets ***LNEC***	We suggest adding the "Annual investments for new and upgrading assets", expressed in "%", calculated as "Cost of investments for new assets (or upgrading of existing ones) / total cost of the investments x 100". The annual values of this ratio can be misleading. A multi-annual analysis must be adopted. This key factor was proposed as a "Performance Indicator" in the WP1.1 report (Fi19).
Annual investments for assets replacement ***LNEC***	We suggest adding the "Annual investments for assets replacement", expressed in "%", calculated as "Cost of investments for the replacement of existing assets / cost of the investments x 100". The annual values of this ratio can be misleading. A multi-annual analysis must be adopted. This key factor was proposed as a "Performance Indicator" in the WP1.1 report (Fi20).
Cost-of-repair and damage compensation ***SINTEF***	Indicates the real cost of network failure
Social costs ***SINTEF***	Indirect cost, like traffic disturbances, ,inconvenience due to flood damage, consequences for hospitals etc of water supply interruptions. The water taxes should not exceed 5% of family's income
Average Household Income [€ / month] ***BRNO***	Important
Subsidies ***CEMAGREF***	Affects capacity to invest and indirectly rehab %.
Provision for depreciation ***CEMAGREF***	Affects general equilibrium of the balance sheet
Maintenance expenses ***CEMAGREF***	Affects general equilibrium of the balanc e sheet (shared cost between investment and operating)
Loans payments (debt) ***CEMAGREF***	Affects the capacity to invest after defining a maximum accepted debt ratio.
Taxation ***CEMAGREF***	depending on countries and type of company or utility , could affect annual counting results

Annual accounting profit or loss ***CEMAGREF***	Ultimate criterion of scenario feasibility

Technological factors

Future pipe materials (metallic vs. plastic)	Affects construction, maintenance and rehab costs and raw material needs and associated costs
LNEC	It is not clear for us how this factor can be materialised in practice. We agree that the key factors must coincide as much as possible with the list of performance indicators PI, utility information (UI) and context information (CI) adopted in the WP1.1 by LNEC. That ensures consistency and enables the establishment of links between the different work packages of CARE-W. If necessary the WP1.1 list must be modified in accordance. However, it is not clear for us how technological factors can be materialised in practice (definition, units, and processing rule) and we have none in our WP1.1 report. What we call "technological resource" includes only computerized information systems (maintenance and customer complaints), mapping (updated mapping and digital mapping) and failure data availability (duration of failure records and nature of failure records). We would appreciate your comments on that.
SINTEF	The choice of new materials in general has very little influence on service life. It does not affect service life whether it is plastic or metallic materials. Cost of different materials might differ
BRNO	important It is not very clear for us. From our point of view the more detailed description including the units is necessary.
BOLOGNA	Differences in pipe materials adopted (and changes in policies adopted by various agencies) are very important. To take this into account, we propose to include as key indicator the % composition of the network by material; this allows to monitor changing tendencies. Also a technical information must be included: costs of rehab techniques must be classified by type and nature of materials adopted.

Future rehab technologies (e.g. No Dig, renovation)	Affects the cost efficiency and sustainability of pipeline rehabilitation (direct and indirect costs/ environmental impact)
LNEC	It is not clear for us how this factor can be materialised in practice. We agree that the key factors must coincide as much as possible with the list of performance indicators PI, utility information (UI) and context information (CI) adopted in the WP1.1 by LNEC. That ensures consistency and enables the establishment of links between the different work packages of CARE-W. If necessary the WP1.1 list must be modified in accordance. However, it is not clear for us how technological factors can be materialised in practice (definition, units, and processing rule) and we have none in our WP1.1 report. What we call "technological resource" includes only computerized information systems (maintenance and customer complaints), mapping (updated mapping and digital mapping) and failure data availability (duration of failure records and nature of failure records). We would appreciate your comments on that.
SINTEF	Structural and not-structural methods have different service life. Cost of different methods might differ
BRNO	important It is not very clear for us. From our point of view the more detailed description including the units is necessary.
BOLOGNA	Differences in pipe materials adopted (and changes in policies adopted by various agencies) are very important. To take this into account, we propose to include as key indicator the % composition of the network by material; this allows to monitor changing tendencies. Also a technical information must be included: costs of rehab techniques must be classified by type and nature of materials adopted.

New key factors suggested as technological factors

Existing materials (ref PI classification) ***SINTEF***	Large influence on future rehabilitation needs
External conditions (pressure, soil etc) Technology cost ***SINTEF***	Large influence on future rehabilitation needs The cost of various technologies should be included
Future repair technologies ***CEMAGREF***	*Affects the cost efficiency and sustainability of the repairs*

New key factors suggested by WRc

Context Indicators	
Pipe details	Material, diameter, joint type, protection, vintage
Pipe environment	Water type (aggressivity), soil type, backfill quality, depth, loading, topography, rainfall variation, temperature variation
Pipe stress factors	Internal pressure, surge pressures, ground movement (e.g. mining activity), highway loading
Pipe condition	Structural condition grade
Pipe installation factors	Workmanship, handling, storage, quality of (and compliance with) National Standards
Level of service and performance requirements	Serviceability parameters (e.g. leakage, burst rate, interruptions to supply, pressure, water quality (aesthetic, microbiological)
Performance Indicators	
Spare capacity vs. future demand	Scope for increasing capacity before investment is required
Levels of service and performance	Serviceability parameters (e.g. leakage, burst rate, interruptions to supply, pressure, water quality (aesthetic, microbiological)
Degree of automation	Differing degrees of automation (telemetry and computers) will have different ratios of opex to capex (and hence different investment requirements)
Level of complaints	Taste, odour, discoloration (data needs to be normalised for comparison)

6.2 Appendix 2 – Final list of key factors

Water supply key factors

W1 ***Population supplied***	This KF[1] is proposed as an "Utility Information" in the WP1.1 report.
[No. of persons] Number of the resident population[2] served by the utility = Service population	Changes in service population require changes in service infrastructure. The number of served persons is a basic information for performance indicators and economic analysis. Caveat: The population supplied must refer to a defined service area. Future population gains by an incorporation of additional service areas and networks must be handled separately.

W2 ***Total per capita consumption***	This KF was proposed as an "Utility Information" in the WP1.1 report
[l / person • day] Annual average revenue-water[3] / population supplied[4] / 365 days	Changes in per capita consumption require changes in service operation to satisfy the demand of the service population and industry. This KF must be considered in long-term planning of water supply systems for the provision of sufficient abstraction and storage capacities (see KF W5). Caveat: This KF includes domestic and industrial water consumption, however real and apparent losses are **NOT** included.

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[1] Key Factor

[2] Total population living on a permanent basis (registered) in the reference area

[3] Revenue-water = billed metered consumption + billed unmetered consumption + exported water (IWA PI project – variables A9, A12, A14, A25)

[4] Key Factor W1

W3 ***Residential per capita consumption***	This KF was proposed as an "Utility Information" in the WP1.1 report.
[l / person • day] Annual domestic[5] revenue-water / population supplied[4] / 365 days	Changes in per capita consumption require changes in service operation in order to satisfy domestic demand. Basic information for the projection of supply needs for domestic and non domestic customers (in combination with KF W1 and KF W2), in case of different water tariffs, required for revenue projection. <u>Caveat</u>: This KF does **NOT** include real and apparent losses

W4 ***Percentage of revenue water***	This KF is 100% minus the percentage of non-revenue water, variable Fi36 in the IWA Performance Indicators project. Thus it corresponds to the IWA Performance Indicator WR1 (Inefficiency of use of water resources), but does not focus on real losses only.
[%] Annual revenue-water / annual revenue- plus non-revenue-water[6]	The percentage of water sold to customers is used by utility managers as an efficiency indicator and target variable. <u>Caveat</u>: Non revenue water comprises not only real and apparent losses but also unbilled water.

W5 ***Yearly water production capacity***	This KF was proposed as an "Utility Information" in the WP1.1 report.
[m³ / year] Yearly abstraction capacity [7] + yearly import allowance	The yearly water production capacity, in relation to the yearly total consumption (KF W1 x KF W2 / W4), is an indicator for the risk of insufficient supply. <u>Caveat</u>: Water export obligations are not considered here.

5 Domestic = households only, without public/private services

6 Non-revenue-water = unbilled metered consumption + unbilled unmetered consumption + real losses + apparent losses (IWA PI project – variables A16, A17, A23, A24, A26)

7 Yearly abstraction capacity = maximum yearly allowance of water abstraction for water supply, based on the availability of water resources

W6 ***Annual network extension***	This KF was proposed as “Utility Information” in the WP1.1 report.
[km / year] average annual extension of transmission and distribution mains length (service connections excluded)	Network extension requires parts of the investment budget and will create rehab needs in the long run. Network performance indicators are related to the updated length of the network Caveat: Network extensions are new construction of pipes in a defined service area. Network extensions by incorporation of additional service areas and networks must be handled separately.

W7 ***Pipe length per capita***	This KF is available from water utility context information.
[m / person] Total length transmission and distribution mains / population supplied[4]	The spatial structure of the service area, its building and population densities strongly influence the efficiency of the water distribution system. This KF may change due to new building activities, locations and preferences. In combination with KF W1 this KF allows to forecast the total network length within the service area. Caveat: The development of this KF must be consistent with the assumption on KF W1 and W6 and the actual network length.

Economic key factors

E1 ***Domestic water tariff***	The water tariff was proposed as a "Performance Indicator" in the WP1.1 report (Fi21) without differentiation in domestic or industrial.
[€ / m³] Price per unit for domestic customers (households) Annual water sales revenue from residential customers / total annual domestic consumption	Allows to forecast, in combination with KF W1 and W3, the cash flow from domestic consumption, constituting the most important part of the water utility budget. <u>Caveat</u>: Future tariffs should account for inflation. Even if there is no special domestic water tariff, this part of the utility budget can be forecast more precisely with the average tariff. Effects of different domestic tariffs on the utilities cash balance could be explored in scenarios.

