WP54: TRUST DSS Memo

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1. Introduction

This document is written for the benefit of internal TRUST reviewers with the aim to help them install and assess the DSS software tool (Deliverable D54.2). A more comprehensive description of the DSS methodology, software tool and demonstration on a real-life example will be provided in the final report (Deliverable 54.3) which is due by the end of the project.

2. DSS Overview

A decision support system (DSS) tool for the strategic planning of an integrated urban water system (UWS) over a pre-defined long-term planning horizon is presented here. The DSS evaluates and ranks a number of user defined alternative intervention strategies (IS or simply alternatives) by evaluating their impact on a number of (user defined) UWS performance indicators (PI), all for a number of (user defined) scenarios.

The four principal steps in using the DSS are as follows:

- 1. Problem definition
- 2. Population of Decision matrices (or impact assessment)
- 3. Ranking of alternatives and viewing detailed results
- 4. Modification and re-evaluation of Intervention Strategies

The first step (problem definition) is used by the user to specify: (1) scenarios of analyses (e.g. different population growth, climate change and other scenarios defining external conditions in which UWS operates); (2) UWS performance metrics/indicators (PI) that will be used to assess UWS performance under different alternatives; (3) definition of intervention strategies (i.e. alternatives) from a predefined list of intervention options supported by the WaterMet² tool. User specific PIs and ISs are allowed too. Scenarios and PIs quantified by WaterMet² can be specified by the user from the two separate lists available in the DSS while the user defined PIs need to be quantified by the user using external tools feeding into the DSS or otherwise.

The second step in using the DSS involves: (a) running the WaterMet² simulation tool to populate the decision matrices with relevant values, i.e. to calculate, for each scenario analysed, the impact of each intervention strategy (i.e. alternative) on each UWS performance metric specified and (b) manually entering the relevant decision matrix values for each user defined IS and PI;

Third step requires the user to specify preferences (i.e. weights) for different criteria, i.e. UWS performance PIs and then ranks the intervention strategies by using a Multi Criteria Decision Analysis (MCDA) method. At this point the user can request to view detailed results coming out of WaterMet² simulations, all for different alternatives, PIs and scenarios.

The final, fourth step, allows the user to add new or modify existing settings (including ISs, PIs and/or scenarios) and re-calculate the ranks of alternative until the best solution is identified.

The DSS software tool is demonstrated below on northern European real-life case study outlined below. Next, the required steps for populating and running the aforementioned process in the DSS will be described.

3. Real life Case Study

The case study shown here is inspired by, although not completely representative of, the UWS of a northern European city (Fig. 1). This UWS is used here as a reference city for the case study combined with assumptions when necessary.



Fig. \ Layout of the main components in the UWS for existing conditions (Behzadian et al. 2014)

The UWS is likely to face the challenge of population growth in the future which imposes increased water demand on the UWS. Two rates of future population growth (i.e. low and high) can be envisaged for a 30 year planning period starting from 2010. The time series of annual factors for these two rates of population growth and associated water demands in the UWS over the planning horizon are given in Tables 1 and 2.

To address the above issues, three types of intervention options are proposed for this strategic planning as follows:

- (1) Addition of a new water resource along with two water treatment works (WTW);
- (2) Increased annual rehabilitation rate for pipes;

(3) Addition of rainwater harvesting (RWH) and grey water recycling (GWR) schemes;

Based on the above individual intervention options, the following seven UWS intervention strategies (alternatives) against the 30 year planning horizon (2011-2040) are proposed:

- (1) Business as usual (BAU);
- (2) Addition of a new water resource along with two WTWs starting from 2020;
- (3) 1% additional annual pipe rehabilitation starting from 2015;
- (4) Addition of RWH and GWR systems at a local level by 25% of households starting from 2015;
- (5) Addition of RWH and GWR systems at a local level by 25% and 50% of households, respectively, starting from 2015;
- (6) Addition of RWH and GWR systems at a local level by 50% of households starting from 2015;
- (7) Addition of RWH and GWR systems at a local level by 25% of households and 0.5% additional rehabilitation annually starting from 2015;