E2 ***Industrial water tariff***	The water tariff was proposed as a "Performance Indicator" in the WP1.1 report (Fi21) without differentiation in domestic or industrial.
[€ / m³] Price per unit for non-domestic customers (industrial, public, commercial customers) Annual water sales revenue from commercial, industrial, public, institutional and other customers (exported water excluded) / total annual non-domestic consumption (total - domestic - exported water)	Allows to forecast, in combination with KF W1, W2, W3 and W4, the cash flow from non-domestic consumption, the other part of the water utility budget. <u>Caveat</u>: Future tariffs should account for inflation. The basis for calculating the industrial water tariff is the residual non domestic water consumption. Even if there is no special water tariff for non domestic use, this part of the utility budget can be forecast more precisely with the average tariff. Effects of different tariffs on the utilities cash balance could be explored in scenarios.

E3 ***Percentage of running costs***	This KF is the ratio of the two variables (G2) and (G1) of the IWA PI-project, while (G2) is proposed in the WP1.1 report to be included as (Fi2).
[%] Annual running costs / annual costs[8]	Running costs (G2) plus capital costs (G3) sum up to annual costs (G1). This KF is an indicator for the potential of cost reduction by water saving measures and used for estimating the marginal cost of leakage reduction. <u>Caveat</u>: This KF depends to a large degree on the share of imported water.

[8] Total annual costs

E4 ***Inflation rate***	This KF was proposed as "Context Information" in the WP1.1 report.
[%] Annual rate of inflation Increase in living costs at the end of the year in relation to the previous year	Affects rehab and running costs as well as fixed costs. Required for the calculation of the rehab date at optimal costs all financial predictions need this KF to calculate real costs and make costs of different dates comparable Caveat: This is **NOT** the specific inflation rate of water tariffs or public works.

E5 ***Average per capita income***	New KF for the scenario writing tool
[€ / month] Average monthly income of the population supplied[4]	This KF was added because it allows to evaluate the acceptability of tariff changes for domestic use. In combination with KF E6, social impacts of new water tariffs can be further explored. Caveat: Future income should account for inflation.

E6 ***Average number of persons per household***	New KF for the scenario writing tool
[persons / households] population supplied[4] / number of households supplied	This KF was added because it allows, in combination with KF E5, to explore in more detail social impacts and acceptability of tariff changes for domestic use. Caveat: The definition of supplied household may differ from the household definition in official statistics.

6.3 Appendix 3 – Results of impact matrices questionnaire

W2-W1	A	B	Justification
LNEC	?	˜	The greater the population supplied, the greater the total per capita consumption tends to be
Amadora	?	˜	
WRc	0	0	
BUT	✍	?	We suppose that the industrial consumption is constant. If W1 in the equation W2=(annual domestic consumption + annual industrial consumption)/W1/365 increases then W2 will decrease
Cemagref	0	0	Socio-professional categories of the consum ers impact more heavily
SINTEF	?	0	consumption habit in cities is different (higher) than in rural areas, but consumption or population may change independently. Additionally, industry is situated mostly in cities
NTNU	0	0	
TUD	?	˜	increasing population leads to increasing consumption, because of the similar developing industry
DREWAG	?	˜	the increased population causes an rise of total per capita consumption for the industry will increase to
Ferrara	?	?	
AGAC	✍	˜	The residential pro capita consumpti on seems not growing linearly with the population. With the population it increases the number of offered services and users of them. The main factors are related with the class of center in terms of commercial, leisure, ecc. services offered by the tow n (we call it "armatura urbana") so better total pro capita consumption vs. level of town services similar to average per capita income rather than total pro capite consumption vs. population supplied
W3-W1	**A**	**B**	**Justification**
LNEC	?	˜	Same as above
Amadora	?	˜	
WRc	0	0	
BUT	0	0	There is no interaction between the key factors
Cemagref	0	0	
SINTEF	?	0	see above, but without the "industry argument"
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	?	?	
AGAC	?	˜	Greater size of the centre implies higher residential per capita consumption
W4-W1	**A**	**B**	**Justification**
LNEC	?	˜	The greater the population supplied, the greater tends to be the capacity of the undertaking to control revenues. But for higher revenues, there is a higher financial capacity to increase the coverage rate
Amadora	?	˜	
WRc	0	0	
BUT	?	˜	If the annual revenue-water in the equation W4=annual revenue-water/(annual revenue-water + non-revenue-water) increases then the W4 will increase similarly. We suppose that the annual revenue water increases with the population supplied, and the non-revenue water is approximately constant
Cemagref	0	0	No obvious relation at network level
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	?	˜	smaller stagnation, less costs for scavenging
Ferrara	0	0	
AGAC	0	0	
W5-W1	**A**	**B**	**Justification**
LNEC	? ✍	˜	The yearly capacity depends greatly on the demands (population supplied). But the constraints of production capacity can also limit the amount of population supplied
Amadora	✍	˜	
WRc	✍	=	For long term planning the size of population served will impact on the overall capacity of water production, as well as the overall headroom in the system
BUT	✍	˜	If the population supplied increases essentially then the water utility must increase yearly water production capacity
Cemagref	✍	=	Global consumption will vary linearly with population size
SINTEF	? ✍	=	the higher the population, the higher must get the prod. capacity. There is also the possibility that industry is drawn to

			places with a high prod. capacity. The capacity might not be increased with the same amount as the population
NTNU	✍	=	
TUD	✍	˜	the demand of the population leads to adequate production capacity
DREWAG	0	0	
Ferrara	? ✍	=	
AGAC	✍	=	Greater size of the town implies higher water production capacity and spare capacity
W6-W1	**A**	**B**	**Justification**
LNEC	? ✍	˜	Similar to above
Amadora	✍	˜	
WRc	?	˜	Increases in population can result in new development and therefore new networks /network extension to supply them
BUT	?	˜	If the population supplied increases then the annual network extension will increase similarly. For the new population supplied we must extend the length of distribution mains yearly
Cemagref	✍	=	Network extension will vary linearly with increasing population
SINTEF	✍	˜	the network must be extended or reconstructed with a higher population, but not necessarily in parallel
NTNU	✍	=	
TUD	?	˜	changes in demand because of changes of the population may result in network revaluation
DREWAG	?	˜	icreased population leads to increased demand and therefore an network extension
Ferrara	✍	˜	
AGAC	?	˜	Related with the development of the town as planned in PRG Piano regolatore general urbano
W7-W1	**A**	**B**	**Justification**
LNEC	? ✍	?	Higher population regions tend to have a lower pipe length per capita. Conversely, if the pipe lengh per capita is high, it becomes cheaper to extend the network and increase the coverage rate
Amadora	✍	˜	
WRc	?	?	Assuming the length of main remains the same, an increase in population density will result in a lower value of pipe length per capita
BUT	✍	?	If the population supplied increases then the pipe length per capita will decrease. If in the equation W7=total length of mains/W1 the W1 increases then the W7 will decrease
Cemagref	0	0	There could be a link from W1 to W7, but it depends on the density of population rather than on population size
SINTEF	?	?	Population density increases normally when the population grows, so the pipe length per capita decreases even if the total length increases
NTNU	✍	0	Caused by increased population density (i.e. coalescing)
TUD	?	?0	decreased population leads to increased pipe length per capita because the network length remains normally unchanged whereas the effect of increasing population is not clearly determinable
DREWAG	?	?	increased population leads to higher densities and therefore to lower pipe length per capita
Ferrara	?	?	A growth in population typically brings to high density of inhabitants, with a low value for W7
AGAC	?	˜	Related with the density of town
E1-W1	**A**	**B**	**Justification**
LNEC	?	?	There is a scale effect. The higher the population, the lower the tariff tends to be for similar levels of quality of service
Amadora	?	?	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	"Scale savings" are not directly related to population size
SINTEF	?	?	mass production reduces unit costs
NTNU	0	0	
TUD	?	0?	A larger population leads to decreasing costs because unit production costs tend to be smaller if the production increases
DREWAG	?	?	increased population leads to increased demand and increased production, but the cost of production do increase with a smaller rate and therefore the costs per unit will decrease
Ferrara	?	?	
AGAC	?	˜	The prevision of population growth and its consumption of the town can affect the tariff. In AGAC case there is a constant light population growth (demographic data since 1995) . Since 1993 the water tariff has not been changed
E2-W1	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	0	0	
WRc	0	0	
BUT	0	0	

Cemagref	0	0	Industrial water tariff are negotiated between the concerned companies and the water service manager
SINTEF	?	?	mass production reduces unit costs
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	?	?	
AGAC	0	0	
E3-W1	**A**	**B**	**Justification**
LNEC	? ✍	0	Similar to E1-W1
Amadora	✍	˜	
WRc	0	0	
BUT	0	0	
Cemagref	?	?	Population increasing could involve an increasing of inv estment
SINTEF	?	˜	An increasing population will increase the running costs, but to a lower degree. Mass production will reduce capital costs. Such the portion of running costs to total costs increases
NTNU	?	?	
TUD	?	˜	Increased population leads to inc reased running costs, but savings (less costs for scavenging) the rate will be lower
DREWAG	0	0	
Ferrara	0	0	
AGAC	?	=	Greater size of the centre implies higher running costs (planned maintanance for network and plants, plants redundancy, billing collection, administrative procedures)
E4-W1	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	0	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E5-W1	**A**	**B**	**Justification**
LNEC	?	˜	If the income is higher, people can afford paying for the investment costs and the coverage rate can grow
Amadora	✍	˜	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	Knowledge of socio-professional categories could accurate the interaction
SINTEF	?	˜	average income in cities is normally higher than in rural areas
NTNU	0	0	
TUD	?	0	economic/ poverty migration causes urbanization/ growth of population
DREWAG	?	0	increased income attracts and causes urbanization effects – may lead to a higher birth rate
Ferrara	0	0	
AGAC	0	0	
E6-W1	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	=	
WRc	0	0	
BUT	0	0	
Cemagref	?	˜	E6 make increase W1, if habitations of sufficient size are available
SINTEF	0	0	
NTNU	?	˜	
TUD	0	0	

DREWAG	0	0	
Ferrara	?	?	
AGAC	0	0	
W3-W2	**A**	**B**	**Justification**
LNEC	✍?	~	
Amadora	✍	=	
WRc	✍?	~	Total Per Capita Consumption (pcc) will include residential pcc
BUT	✍	~	The residential per capita consumption is a part of the total per capita consumption. If the residential per capita consumption increases then the total per capita cons umption will increase similarly and to the contrary
Cemagref	?	~	The relation depends on industrial part
SINTEF	?	0	Since W3 contains W2 they interrelate with each other, but since the industrial consumption can change in each direction they develop not necessarily similar
NTNU	?	~	
TUD	?	~	The residential per capita consumption is part of the total per capita consumption and therefore influences the total per capita consumption.
DREWAG	?	~	The residential per capita consumption is part of the total per capita consumption and therefore influences the total per capita consumption – but there is no influence the other way around.
Ferrara	✍	~	
AGAC	0	0	
W4-W2	**A**	**B**	**Justification**
LNEC	?	~	If for the same amount of water distributed the number of customers is lower, the undertaking can control them more easily; when higher consumption mean higher income, the non-renenue water is lower for higher consumption
Amadora	?	~	
WRc	?	~	If it is assumed that losses (leakage) remain constant then a change in the % revenue-water will be a result of a change in the amount of revenue-water. If pcc changes then the amount of revenue-water will also change (as consumption can be charged to the customer). However, it should be noted that an increase in demand (consumption) may require higher pressures which may increase losses and therefore the revenue-water ratio will not change
BUT	?	~	If the total per capita consumption increases then the amount of revenue water will increase, and the percentage of revenue water will increase too. We suppose that the amount of non-revenue water is approximately constant
Cemagref	?	~	Revenue water will increase with population without increasing the leaks
SINTEF	?	~	Under the assumption that the amount of non-revenue water remains constant, an increase of water consumption will increase the percentage of revenued water
NTNU	?	~	
TUD	?	~	an increased consumption does not lead to an increase of leakage, leakage may limit consumption in some cases
DREWAG	?	~	marginal influence, increased consumption on an unchanged network leads to smaller leakage/revenue ratio
Ferrara	?	~	If W2 increases, then also Revenue Water will increase, and W4 with it; "~" and not "=" because water losses usually grow when W2 increases
AGAC	0	0	
W5-W2	**A**	**B**	**Justification**
LNEC	? ✍	~	Similar to W5 – W1
Amadora	✍	~	
WRc	✍	=	
BUT	?	~	If the total per capita consumption increases then the water utility must increase the yearly water production capacity to satisfy the demand of water
Cemagref	✍	=	Consumption per capita is almost proportional to total consumption
SINTEF	?	~	the higher the consumption per capita, the higher must get the prod. capacity. The capacity is not necessarily increased with the same amount as the consumption
NTNU	✍	=	
TUD	? ✍	~	demand has a very important influence on the yearly production capacity
DREWAG	0	0	
Ferrara	✍	=	
AGAC	0	0	
W6-W2	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	0	~	
WRc	0	0	
BUT	0	0	

Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
W7-W2	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	0	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E1-W2	**A**	**B**	**Justification**
LNEC	?	?	For higher tariffs the percapita consumption tends to decrease. For Higher per capita consumption, there is a scale effect and the tariff can decrease
Amadora	?	?	
WRc	?	?	The water tariff will influence demand, particularly for billed-measured (metered) customers. The more expensive the tariff the less water will be consumed. This will only be true upto a certain point as there will always be a large proportion of the demand which will be essential use. Water is very price inelastic so any relationship between tariffs and consumption would be very weak
BUT	✍?	?	If the domestic water tariff increases then consumers reduce consumption of water - the total per capita consumption will decrease. If the total per capita consumption increases then the domestic water tariff should decrease, but water utility often keeps the same domestic water tariff
Cemagref	?	?	by elasticity of consumption according to the prices
SINTEF	?	?	An increase of domestic water price will cause saving actions by the residential customers and therewith a decrease of total per capita water consumption
NTNU	?	?	NB! Depending on water metering or not In Norway seldom water metering
TUD	?	?	A new tariff causes changes in customer consumption behavior (saving costs), changes in customer consumption behavior causes adaptations in tariff structure (cost covering)
DREWAG	?	?	increasing tariffs cause decreasing consumption and vice versa, increased consumption enables discounts
Ferrara	✍?	?	
AGAC	✍	?	The water tariff can reduce the residential per capite consumption if: the billing is strictly related with the consumption which is to say no forfait consumption on a general basis; the meter is closer to the customer which is to say no intermediation in the billing process but pretty direct to the single family unit The banded domestic water tariff is the following: - a fixed negligible (secolar!) cost of 5400 lire (less than 3 euros) mimum 50 m3 per customer (volume minimo impegnato) lower 84 m3 £ 960 from 85 to 132 m3 £ 1310 from 133 to 180 m3 £ 1925 upper 180 m3 £ 2370
E2-W2	**A**	**B**	**Justification**
LNEC	?	?	Similar to above
Amadora	0	0	
WRc	?	?	Same as E1 to W2
BUT	?	?	If the industrial water tariff increases then the total per capita consumption will decrease, because industry reduces consumption and so the amount of industry consumption in the W2 KF decreases
Cemagref	0	0	
SINTEF	?	?	An increase of industrial water price will cause saving actions by the industry and therewith a decrease of total per capita

			water consumption
NTNU	0	0	
TUD	?	?	A new tariff causes changes in customer consumption behavior (saving costs), changes in customer consumption behavior causes adaptations in tariff structure (cost covering)
DREWAG	?	?	increasing tariffs cause decreasing consumption and vice versa, increased consumption enables discounts
Ferrara	✍?	?	
AGAC	?	?	In Reggio the industrial water tariff is deduced from domestic water tariff . The structure is simplified and there is only one band of £ 1310 for a forfeit volume to supply. The exceedance will be charged more on a case by case basis. As for the domestic one the industrial tariff structure could be more focused for stabilized the consumption
E3-W2	**A**	**B**	**Justification**
LNEC	?	?	Similar to E3-W1
Amadora	✍	O	
WRc	?		If pcc increases then running costs (OPEX) will also increase. Capital investment and maintenance (CAPEX) will also increase to meet the new demand, but the rate of increase will depend on asset condition and headroom. CAPEX increase would be expected to follow a 'step' path, whereas OPEX would be more gradual. In the short term the rate of increase of CAPEX would be lower than the rate of increase of OPEX but, at times CAPEX will increase at a greater rate. In the long term, the variation of the ratio of OPEX to CAPEX (% running costs) will depend on company policy
BUT	0	0	
Cemagref	0	0	
SINTEF	?	~	An increasing consumption will increase the running costs, but to a lower degree. Mass production will reduce capital costs. Such the portion of running costs to total costs increases
NTNU	?	~	Increased cost for pumping, treatment etc
TUD	?	~	Increased consumption leads to increased running costs, but savings (less costs for scavenging) the rate will be lower
DREWAG	?	?	marginal influence, increased consumption within an unchanged network causes smaller stagnation, less costs for scavenging
Ferrara	0	0	Increased consumption leads to increased running costs, but savings (less costs for scavenging) the rate will be lower
AGAC	0	0	
E4-W2	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	?	
WRc	0	0	
BUT	0	0	
Cemagref	?	?	by elasticity of consumption according to the prices
SINTEF	0	0	
NTNU	0	?	NB! Depending on water metering or not In Norway seldom water metering
TUD	0	0	
DREWAG	?	?	increased inflation rate causes decrease of spending power and therefore decreases the consumption
Ferrara	?	?	A high value for the inflation rate will make the water tariffs grow up, and this will discourage water consumption
AGAC	0	0	
E5-W2	**A**	**B**	**Justification**
LNEC	?	~	Similar to E5-W1
Amadora	✍	~	
WRc	?	~	A larger income will mean bigger properties, more appliances and bigger gardens and hence a larger consumption. This will be a weak relationship as a large proportion of consumption will be essential use and therefore not related to affluence
BUT	?	~	If the average per capita income decreases then the total per capita consumption will decrease similarly, because some consumers reduce the consumption of water, they don't have money to pay the water bill
Cemagref	?	=	High income involves rather high level of consumption, including water
SINTEF	?	~	An increased income will probably raise the living standard and therewith the water consumption due to more water using facilities
NTNU	?	=	NB! Depending on water metering or not In Norway seldom water metering
TUD	?	~	The available income limits the possible spending and therefore the consumption
DREWAG	?	~	an increase of the available budget leads to higher consumption
Ferrara	?	~	
AGAC	✍	=	Higher average per capita income implies more private services (more comfortable houses with double or more bathrooms, dishwasher)
E6-W2	**A**	**B**	**Justification**
LNEC	?	?	Every house has a minimum water consumption for cleaning and plants watering. The remaining is proportional to the

			number of residents
Amadora	✍	~	
WRc	?	?	Household consumption will increase with a great number of people in the house as there will be more toilet and shower/bath use. However, some consumption will remain constant as, such as dishwashers, washing machines or garden watering. With more people in the house the household consumption will increase to some extent. The pcc will however reduce
BUT	?	?	If the average number of person per household increases then the total per capita consumption will decrease, because men living in a group have lower consumption of water, they can cook, wash and so on together
Cemagref	?	?	In case of scale savings of water inside the households
SINTEF	?	?	water consumption increases not parallel to an increasing number of persons in a household. Such the consumption per capita will slightly decease
NTNU	?	?	
TUD	?	?	smaller households use on average more water then bigger ones because the water using equipment (such as dishwashers and washing machines) is similar
DREWAG	?	?	smaller households tend to be less effective in water consumption
Ferrara	0	0	
AGAC	?	?	Higher number of persons per household implies less consumption per capita
W4-W3	**A**	**B**	**Justification**
LNEC	?	~	Similar to W4-W2
Amadora	?	~	
WRc	?	~	See W4 to W2
BUT	?	~	If the residential per capita consumption increases then the amount of revenue water will increase, and the percentage of revenue water will increase similarly. We suppose that the amount of non-revenue water is approximately constant
Cemagref	?	~	Revenue water will increase with population without increasing the leaks
SINTEF	?	~	Under the assumption that the amount of non-revenue water remains constant, an increase of water consumption will increase the percentage of revenue water
NTNU	?	~	
TUD	?	~	an increased consumption does not lead to an increase of leakage, leakage may limit consumption in some cases
DREWAG	?	~	marginal influence, increased consumption on an unchanged network leads to smaller leakage/revenue ratio
Ferrara	?	~	Same as W4-W2
AGAC	0	0	
W5-W3	**A**	**B**	**Justification**
LNEC	? ✍	~	Similar to W5-W2
Amadora	✍	~	
WRc	?	=	If pcc changes then the yearly total consumption will change. This will impact on the headroom available in the system and therefore the yearly production capacity
BUT	?	~	If the residential per capita consumption increases then the water utility must increase the yearly water production capacity to satisfy the demand of water
Cemagref	✍	=	Residential consumption is almost proportional to global consumption
SINTEF	?	~	the higher the consumption per capita, the higher must get the prod. capacity. The capacity is not necessarily increased with the same amount as the consumption
NTNU	✍	=	
TUD	? ✍	~	demand has a very important influence on the yearly production capacity
DREWAG	0	0	
Ferrara	✍	=	
AGAC	0	0	
W6-W3	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	0	~	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	