The first strategy assumes business as usual (BAU), i.e. effectively 'do nothing' in the UWS over the planning horizon 2011-2040. In fact, the BAU assumes there is no intervention options are added to the UWS over the planning horizon when the specific rate of population growth (high or low) is envisaged. Therefore, the performance of the other six intervention strategies (# 2-7) comprised of at least one intervention option are compared to each other plus the first strategy. Note that the intervention strategies numbered 3 to 7 start from 2015 while strategy 2 starts from 2020. Applying each of these intervention strategies is expected to have some specific impacts on the performance metrics of the UWS. These performance metrics specified for this analysis are described in the following.

Scenario variables	Annual population growth factor	Annual industrial water demand growth factor	Annual irrigation water demand growth factor				
Units	-	-	-				
Year 2011	1.0000	1.0000	1.0000				
Year 2012	1.0121	1.0121	1.0121				
Year 2013	1.0119	1.0119	1.0119				
Year 2014	1.0118	1.0118	1.0118				
Year 2015	1.0117	1.0117	1.0117				
Year 2016	1.0115	1.0115	1.0115				
Year 2017	1.0114	1.0114	1.0114				
Year 2018	1.0113	1.0113	1.0113				
Year 2019	1.0111	1.0111	1.0111				
Year 2020	1.0110	1.0110	1.0110				
Year 2021	1.0109	1.0109	1.0109				
Year 2022	1.0108	1.0108	1.0108				
Year 2023	1.0107	1.0107	1.0107				
Year 2024	1.0106	1.0106	1.0106				
Year 2025	1.0104	1.0104	1.0104				
Year 2026	1.0103	1.0103	1.0103				
Year 2027	1.0102	1.0102	1.0102				
Year 2028	1.0101	1.0101	1.0101				
Year 2029	1.0100	1.0100	1.0100				

Table 1. Time series of annual factors for low rate of population growth and associated two water demands in the UWS

Scenario variables	Annual population growth factor	Annual industrial water demand growth factor	Annual irrigation water demand growth factor
Year 2030	1.0099	1.0099	1.0099
Year 2031	1.0013	1.0013	1.0013
Year 2032	1.0013	1.0013	1.0013
Year 2033	1.0013	1.0013	1.0013
Year 2034	1.0013	1.0013	1.0013
Year 2035	1.0013	1.0013	1.0013
Year 2036	1.0013	1.0013	1.0013
Year 2037	1.0013	1.0013	1.0013
Year 2038	1.0013	1.0013	1.0013
Year 2039	1.0013	1.0013	1.0013
Year 2040	1.0013	1.0013	1.0013

Table 2. Time series of annual factors for high rate of population growth and associated two water

demands	in the	UWS
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Scenario variables	Annual population growth	Annual industrial water demand growth	Annual irrigation water demand growth
Units	-	-	-
Year 2011	1.0000	1.0000	1.0000
Year 2012	1.0240	1.0240	1.0240
Year 2013	1.0230	1.0230	1.0230
Year 2014	1.0230	1.0230	1.0230
Year 2015	1.0220	1.0220	1.0220
Year 2016	1.0220	1.0220	1.0220
Year 2017	1.0210	1.0210	1.0210
Year 2018	1.0210	1.0210	1.0210
Year 2019	1.0200	1.0200	1.0200
Year 2020	1.0200	1.0200	1.0200
Year 2021	1.0200	1.0200	1.0200
Year 2022	1.0190	1.0190	1.0190
Year 2023	1.0190	1.0190	1.0190
Year 2024	1.0180	1.0180	1.0180
Year 2025	1.0180	1.0180	1.0180
Year 2026	1.0180	1.0180	1.0180
Year 2027	1.0170	1.0170	1.0170
Year 2028	1.0170	1.0170	1.0170
Year 2029	1.0170	1.0170	1.0170
Year 2030	1.0170	1.0170	1.0170
Year 2031	1.0140	1.0140	1.0140
Year 2032	1.0140	1.0140	1.0140
Year 2033	1.0130	1.0130	1.0130
Year 2034	1.0130	1.0130	1.0130
Year 2035	1.0130	1.0130	1.0130
Year 2036	1.0130	1.0130	1.0130
Year 2037	1.0130	1.0130	1.0130
Year 2038	1.0130	1.0130	1.0130
Year 2039	1.0120	1.0120	1.0120
Year 2040	1.0120	1.0120	1.0120