AGAC	0	0	
W7-W3	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	0	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E1-W3	**A**	**B**	**Justification**
LNEC	✍?	?	Similar toE1-W2, with a stronger influence E1 to W2
Amadora	✍	?	
WRc	?	?	Same as E1 to W2
BUT	✍?	?	If the domestic water tariff increases then consumers reduce consumption of water – the residential per capita consumption will decrease. If the residential per capita consumption increases then the domestic water tariff should decrease, but water utility often keeps the same domestic water tariff
Cemagref	?	?	by elasticity of consumption according to the prices
SINTEF	✍	?	An increase of domestic water price will cause saving actions by the residential customers and therewith a decrease of residential per capita water consumption
NTNU	0	0	
TUD	?	?	A new tariff causes changes in customer consumption behavior (saving costs), changes in customer consumption behavior causes adaptations in tariff structure (cost covering)
DREWAG	✍	?	increasing tariffs cause decreasing consumption and vice versa, increased consumption enables discounts
Ferrara	✍?	?	
AGAC	✍	?	As E1 and W2
E2-W3	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	0	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	?	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E3-W3	**A**	**B**	**Justification**
LNEC	?	?	Similar to E3-W1
Amadora	✍	O	
WRc	?		Same as E3 to W2
BUT	0	0	
Cemagref	0	0	
SINTEF	?	~	An increasing consumption will increase the running costs, but to a lower degree. Mass production will reduce capital costs. Such the portion of running costs to toatl costs increases
NTNU	0	0	
TUD	?	~	Increased consumption leads to increased running costs, but savings (less costs for scavenging) the rate will be lower
DREWAG	?	?	marginal influence, increased consumption within an unchanged network causes smaller stagnation, less costs for scavenging
Ferrara	0	0	
AGAC	0	0	

E4-W3	A	B	Justification
LNEC	0	0	
Amadora	✍	?	
WRc	0	0	
BUT	0	0	
Cemagref	?	?	by elasticity of consumption according to the prices
SINTEF	0	0	
NTNU	?	?	
TUD	0	0	
DREWAG	?	?	increased inflation rate causes decrease of spending power and therefore decreases the consumption
Ferrara	?	?	Same as E4-W2
AGAC	0	0	
E5-W3	**A**	**B**	**Justification**
LNEC	?	˜	Similar to E5-W1
Amadora	✍	˜	
WRc	?	˜	See E5 to W2
BUT	?	˜	If the average per capita income decreases then the residential per capita consumption will decrease similarly, because some consumers reduce the consumption of water, they don't have money to pay the water bill
Cemagref	✍	=	High income involves rather high level of consumption, including water
SINTEF	?	˜	An increased income will probably raise the living standard and therewith the water consumption due to more water using facilities
NTNU	?	=	
TUD	?	˜	The available income limits the possible spending and therefore the consumption
DREWAG	?	˜	an increase of the available budget leads to higher consumption
Ferrara	?	˜	
AGAC	✍	=	As E5 and W2
E6-W3	**A**	**B**	**Justification**
LNEC	✍	?	Similar to E6-W2 with a stronger influence of E6 to W3.
Amadora	✍	˜	
WRc	?	?	See E6 to W2
BUT	?	?	If the average number of person per household increases then the residential per capita consumption will decrease, because men living in a group have lower consumption of water, they can cook, wash and so on together
Cemagref	✍	?	In case of scale savings of water inside the households
SINTEF	?	?	water consumption increases not parallel to an increasing number of persons in a household. Such the consumtion per capita wil sligthly decease (more obvious than E6-W2)
NTNU	?	?	
TUD	?	?	smaller households use on average more water then bigger ones because the water using equipment (such as dishwashers and washing machines) is similar
DREWAG	?	?	smaller households tend to be less effective in water consumption
Ferrara	0	0	
AGAC	✍	=	Big blocks with one central meter implies a less controlled consumption of water. In similar cases the payment is accordingly to the size of each apartment
W5-W4	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	?	˜	
WRc	?	?	A change in the % revenue water would be caused by a change in either the amount of Revenue-water or the amount of Non-revenue-water (actually the leakage element). This would result in a change in the total water used (revenue-water plus non-revenue-water). This will impact on the headroom available in the system and therefore the yearly production capacity. This argument assumes that either the revenue-water changes and non-revenue-water remains the same, or visa versa
BUT	0	0	
Cemagref	?	?	In case of leaks reduction
SINTEF	0	0	
NTNU	?	?	
TUD	?	0	
DREWAG	0	0	

Ferrara	0	0	
AGAC	✍	=	Increase in water losses implies higher water production
W6-W4	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	˜	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	?	˜	The annual network extension rejuvenates the network and increases the percentage of revenue water because of decrease of related
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
W7-W4	**A**	**B**	**Justification**
LNEC	?	?	Revenue includes real losses. The higher the pipe length per capita, the higher the real losses tend to be
Amadora	✍	˜	
WRc	?	=	As the length of main per capita decreases (i.e. the population becomes more dense) the number of service connections will increase. This will increase the likelihood of leakage (losses). If it is assumed that the total water use (revenue-water plus non-revenue-water) remains constant then an increase in leakage will reduce the % of revenue-water. A reduction in m/person will equal a reduction in %revenue-water
BUT	?	?	The higher density of consumers the lower length of mains (leakage of water is lower) and so the higher amount of revenue water – higher percentage of revenue water
Cemagref	?	?	Longer per inhabitant the network is, higher the leaks risk is
SINTEF	0	0	
NTNU	?	?	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	?	?	Higher pipe length per capita increases the probability of failures
E1-W4	**A**	**B**	**Justification**
LNEC	?	?	Higher tariffs justify water losses control up to lower levels; if the water losses are lower, the running costs decrease and tariffs as well
Amadora	✍	˜	
WRc	?	?	Pcc is influenced by tariff (see E1 to W2) and % revenue-water is influenced by pcc (see W4 to W2). Again this will only be true if losses (leakage) remains constant
BUT	0	0	
Cemagref	0	0	
SINTEF	?	?	When percentage of revenue (billed) water increases can the water prize be reduced (either less losses which must be divided or the same losses can be divided over more customers)
NTNU	0	0	
TUD	?	?	As smaller the percentage of revenue water is as higher will be the tariff to reach cost coverage
DREWAG	?	?	marginal influence – less water losses may enable tariff adaptation
Ferrara	?	?	If W4 increases thanks to a reduction, for example, in water losses, then E1 will drop down
AGAC	?	?	The water tariff should cover among others the band of running costs and the volume of losses wights on the operating costs
E2-W4	**A**	**B**	**Justification**
LNEC	?	?	Similar to E1-W4
Amadora	✍	˜	
WRc	?	?	See E1 to W4
BUT	0	0	
Cemagref	0	0	
SINTEF	?	?	When percentage of revenue (billed) water increases can the water prize be reduced (either less losses which must be divided or the same losses can be divided over more customers)
NTNU	0	0	

TUD	?	?	As smaller the percentage of revenue water is as higher will be the tariff to reach cost coverage
DREWAG	?	?	marginal influence – less water losses may enable tariff adaptation
Ferrara	?	?	Same as above
AGAC	0	0	
E3-W4	**A**	**B**	**Justification**
LNEC	?	˜	Similar to E1-W4
Amadora	✍	˜	
WRc	?	?	A change in demand (revenue-water) would result in a change in running costs (OPEX). If leakage and CAPEX (capital costs) are assumed to remain constant then a change to revenue-water and OPEX will change the % revenue-water and % running costs respectively
BUT	0	0	
Cemagref	?	?	Higher running (and maintenance) costs are, lower the leaks are (hopefully) and conversely
SINTEF	?	0	Either the losses are reduced (higher percentage of revenue water), which results in reduced running costs (lower percentage of running costs), or the billed consumption increases (higher percentage of revenue water), which results in a lower unit cost for running costs (but higher percentage of running costs, see E3-W2/3). So the relation is not indepently, but depends on other factors!
NTNU	?	?	More efficient use of water, reduces leakage etc
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	✍	=	The running costs depends strongly on energy consumption and applied energy tariff (luckly mostly in Reggio the water doesn't need tough treatment and therefore it is extraced from the natural ground water storage and pumped directly without bottlenecks due to treatment)
E4-W4	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	?	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	?	?	a high inflation rate leads to illegal abstraction
Ferrara	0	0	
AGAC	0	0	
E5-W4	**A**	**B**	**Justification**
LNEC	?	0	Similar to E5-W1
Amadora	✍	=	
WRc	?	˜	Income will influence demand (pcc) (see E5 to W2) and pcc will influence % revenue-water (see W4 to W2).
BUT	0	0	
Cemagref	?	˜	through the medium of W2
SINTEF	?	˜	An increased income will probably raise the water consumption (E5-W2/3) and therewith the percentage of revenue water
NTNU	?	˜	
TUD	0	0	
DREWAG	?	?	a low income leads to illegal abstraction
Ferrara	0	0	
AGAC	0	0	
E6-W4	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	=	
WRc	?	?	See E6 to W2 and W4 to W2
BUT	0	0	
Cemagref	?	?	In case of scale savings of water inside the households
SINTEF	?	˜	See E6-W2/3 and above
NTNU	?	?	

TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
W6-W5	**A**	**B**	**Justification**
LNEC	?	˜	If our producion capacity is constrained, it makes no sense to extend the network lenght to supply more people. If the population supplied increases (network is extended) the production capacity will have to grow
Amadora	0	˜	
WRc	?	˜	An annual increase to the network would mean that the population supplied has increased (see W6 to W1). The total water used would therefore increase, which will influence the yearly water production capacity (see W5 to W1).
BUT	?	˜	If the annual network extension increases then we can estimate that the yearly water production capacity will increase similarly, because there is at least the higher amount of leakage of water
Cemagref	✍	=	Extension means increase in served population
SINTEF	✍	=	A network extension means an increased population must be supplied (W6-W1) and therewith the production capacity must be increased (W5-W1).
NTNU	✍	=	
TUD	?	˜	increase of network extension is normally caused by increased demand this increased demand leads to increased production capacity
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
W7-W5	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	?	˜	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E1-W5	**A**	**B**	**Justification**
LNEC	?	?	Investments to increase the capacity may affect the tariffs
Amadora	✍	?	
WRc	?	?	To increase the yearly production capacity capital investment would be required. The UK regulator's (OFWAT) principle is that expenditure to meet growth and new customer requirements should be self funding, therefore tariffs can not be used to generate funds for capital investment. However, investments to increase production capacity could generate savings in the unit cost of water as newer, more efficient systems are installed. A water company may then have a legitimate case to either reduce or freeze tariffs. This would be a very weak relationship as any changes to tariffs would be determined by the regulator
BUT	?	?	If the domestic water tariff increases then domestic consumers reduce consumption of water and there is need to decrease the yearly water production capacity
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	?	?	mass production enables salutary production
DREWAG	?	?	increased production leads to higher efficiency in production and may cause decreasing tariffs
Ferrara	?	?	
AGAC	?	?	A sligth growth of tariff can cope with the risk of insufficient supply
E2-W5	**A**	**B**	**Justification**
LNEC	?	?	Same as above
Amadora	✍	?	
WRc	?	?	Same as E1 to W5
BUT	?	?	If the industrial water tariff increases then industrial consumers reduce consumption of water and there is need to decrease the yearly water production capacity

Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	?	?	mass production enables salutary production
DREWAG	?	?	increased production leads to higher efficiency in production and may cause decreasing tariffs
Ferrara	?	?	
AGAC	?	?	As above
E3-W5	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	~	
WRc	?	~	Production capacity will only influence the % running costs at the time investment is required to increase the production capacity. Production capacity will remain the same until a point is reached whereby the demand is close to or in excess of the capacity of the system. At this point capital investment would be required to increase the production capacity. The relationship between OPEX and CAPEX at this point will change as investment is needed and efficiencies in operation are introduced
BUT	0	0	
Cemagref	0	0	
SINTEF	?	?	When production capacity is increased, then the capital costs will raise and therewith the percentage of running costs decrease
NTNU	0	0	
TUD	?	?	mass production enables salutary production
DREWAG	?	~	increased production leads to higher efficiency in production and leads to higher running costs
Ferrara	0	0	
AGAC	?	=	Greater water plant and needs of redundancy, fixed power supplies affects the running costs
E4-W5	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	?	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E5-W5	**A**	**B**	**Justification**
LNEC	?	0	Similar to E5-W1
Amadora	✍	0	
WRc	?	~	The average per capita income will influence the pcc (E% to W2) and the pcc will influence water production capacity (W5 to W2).
BUT	0	0	
Cemagref	?	~	through the medium of W2
SINTEF	?	~	An income increase may result in an increased water consumption (E5-W2/3). Therewith the production capacity must be increased (W5-W2/3).
NTNU	0	0	NB! Depending on water metering or not In Norway seldom water metering
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	?	~	Redundancy and higher service standard are related with the town level of services and average per capita income
E6-W5	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍?	~	
WRc	0	0	
BUT	0	0	
Cemagref	?	?	In case of scale savings of water inside the households

SINTEF	0	0	
NTNU	?	?	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
W7-W6	**A**	**B**	**Justification**
LNEC	?	~	To supply the same amount of population, the pipe lenght per capita affects the extension required
Amadora	?	~	
WRc	?	0	Extensions to the network for new developments may change the population density (m/person) depending on the type of development.
BUT	0	0	
Cemagref	0	0	No obvious link, depending on the type of new buildings (extensive or intensive)
SINTEF	?	0	A network extension will probably change the pipe length per capita, but this value can raise as well as shrink
NTNU	0	0	
TUD	?	~	if network extension increases then pipe length per capita will increase too, the even if population has increased, because network extension takes place in low density areas
DREWAG	0	0	
Ferrara	✍	~	
AGAC	?	~	Annual network extension modify (demographic trend of the town) the pipe length per capita
E1-W6	**A**	**B**	**Justification**
LNEC	?	0	Similar E1-W5. Conversely, if there is financial capacity from the water revenue, there is increase capacity to extend the network
Amadora	✍	~	
WRc	0	0	The UK regulator's (OFWAT) principle is that expenditure to meet growth and new customer requirements should be self funding, therefore tariffs can not be used to generate funds for capital investment, i.e. new mains
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	?	~	
AGAC	0	0	
E2-W6	**A**	**B**	**Justification**
LNEC	?	0	Similar to E1-W6
Amadora	?	O	
WRc	0	0	Same as E1 to W6
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	?	?	marginal effect, decreasing tariffs may cause industrial settlement
Ferrara	0	0	
AGAC	0	0	
E3-W6	**A**	**B**	**Justification**
LNEC	?	0	If the network is expanded and becomes longer, the running cost will increase as well
Amadora	?	~	
WRc	✍	?	The larger the network extension, the higher CAPEX will be. OPEX will also increase, but not to such a great extent
BUT	?	?	If the annual network extension increases then the amount of capital costs will increase and so the percentage of running costs will decrease
Cemagref	0	0	
SINTEF	✍	?	A network extension will increase the capital costs significantly. Thus the percentage of running costs will decrease
NTNU	0	0	

TUD	?	0	changes in network extension will impact the running costs because of increasing capital costs
DREWAG	?	˜	marginal impact, operational costs will increase because of the bigger network
Ferrara	✍	˜	If W6 increases , then Maintenance Costs will go up as well, and so will do E3
AGAC	?	˜	Annual network extension is part of the capital works and expenses. Part of the work is confounded by the customer who will benefit of the new extension
E4-W6	**A**	**B**	**Justification**
LNEC	?	?	The inflation rate affects the oportunity to invest
Amadora	?	?	
WRc	0	0	
BUT	?	?	If the inflation rate increases then the capital costs can depreciate and so the inflation rate can affect the annual network extension
Cemagref	?	?	At least in the first years after investments
SINTEF	?	?	A high inflation rate will not motivate to great investments because of high interest rates
NTNU	?	?	
TUD	?	0	an high inflation rate may be the cause for adverse capital market and therefore reduce network extension
DREWAG	?	?	increased inflation rate causes decreasing investments and therefore less network extension
Ferrara	0	0	
AGAC	0	0	
E5-W6	**A**	**B**	**Justification**
LNEC	?	0	Similar to E5-W1
Amadora	?	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	?	˜	impacts the tariffs and therefore possible revenues and network extension
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E6-W6	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	No obvious link. There could be an inverse link if a decrease in E6 is caused by an extensive growth of the served area
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E1-W7	**A**	**B**	**Justification**
LNEC	?	˜	Higher pipelenght percapita is associated with higher losses and operations/maintenance costs, affecting the tariff
Amadora	0	0	
WRc	0	0	
BUT	0	0	
Cemagref	?	˜	It is more expensive to serve a low population density area than a high density one
SINTEF	?	˜	A higher pipe length per capita means also increased investment and maintenance costs per capita. This can be transferred to the water tariff (not in all countries)
NTNU	?	˜	
TUD	?	˜	increased length per capita causes higher operational cost and this will impact the tariffs
DREWAG	0	0	
Ferrara	?	˜	If W7 increases, then Maintenance Costs (per capita) will go up as well, and so will do E1

AGAC	?	˜	It is under discussion the "volume minimo impegnato" part of the tariff. This should be considered not as a volume but as the water service availability. So the fixed cost will be increased and the "volume minimo impegnato" will be abolished. The fixed price will be an increase in the current one of 3X . There is no solid criteria to work out the fixed price for water service availability. IT WOULD BE WELCOME A SUGGESTION ! A POSSIBLE WAY (?) TO WORK OUT THE WATER SERVICE AVAILABILITY COULD BE TO FIND A SOLID RELATION WITH THE PIPE LENGTH PER CAPITA.
E2-W7	**A**	**B**	**Justification**
LNEC	?	˜	Same as above
Amadora	0	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	No obvious link
SINTEF	?	˜	A higher pipe length per capita means also increased investment and maintenance costs per capita. This might be also transferred to the industrial water tariff (not in all countries)
NTNU	0	0	
TUD	?	˜	increased length per capita causes higher operational cost and this will impact the tariffs
DREWAG	?	?	decreasing tariffs may lead to industrial settlement and therefore network extension – marginal impact
Ferrara	?	˜	Same as above
AGAC	0	0	
E3-W7	**A**	**B**	**Justification**
LNEC	✍	0	Higher pipelenght percapita is associated with higher losses and operations/maintenance costs
Amadora	0	?	
WRc	0	0	
BUT	0	0	
Cemagref	?	˜	Running costs are linearly related to pipeline length
SINTEF	?	?	A higher pipe length per capita means normally an extension of the water network. This will lead to an increased capital cost and therewith a decrease of the percentage of running costs (E3-W6)
NTNU	?	˜	
TUD	?	0	increased pipe length per capita impacts operational costs as well as capital costs
DREWAG	0	0	
Ferrara	?	˜	Same as above
AGAC	✍	˜	The growth of pipe stock increases the running costs (inspections, wash out, cartografic data,ecc.)
E4-W7	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	?	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E5-W7	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	?	˜	
WRc	0	0	
BUT	0	0	
Cemagref	?	˜	High income are more often encountered in low population density areas
SINTEF	0	0	
NTNU	0	0	
TUD	?	˜	raised incomes will lead to low density settlement and therefore a higher network extension
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	