According to the performance criteria of sustainability dimensions of water systems (Alegre *et al.*, 2012), six performance metrics are considered for this analysis. These metrics include five quantitative criteria (C_1 - C_5), and a single qualitative criterion. A brief description of these metrics is outlined below:

- (1) <u>Reliability of water supply (C1)</u>: the ratio of water delivered to customers to the total water demand.
- (2) <u>Total cost (C₂)</u>: annual average of the discounted initial capital investment of interventions plus discounted value of the fixed and variable costs in different UWS components to the first year with a specific discount rate.
- (3) <u>GHG emissions (C₃)</u>: annual average of the aggregated greenhouse gas emissions (GHG), as Global Warming Potential (GWP100) measured in units of carbon dioxide equivalents (CO₂eq) from all components of the UWS.
- (4) <u>Leakage (C₄):</u> Annual average of leakage volume is measured in all conveyance components of water supply assuming leakage is a fixed percentage of water supply in water supply conveyance components.
- (5) <u>CSO volume (C₅):</u> Annual average of spill volume of CSOs (combined sewer overflow) is measured when daily flow in sewer network exceeds the capacity of a CSO structure.
- (6) <u>Social acceptance (C₆)</u>: the extent to which an intervention strategy would be supported by society, especially water consumers; in order to fulfil the water demands with respect to a number of factors especially safety and health issues.

Comparison of the intervention strategies with respect to the above performance metrics can be conducted based on either equal metric weights or some specific weighting schemes based on priorities of different groups/parties. For the sake of this analysis, three weighting schemes, including equal weights, Water Company and Consumer perspectives, are considered for ranking the intervention strategies (Table 3).

	0					
	Reliability of Supply	Total Costs	GHG emissions	Leakage	CSO volume	Social acceptance
Equal weights	1	1	1	1	1	1
Public	4	1	3	1	3	5
Water	5	2	Э	Λ	1	Л
company	J	3	2	4	T	4

Table 3. Weights of the metrics from different perspectives

4. DSS Application

The developed DSS tool is used here to demonstrate the assessment of aforementioned intervention strategies with respect to the specified performance indicators for the challenges of a long-term planning for this UWS which is facing likely future population growth. Therefore, a step-by-step procedure for setting up and running the DSS for the analysis of the aforementioned real life problem is described in the following.

Before running the DSS, the input data need to be specified and populated through the buttons in the configuration menu or left-hand pane as shown in Fig. 2. Input data requires specifying the following four steps which will be described in the next section in more detail:

- (1) Specification of general data describing the problem analysed;
- (2) Specification of scenarios and associated data;
- (3) Specification of performance metrics and associated data.
- (4) Specification of intervention strategies (Alternatives) and associated data;

For three parts of these data (i.e. Scenario, Metrics and Alternatives), there are four buttons available in the top ribbon menu for the user to **Add**, **Edit**, **Clone** and **Delete** the associate data. These buttons are explained below in further details when describing each group of input data of the case study problem. Once the program is opened, the the existing built model in this demo is uploaded automatically.