E6-W7	A	B	Justification
LNEC	✍	?	
Amadora	✍	?	
WRc	?	?	If it is assum ed that the number of houses remains constant but the number of people per household increases then the length of main per person will decrease
BUT	?	?	If the average number of person per household increases then the density of consumers increases too and so the pipe length per capita will decrease
Cemagref	?	?	Pipeline length is inversely related to population density
SINTEF	?	?	An increased number of persons per household will decrease the pipe length per capita when there is no network extension
NTNU	?	?	
TUD	?	?	increased household sizes will lead to an decrease of network length per capita assuming that population size hasn't changed
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E2-E1	**A**	**B**	**Justification**
LNEC	?	~	
Amadora	0	~	
WRc	?	=	Within the UK tariffs are balanced. An increase in costs will lead to an increase in both the industrial and domestic tariffs. An alternative regulatory structure may allow increases in one tariff to balance decreases in the other
BUT	?	~	Water utility often increases both tariffs at the same time, but they can do it with a different rate. If the industrial water tariff increases then the domestic water tariff will increase too
Cemagref	0	~	These KF don't impact on each other but tend to vary similarly
SINTEF	?	~	Changes in water prize will reflect on both domestic and industrial water prize. Contracts between water consuming industry and water utilities will prevent from a parallel development
NTNU	0	~	
TUD	?	~	They are related to but do not directly impact each other, depending on the same factors
DREWAG	?	0	There is an relationship but the impact depends on utility policy
Ferrara	?	0	
AGAC	0	0	
E3-E1	**A**	**B**	**Justification**
LNEC	?	0	Higher cost imply higher tariffs
Amadora	✍	0	
WRc	?		An increase in tariff will influence consumption (see E1 to W2). As consumption changes the % of running costs will also change, as per note E3 to W2. We have left the direction of the relationships blank because the change of CAPEX and OPEX to meet consumption changes will depend on company policy. Note that any relationship between tariff and consumption will be weak
BUT	0	0	
Cemagref	0	0	It depends on the tariff composition
SINTEF	?	?	A raising water tariff will lead to water saving actions by the customers. Thus the consumption decreases and so will the percentage of running costs (E3-W2)
NTNU	0	0	
TUD	?	~	the cost impact the tariffs to reach cost coverage
DREWAG	0	0	
Ferrara	✍	~	
AGAC	✍	=	Running costs are part of tariff
E4-E1	**A**	**B**	**Justification**
LNEC	?	=	Higher inflation rates imply higher capital costs and therefore higher tariffs
Amadora	✍	=	
WRc	✍	~	If the water company funding is constant (i.e. no major investment or imposed price cuts) then the relation of inflation rate to tariff will be strong. Otherwise (as in the recent UK P_o price cuts) the relationship will be weak
BUT	✍	=	If the inflation rate increases then the domestic water tariff will increase parallel. If the inflation rate increases then the total costs increase too and water utility needs to increase the revenue from water bills
Cemagref	✍	=	Water tariffs tend to vary according to other prices
SINTEF	✍	=	The water prize is naturally bounded to the inflation rate. If no other actions are undertaken by the water utility the prize will develop in parallel
NTNU	✍	=	

TUD	?	~	Inflation impacts the tariffs (cost coverage)
DREWAG	?	~	Inflation causes tariff adaptation but the net-tariff remains nearly unchanged
Ferrara	✍	=	
AGAC	?	~	Inflation rate increases running costs (manpower, energy, “open” contract for maintenance which is signed every three year) and the tariff
E5-E1	**A**	**B**	**Justification**
LNEC	?	0	If the income is higher, people can afford paying for higher tariffs
Amadora	?	~	
WRc	0	0	
BUT	?	~	If the average per capita income increases then water utility trends to increase the domestic water tariff. This impact between these key factors is a similar to the previous impact E4 -> E1
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	?	~	The available income impacts tariffs
DREWAG	?	?	increased income – increased consumption – decreased tariffs
Ferrara	0	0	
AGAC	✍	=	Annual water cost for a average family income is considered. The tariff changes with higher consumption than the average
E6-E1	**A**	**B**	**Justification**
LNEC	?	?	Due to scale effect
Amadora	✍	?	
WRc	0	0	
BUT	0	0	
Cemagref	?	~	Scale savings in areas with high density of population
SINTEF	?	~	Depending on the water prizing system in some countries with no water metering the water prize is fixed regarding the number of persons in a household or/and the dwelling space
NTNU	?	~	
TUD	?	0	household size impacts the available income and therefore impacts tariffs
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E3-E2	**A**	**B**	**Justification**
LNEC	?	0	Higher cost imply higher tariffs
Amadora	✍	0	
WRc	?		Same as E3 to E1
BUT	0	0	
Cemagref	0	0	
SINTEF	?	?	A raising water tariff will lead to water saving actions by the customers. Thus the consumption decreases and so will the percentage of running costs (E3-W2)
NTNU	0	0	
TUD	?	~	the cost impact the tariffs to reach cost coverage
DREWAG	0	0	
Ferrara	✍	~	
AGAC	✍	=	Increasing supplying needs increases tariff
E4-E2	**A**	**B**	**Justification**
LNEC	?	=	Similar to E4-E1
Amadora	✍	=	
WRc	✍	~	Same as E4 to E1
BUT	✍	=	If the inflation rate increases then the industrial water tariff will increase parallel. If the inflation rate increases then the total costs increase too and water utility needs to increase the revenue from water bills
Cemagref	✍	=	Water tariffs tend to vary according to other prices
SINTEF	✍	~	The water prize is naturally bounded to the inflation rate. Due to contracts the water prize may not develop in parallel
NTNU	✍	=	
TUD	?	~	Inflation impacts the tariffs (cost coverage)

DREWAG	?	˜	Inflation causes tariff adaptation but the net-tariff remains nearly unchanged
Ferrara	✍	=	
AGAC	?	˜	Inflation rate should be consider in the tariff
E5-E2	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	?	˜	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E6-E2	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E4-E3	**A**	**B**	**Justification**
LNEC	?	0	Similar to E4-E1
Amadora	✍	=	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	?	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	?	˜	If E4 increases, then Maintenance Costs and Internal Manpower Costs will go up as well, and so will do E3
AGAC	✍	0	Manpower, energy and "open" contract for maintanance costs are affected by the inflation rate
E5-E3	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	?	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	?	˜	An increase of average income might increase the water consumption as stated in E5-W2/3. This again will increase the percentage of revenue water (W4-W2/3) and therewith the percentage of running costs (E3-W2/W3). However, in countries where is no water metering, such an increase in consumption can not directly be billed, but will be stated as an increase in water losses. But also that increases the percentage of running costs
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E6-E3	**A**	**B**	**Justification**

LNEC	0	0	
Amadora	✍	?	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	Population density affects similarly running and investment cost
SINTEF	0	0	Despite there is no interaction marked, there is some small relation between these two factors. It has been stated that the average number of persons per household will influence the water consumption and therewith also the percentage of running costs will be influenced. However, this relation is too weak and depends on too many parameters to put a mark on here
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E5-E4	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	?	
WRc	?	=	
BUT	✍	=	If the inflation rate increases then the average per capita income will increase parallel. The inflation rate always affects the average per capita income and the average per capita income always increases the inflation rate. It is known from economics
Cemagref	✍	?	In inflation context, salaries tend to increase with a delay with respect to prices
SINTEF	✍	=	Inflation rate and income are strongly interrelated to each other (basic economic law)
NTNU	✍	?	
TUD	?	0	
DREWAG	?	~	income increases with inflation but spending power decreases (time lag)
Ferrara	✍	~	
AGAC	0	0	
E6-E4	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	0	0	
WRc	0	0	
BUT	0	0	
Cemagref	0	0	
SINTEF	0	0	
NTNU	0	0	
TUD	0	0	
DREWAG	0	0	
Ferrara	0	0	
AGAC	0	0	
E6-E5	**A**	**B**	**Justification**
LNEC	0	0	
Amadora	✍	~	
WRc	?	?	In the past 20 years, in the UK per capita income has increased on average. During the same period there has been a decrease in the average occupancy rate. This is a weak relationship and only supported by statistical evidence, no great causal factors identified
BUT	0	0	
Cemagref	?	?	Rich households tend to restrict their prolificacy
SINTEF	0	0	Despite there is some statistical evidence for a relation between these two parameters, there are too many further factors influencing this relation, such it would be misleading if a relation is marked here
NTNU	?	?	
TUD	?	?	high income households tend to be singles or dinks (double income no kids)
DREWAG	?	~	marginal impact – higher income may cause higher prolificacy
Ferrara	0	0	
AGAC	?	?	Average lower income implies average higher number of people in the household

6.4 Appendix 4 – Final impact matrices

Con-clusion	*A*	B	*Justification*
W2-W1	?	˜	Increasing population leads to increasing consumption, because of the similar developing industry, but consumption/ population might change independently. Additional industry tends to prefer major urban areas for settlement, therefore the growth of the population might lead to additional industrial settlement and industrial consumption as part of the total consumption.
W3-W1	**0**	**0**	Although the consumption habit is different on major urban settlements, the changes caused by increased population is neglectable small, at least there is no significant and direct relation on short term changes in consumption habits caused by changes in population and vice versa.
W4-W1	**0**	**0**	Smaller stagnation, less costs for scavenging – the savings out of this are marginal and should not be taken into account, because there are many other factors who might put these minimal savings down to zero or even below.
W5-W1	✍	˜	The larger the population, the higher must be the production capacity in order to satisfy demand. However, the capacity might not increase by the same rate as population. Additionally the constraints of production capacity may limit the amount of population supplied.
W6-W1	✍	˜	The increase of the population will normally lead to development of new settlement areas within the urban area and is therefore followed by increased network extension to supply these areas – the extension rate tends to be larger then the population growth rate for the new developed areas are normally low density areas. Development very seldom takes place within the existing areas.
W7-W1	?	**0**	If residential density declines then the pipe length per capita increases (constant network length assumed). Increase of population might result in decrease of pipe length per capita, but the increase of population is mostly followed by new development and therefore an increasing pipe length per capita -rate, as the new areas are tend to be low density areas.
E1-W1	?	**?**	There is a scale effect. The higher the population, the lower the tariff tends to be for similar levels of quality of service, because mass production will cause cost benefits.
E2-W1	**0**	**0**	Industrial water tariffs are independent and not influenced by changes in population.
E3-W1	?	˜	An increasing population will increase the running costs, but to a lower degree. Mass production will reduce fixed costs per capita. Such the portion of running costs to total costs increases.
E4-W1	**0**	**0**	There is no interaction between these factors.
E5-W1	?	**0**	Economic/ poverty migration causes urbanization/ growth of population but the effects are not clearly determinable.
E6-W1	**0**	**0**	Might develop independently in different directions, therefore no prediction is made.