Fig. 2 General layout of the DSS

4.1 General Data

Using the GUI of the DSS software, the following data, according the information in section 2, is defined for the general data of case study problem:

- Name/description: Long-term planning of the a northern European city water supply system
- Planning horizon start year: 2011
- Planning horizon time steps: 30 time steps, each 1 year-long (i.e. end of planning horizon in year 2040)

4.2 Specification of Scenarios

The following specifications of the two scenarios of the case study problem described in Tables 1 and 2 are added in the Scenario section of the DSS by clicking **Add** button as shown in Fig. 3:

Scenario types and related information supported by the DSS are shown in Table 1. Each scenario is defined in the DSS as follows:

- 1. Scenario#1
 - a. ID: Low Growth
 - b. Description: Low Population Growth
 - c. Type: Water Demand Growth
 - d. Variable(s): The three variables with annual time series values listed in Table 1 are specified in this scenario.
- 2. Scenario#2
 - a. ID: High Growth
 - b. Description: High Population Growth
 - c. Type: Water Demand Growth
 - d. Variable(s): The three variables with annual time series values listed in Table 2 are specified in this scenario

Note that as soon as a "Water Demand Growth" type is selected from dropdown box, the associated variables (here four variables) are automatically shown. If the user tends to include the scenario in ranking, the relevant checkbox in this form needs to be checked otherwise it can be left unchecked or check needs to be cleared in the checkbox. Once a scenario is build, it can be edited, cloned (a quick way to make a new one based on the data in one of the build scenario) and deleted by double clicking on the relevant scenario in the list of existing scenarios. Finally, the input data for both scenarios in the case study problem are populated in the relevant form (Fig. 4).

💽 Scenario			
Settings			
User ID:		✓ Include in	n ranking
Description:			
Type: Water Demand Growth	1		-
Variables Name	Туре	Value	Unit
Annual Indoor Growth in Local Area	Annual Values		%
Annual Industrial//Commercial	Annual Values		%
Annual Irrigation Growth	Annual Values		%
Annual Frost Tapping Growth	Annual Values		%

Fig. 3 A sample form in the DSS for adding a new scenario

O TRUST WP54 DSS						X
Configuration	Evaluation					?
Add Edit Clo	ne Delete	Add Edit	Clone Delete	Add Edit CI	Delete Load Demo Example	
Scenario		Μ	letric	Alternati	ve Debug	
General	Scenario No.	User ID	Description		Туре	
	S0.	Low Growth	Low Population Grow	rth	Water Demand Growth	
Scenarios (2)	S1.	High Growth	High Population Gro	wth	Water Demand Growth	
Metrics (6)						
Alternatives (7)						
Ranking						

Fig. 4 Populated input data for both scenarios of the case study problem in the DSS

4.3 Specification of Intervention Strategies

The third step is to define intervention strategies as a set of individual interventions, each applied at pre-specified point in time over the planning horizon. Therefore, the specifications of the seven intervention strategies described in section 2 are added in the **Alternative** section of the DSS based on the data in Table 4. In the DSS, a new intervention strategy can be added by clicking **Add** button in **Alternative** section of the **Configuration** ribbon menu (Fig. 1). For each intervention strategy, a new individual intervention option can be added by clicking **Add** button in the form of intervention strategy for which the individual intervention option is intended (Fig. 5). In the form of individual intervention option, associated variables is displayed once the user selects the type of interest. A

sample of populated individual intervention option (for Intervention Strategy 2) is shown in Fig. 6. As such, a sample of populated intervention strategy (for Intervention Strategy 7) is shown in Fig. 5.

Alternat	tive			
ettings				
Us	ser ID: RWH 25%,	GWR 25%, Additior		✓ Include in ranking
Descrip	ption: Addition o	f RWH and GWR systems at a local level by 25	% of households plus 0.5!	
nterventi	ions			
Add	Edit Clone	Delete		
Int. no.	User ID	Description	Intervention	Time
10	RWH	Apply additional rainwater harvesting	Adding RWH scheme in local area	
11	GWR	Apply additional grey water recycling	Adding GWR scheme in local area	
		A sector and distance from the ball to be	Increase in annual pineline	