Con-clusion	*A*	B	***Justification***
W3-W2	✍	˜	The residential per capita consumption is part of the total per capita consumption and therefore influences the total per capita consumption – but there is no influence the other way around.
W4-W2	?	˜	An increased consumption does not lead to an increase of leakage, leakage might limit consumption in some cases but this influence is rather marginal. However, it should be noted that an increase in demand (consumption) might require higher pressures which might increase losses and therefore the revenue-water ratio will not change with the same ratio as the consumption.
W5-W2	✍	˜	If the total per capita consumption changes then the yearly total consumption will change too because consumption per capita is almost proportional to total consumption. This will impact on the headroom available in the system and therefore the yearly production capacity.
W6-W2	**0**	**0**	There is no interaction between these factors.
W7-W2	**0**	**0**	There is no interaction between these factors.
E1-W2	?	**?**	A new tariff causes changes in customer consumption behaviour. On fallen tariffs the consumption might increase (getting more out of the same budget), on raised tariffs the consumption might decrease (saving costs in order to keep to the budget). Changes in customer consumption behaviour causes adaptations in tariff structure (cost covering). Increased consumption enables discounts, decreased consumption might raise the tariffs.
E2-W2	?	**?**	A new tariff causes changes in customer consumption behaviour. On fallen tariffs the consumption might increase (getting more out of the same budget), on raised tariffs the consumption might decrease (saving costs in order to keep to the budget). Changes in customer consumption behaviour causes adaptations in tariff structure (cost covering). Increased consumption enables discounts, decreased consumption might raise the tariffs.
E3-W2	?	˜	An increased consumption will raise the running costs, but to alower degree. Mass production will reduce capital costs. Such the portion of running costs to total costs increases.
E4-W2	?	**?**	Increased inflation rate causes decrease of spending power and therefore decreases the consumption. A high value for the inflation rate will make the water tariffs go up, and this will discourage water consumption.
E5-W2	?	˜	A larger income will lead to bigger properties, more appliances and bigger gardens and hence a larger consumption. The available income limits the possible spending and therefore the consumption. This will be a weak relationship as a large proportion of consumption will be essential use and therefore not related to affluence.
E6-W2	?	**?**	Smaller households tend to be less effective in water consumption, household consumption will increase with a great number of people in the house as there will be more toilet and shower/bath use. However, some consumption will remain constant such as dishwashers, washing machines or garden watering. Therefore the per capita consumption will

Con-clusion	*A*	B	***Justification***
			however reduce.
W4-W3	?	˜	An increased consumption does not lead to an increase of leakage, leakage might limit consumption in some cases but this influence is rather marginal. However, it should be noted that an increase in demand (consumption) might require higher pressures which might increase losses and therefore the revenue-water ratio will not change with the same ratio as the consumption.
W5-W3	?	˜	If the residential per capita consumption changes then the residential as a part of yearly total consumption will change too because consumption per capita is almost proportional to total consumption. This will impact on the headroom available in the system and therefore the yearly production capacity.
W6-W3	**0**	**0**	There is no interaction between these factors.
W7-W3	**0**	**0**	There is no interaction between these factors.
E1-W3	✍?	**?**	A new tariff causes changes in customer consumption behaviour. On fallen tariffs the consumption might increase (getting more out of the same budget), on raised tariffs the consumption might decrease (saving costs in order to keep to the budget). Changes in customer consumption behaviour causes adaptations in tariff structure (cost covering). Increased consumption enables discounts, decreased consumption might raise the tariffs.
E2-W3	**0**	**0**	There is no interaction between these factors.
E3-W3	?	˜	An increased consumption will raise the running costs, but to a lower degree. Mass production will reduce capital costs. Such the portion of running costs to total costs increases.
E4-W3	?	**?**	Increased inflation rate causes decrease of spending power and therefore decreases the consumption. A high value for the inflation rate will make the water tariffs go up, and this will discourage water consumption.
E5-W3	✍	˜	A larger income will lead to bigger properties, more appliances and bigger gardens and hence a larger consumption. The available income limits the possible spending and therefore the consumption. This will be a weak relationship as a large proportion of consumption will be essential use and therefore not related to affluence.
E6-W3	?	**?**	Smaller households tend to be less effective in water consumption, household consumption will increase with a great number of people in the house as there will be more toilet and shower/bath use. However, some consumption will remain constant such as dishwashers, washing machines or garden watering. Therefore the per capita consumption will however reduce.
W5-W4	**0**	**0**	There is no direct impact. The increased water production caused by raised water losses is a neglectable effect within the European Community.
W6-W4	?	˜	The annual network extension rejuvenates the network and increases the percentage of revenue water because of decrease of losses and

Con-clusion	*A*	B	*Justification*
			related cost.
W7-W4	?	˜	As the length of main per capita decreases (i.e. the population becomes more dense) the number of service connections will increase. This will increase the likelihood of leakage (losses). If it is assumed that the total water use (revenue-water plus non-revenue-water) remains constant then an increase in leakage will reduce the % of revenue-water. A reduction in m/person will equal a reduction in %revenue-water
E1-W4	?	**?**	If percentage of revenue (billed) water increases the water price might be reduced (either less losses which must be shared or the same losses are shared by more customers), As smaller the percentage of revenue water is as higher will be the tariff to reach cost coverage
E2-W4	?	**?**	If percentage of revenue (billed) water increases the water price might be reduced (either less losses which must be shared or the same losses are shared by more customers), As smaller the percentage of revenue water is as higher will be the tariff to reach cost coverage
E3-W4	?	**0**	The running costs depends strongly on energy consumption and applied energy tariff. Either the losses are reduced (higher percentage of revenue water), which results in reduced running costs (lower percentage of running costs), or the billed consumption increases (higher percentage of revenue water), which results in a lower unit cost for running costs (but higher percentage of running costs, see E3-W2/3). So the relation depends on other factors too!
E4-W4	**0**	**0**	The effect if illegal abstraction is marginal and can be neglected.
E5-W4	?	˜	Income will influence demand (per capita consumption) (see E5 to W2) and per capita consumption will influence the percentage of revenue-water.
E6-W4	?	**?**	Household consumption will increase with a great number of people in the house as there will be more toilet and shower/bath use. However, some consumption will remain constant as, such as dishwashers, washing machines or garden watering. With more people in the house the household consumption will increase to some extent. The per capita consumption will however reduce.
W6-W5	?	˜	An annual increase to the network would mean that the population supplied has increased (see W6 to W1). The total water used would therefore increase, which will influence the yearly water production capacity (see W5 to W1). A network extension means an increased population must be supplied (W6-W1) and therewith the production capacity must be increased (W5-W1).
W7-W5	**0**	**0**	There is no influence between this factors.
E1-W5	?	**?**	To increase the yearly production capacity capital investment would be required. The expenditure to meet growth and new customer requirements should be self funding. Therefore tariffs should not be used to generate funds for capital investment. However, investments to increase production capacity could generate savings in the unit cost of water as newer, more efficient systems are installed. If increased production is carried out with no additional investment, it will lead to

Con-clusion	*A*	B	*Justification*
			higher efficiency in production and may cause decreasing tariffs.
E2-W5	?	**?**	To increase the yearly production capacity capital investment would be required. The expenditure to meet growth and new customer requirements should be self funding. Therefore tariffs should not be used to generate funds for capital investment. However, investments to increase production capacity could generate savings in the unit cost of water as newer, more efficient systems are installed. If increased production is carried out with no additional investment, it will lead to higher efficiency in production and may cause decreasing tariffs.
E3-W5	?	**?**	When production capacity is increased, then the capital costs might raise and therewith the percentage of running costs decrease. Increase can also happen by extended water import allowance and this will not raise the capital costs.
E4-W5	**0**	**0**	There is no influence between this factors.
E5-W5	?	**0**	This impact is rather marginal. The average per capita income will influence the per capita consumption (E5 to W2) and the per capita consumption will influence water production capacity (W5 to W2).
E6-W5	**0**	**0**	There is no influence between this factors.
W7-W6	?	**˜**	If network extension increases then pipe length per capita will increase in most cases too, even if population has increased, because network extension takes place in low density areas.
E1-W6	**0**	**0**	There is no influence between this factors.
E2-W6	**0**	**0**	There is no influence between this factors.
E3-W6	?	**?**	The larger the network extension, the higher capital expenditures will be. Operational expenditures will also increase, but not to such a great extent
E4-W6	?	**?**	An high inflation rate may be the cause for adverse capital market and therefore reduce network extension.
E5-W6	?	**˜**	Impacts the tariffs and therefore possible revenues and network extension, can never develop reverse because of the tight relation to residential development.
E6-W6	**0**	**0**	No obvious link. There could be an inverse link if a decrease in E6 is caused by an extensive growth of the served area.
E1-W7	?	**˜**	Increased length per capita causes higher operational cost and this will impact the tariffs.
E2-W7	?	**˜**	Increased length per capita causes higher operational cost and this will impact the tariffs.
E3-W7	?	**?**	A higher pipe length per capita means normally an extension of the water network. This will lead to an increased capital cost and therewith a decrease of the percentage of running costs (E3-W6).
E4-W7	**0**	**0**	There is no influence between this factors.
E5-W7	?	**˜**	Raised incomes will lead to low density settlement and therefore a

Con-clusion	*A*	B	***Justification***
			higher network extension. High income are more often encountered in low population density areas.
E6-W7	?	**?**	If it is assumed that the number of houses remains constant but the number of people per household increases then the length of main per person will decrease.
E2-E1	?	~	They are related to but do not directly impact each other, depending on the same factors. There is an relationship but the impact depends on utility policy.
E3-E1	?	**0**	It depends on the tariff composition and local conditions, An increase in tariff will influence consumption (see E1 to W2). As consumption changes the percentage of running costs will also change, as per note E3 to W2. The change of capital expenditures and operational to meet consumption changes will depend on company policy. Note that any relationship between tariff and consumption will be weak, A raising water tariff will lead to water saving actions by the customers. Thus the consumption decreases and so will the percentage of running costs.
E4-E1	✍	~	Inflation impacts the tariffs (cost coverage). Inflation causes tariff adaptation but the net-tariff remains nearly unchanged
E5-E1	?	~	If the average per capita income increases then water utility tends to increase the domestic water tariff. This impact between these key factors is a similar to the previous impact E4 -> E1
E6-E1	?	**0**	Depending on the water pricing system in some countries with no water metering the water price is fixed regarding the number of persons in a household or/and the dwelling space.
E3-E2	?	**0**	It depends on the tariff composition and local conditions, An increase in tariff will influence consumption (see E1 to W2). As consumption changes the percentage of running costs will also change, as per note E3 to W2. The change of capital expenditures and operational to meet consumption changes will depend on company policy. Note that any relationship between tariff and consumption will be weak, A raising water tariff will lead to water saving actions by the customers. Thus the consumption decreases and so will the percentage of running costs.
E4-E2	✍	~	Inflation impacts the tariffs (cost coverage). Inflation causes tariff adaptation but the net-tariff remains nearly unchanged
E5-E2	**0**	**0**	There is no interaction between these factors.
E6-E2	**0**	**0**	There is no interaction between these factors.
E4-E3	?	~	Impacts both-operational and capital costs, but capital costs benefit from “time lag” on the capital market so they may decrease.
E5-E3	**0**	**0**	There is no interaction between these factors.
E6-E3	**0**	**0**	There is no interaction between these factors.
E5-E4	✍	~	If the inflation rate increases then the average per capita income will increase parallel. The inflation rate always affects the average per capita income and the average per capita income always increases the inflation rate.

Con-clusion	*A*	B	*Justification*
E6-E4	**0**	**0**	There is no interaction between these factors.
E6-E5	?	**?**	In the past years, the per capita income has increased on average. During the same period there has been a decrease in the average occupancy rate. This is a weak relationship and only supported by statistical evidence, no great causal factors identified. Rich households tend to restrict their prolificacy.

Impact Matrix A interactions between paired key factors	W1 Population supplied	W2 Total per capita consumption	W3 Residential per capita consumption	W4 Percentage of revenue water	W5 Yearly water production capacity	W6 Annual network extension	W7 Pipe length per capita	E1 Domestic water tariff	E2 Industrial water tariff	E3 Percentage of running costs	E4 Inflation rate	E5 Average per capita income	E6 Average number of person per household
W1 Population supplied													
W2 Total per capita consumption	?												
W3 Residential per capita consumption	0	✍											
W4 Percentage of revenue water	0	?	?										
W5 Yearly water production capacity	✍	✍	?	0									
W6 Annual network extension	✍	0	0	?	?								
W7 Pipe length per capita	?	0	0	?	0	?							
E1 Domestic water tariff	?	?	✍?	?	?	0	?						
E2 Industrial water tariff	0	?	0	?	?	0	?	?					
E3 Percentage of running costs	?	?	?	?	?	?	?	?	?				
E4 Inflation rate	0	?	?	0	0	?	0	✍	✍	?			
E5 Average per capita income	?	?	✍	?	?	?	?	?	0	0	✍		
E6 Average number of person per household	0	?	?	?	0	0	?	?	0	0	0	?	

Symbol	Meaning
✍	Key factor to the left has a **strong influence on** key factor above
✍	Key factor to the left is **strongly influenced by** key factor above
✍	Both key factors **interact strongly** with each other
?	Key factor to the left has **some influence on** key factor above
?	Key factor to the left is **somewhat influenced by** key factor above
?	Both key factors **interact** with each other
0	There is **no interaction** between the two key factors
✍?	Key factor to the left has a **strong influence on** key factor above and is **somewhat influenced by** key factor above
? ✍	Key factor left has **some influence on** key factor above and is **strongly influenced by** key factor above

Impact Matrix B relations between tendencies of paired key factors	W1 Population supplied	W2 Total per capita consumption	W3 Residential per capita consumption	W4 Percentage of revenue water	W5 Yearly water production capacity	W6 Annual network extension	W7 Pipe length per capita	E1 Domestic water tariff	E2 Industrial water tariff	E3 Percentage of running costs	E4 Inflation rate	E5 Average per capita income	E6 Average number of person per household
W1 Population supplied													
W2 Total per capita consumption	~												
W3 Residential per capita consumption	0	~											
W4 Percentage of revenue water	0	~	~										
W5 Yearly water production capacity	~	~	~	0									
W6 Annual network extension	~	0	0	~	~								
W7 Pipe length per capita	0	0	0	~	0	~							
E1 Domestic water tariff	?	?	?	?	?	0	~						
E2 Industrial water tariff	0	?	0	?	?	0	~	~					
E3 Percentage of running costs	~	~	~	0	?	?	?	0	0				
E4 Inflation rate	0	?	?	0	0	?	0	~	~	~			
E5 Average per capita income	0	~	~	~	0	~	~	~	0	0	~		
E6 Average number of person per household	0	?	?	?	0	0	?	0	0	0	0	?	

=	Key factor to the left develops **parallel** to key factor above
~	Key factor to the left develops **similarly** to key factor above
?	Key factor to the left develops **reversely** to key factor above
O	Key factor to the left may develop **independently** from key factor above

6.5 Appendix 5 – Rehab key factors and software matrices

R1 **Failure rate**	This KF is related to IWA PI Op26 (see WP1.1 report).
[No. of failures / km • year] number of failures per km and year	Changes in failure rate indicate the need for rehabilitation Caveat: Failure rate does not include failures of service connection if the service connections are excluded in the *KANEW* – analysis .

R2 **Rehabilitation rate**	This KF is related to IWA PI Op15 (see WP1.1 report).
[%] km of water mains rehabilitated per year in relation to the total length of water mains in km	Changes in rehabilitation rate may influence network condition and rehab needs of the network.. Caveat: As network extension increases the total length of the network, the rehab rate may decrease without worsen the network conditions as extension does decreases network age.

R3 **Leakage rate**	This KF is related to IWA PI Op22-25 (see WP1.1 report).
[m³/km] m³ of water losses (or non-revenue water) in relation to the total length of water mains in km	Changes in Leakage rate indicate the efficiency of rehabilitation projects. Caveat: Water losses or non-revenue water can be chosen but once selected it must not changed.

Impact Matrix A interactions between paired key factors	W1 Population supplied	W2 Total per capita consumption	W3 Residential per capita consumption	W4 Percentage of revenue water	W5 Yearly water production capacity	W6 Annual network extension	W7 Pipe length per capita	E1 Domestic water tariff	E2 Industrial water tariff	E3 Percentage of running costs	E4 Inflation rate	E5 Average per capita income	E6 Average number of person per household	R1 Failure rate	R2 Rehabilitation rate	R3 Leakage rate
W1 Population supplied																
W2 Total per capita consumption	?															
W3 Residential per capita consumption	0	✍														
W4 Percentage of revenue water	0	?	?													
W5 Yearly water production capacity	✍	✍	?	0												
W6 Annual network extension	✍	0	0	?	?											
W7 Pipe length per capita	?	0	0	?	0	?										
E1 Domestic water tariff	?	?	✍?	?	?	0	?									
E2 Industrial water tariff	0	?	0	?	?	0	?	?								
E3 Percentage of running costs	?	0	?	?	?	?	?	?	?							
E4 Inflation rate	0	?	?	0	0	?	0	✍	✍	?						
E5 Average per capita income	?	?	✍	?	?	?	?	?	0	0	✍					
E6 Average number of person per household	0	?	?	?	0	0	?	?	0	0	0	?				
R1 Failure rate	0	0	0	?	?	?	0	?	?	?	0	0	0			
R2 Rehabilitation rate	0	0	0	✍	✍	?	0	?	?	?	?	0	0	?		
R3 Leakage rate	0	0	0	✍	✍	?	0	?	?	?	0	0	0	?	?	

✍	Key factor to the left has a **strong influence on** key factor above
✍	Key factor to the left is **strongly influenced by** key factor above
✍	Both key factors **interact strongly** with each other
?	Key factor to the left has **some influence on** key factor above
?	Key factor to the left is **somewhat influenced by** key factor above
?	Both key factors **interact** with each other
0	There is **no interaction** between the two key factors
✍?	Key factor to the left has a **strong influence on** key factor above and is **somewhat influenced by** key factor above
? ✍	Key factor left has **some influence on** key factor above and is **strongly influenced by** key factor above

Impact Matrix B relations between tendencies of paired key factors	W1 Population supplied	W2 Total per capita consumption	W3 Residential per capita consumption	W4 Percentage of revenue water	W5 Yearly water production capacity	W6 Annual network extension	W7 Pipe length per capita	E1 Domestic water tariff	E2 Industrial water tariff	E3 Percentage of running costs	E4 Inflation rate	E5 Average per capita income	E6 Average number of person per household	R1 Failure rate	R2 Rehabilitation rate	R3 Leakage rate
W1 Population supplied																
W2 Total per capita consumption	~															
W3 Residential per capita consumption	0	~														
W4 Percentage of revenue water	0	~	~													
W5 Yearly water production capacity	~	~	~	0												
W6 Annual network extension	~	0	0	~	~											
W7 Pipe length per capita	0	0	0	~	0	~										
E1 Domestic water tariff	?	?	?	?	?	0	~									
E2 Industrial water tariff	0	?	0	?	?	0	~	~								
E3 Percentage of running costs	~	~	~	0	?	?	?	0	0							
E4 Inflation rate	0	?	?	0	0	?	0	~	~	~						
E5 Average per capita income	0	~	~	~	0	~	~	~	0	0	~					
E6 Average number of person per household	0	?	?	?	0	0	?	0	0	0	0	?				
R1 Failure rate	0	0	0	?	0	0	0	0	0	0	0	0	0			
R2 Rehabilitation rate	0	0	0	~	0	0	0	0	0	0	0	0	0	?		
R3 Leakage rate	0	0	0	?	0	0	0	0	0	0	0	0	0	~	?	

=	Key factor to the left develops **parallel** to key factor above
~	Key factor to the left develops **similarly** to key factor above
?	Key factor to the left develops **reversely** to key factor above
0	Key factor to the left may develop **independently** from key factor above

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