Fig. 5 An intervention strategy populated for the case study problem in the DSS

Settings User ID: Ne Description: Im Type: Ac	w Resources plement new resource Iditional Water resources								
User ID: Ne Description: Im Type: Ac	w Resources plement new resource Iditional Water resources								
Description: Im Type: Ac	plement new resource Iditional Water resources								
Туре: Ас	Iditional Water resources								
		/WTWs	Type: Additional Water resources/WTWs 👻						
Variables									
	- Distribution 4	Malara	20.00 %						
Split Coefficient f	or Distribution 1	Value	38.00 %						
Split Coefficient f	or Distribution 2	Value	20.00 %						
Split Coefficient f	or Distribution 4	Value	0.00 %						
Split Coefficient f	or Distribution 5	Value	37.00 %						
Total Capital Cost	5	Value	52300000.00 €						

Fig. 6 An individual intervention option populated for the case study problem in the DSS

Finally, the list of intervention strategies is completed as shown in Fig. 7 for the seven intervention strategies of the case study problem in the DSS.

O TRUST WP54 D	SS											x
Configu	ration	Evaluation										?
Add Edit	Clone	e Delete	Add	Edit	Clone	Delete	Add	Edit	Clone	e elete	Load Demo Example	
S	Scenario Metric					Alte	ernative		Debug			
General		Alternative no.	User ID					Description				
Scenarios (4)	Scoppring (4) A0.			Business as Usual			Business as Usual: no interventions undertaken					
Scenarios (4)		A1.	Additional Re	Additional Resource		Addition of a New Water Resource plus two WTWs from 2020			020			
		A2.	Additional Re	habilitatio	ation 1% 1% Additional Rehabilitation Annually from 2015							
Metrics (6)		A3.	RWH 25%, GWR 25%			Addition of RWH and GWR systems at a local level by 25% of			of			
		A4.	RWH 25%, GW	/R 50%				Addition of RWH and GWR systems at a local level by 25%				
Alternatives (7)	A5.	RWH 50%, GW	/R 50%				Addition of RWH and GWR systems at a local level by 50% of			of	
		A6.	RWH 25%, GW	/R 25%, Ad	iditional Re	habilitation (.5%	Addition of RWH and GWR systems at a local level by 25% of			of	
Ranking												

Fig. 7 List of populated intervention strategies for the case study problem in the DSS

Intervention	Intervention	Individual	Individual	Individual
Strategy ID	description			
	(name)			
1	Business as usual	None	None	None
2	Addition of a	Description: New water		
	new water	resource/WTWs		
	resource along	Occurrence type: one-off		
	with two WTWs	First occurrence: 2020		
	starting from	Location: water		
	2020	resources/WTWs		
		Variables:		
		Name= Split percentage for		
		distribution mains		
		Component ID= 1		
		Magnitude= 38		
		ID =2		
		Name= Split percentage for		
		distribution mains		
		Units=%		
		Component ID= 2		
		Magnitude= 5		
		ID =3		
		Name= Split percentage for		
		distribution mains		

Table 4. Spe	cifications of the int	ervention strategies	specified in the nume	rical example

Intervention	Intervention	Individual	Individual	Individual
Strategy ID	strategy	Intervention 1	Intervention 2	Intervention 3
	description			
	(name)	Units=%		
		Component ID= 3		
		Magnitude= 20		
		ID =4		
		Name= Split percentage for		
		distribution mains		
		Component ID- 5		
		Magnitude= 37		
		Mugintude 37		
		ID =5		
		Name= Total Capital Costs		
		Units= Euros		
		Magnitude= 523×10°		
3	1% additional	Description: Increase in		
	rehabilitation	annual pipeline		
	annually starting	rehabilitation rate		
	from 2015	Occurrence type: recurring		
		First occurrence: 2015		
		Time period: 25 years		
		Location: Distribution mains		
		Variables:		
		ID –1		
		Name= Leakage Rate		
		Component ID=		
		subcatchment 1		
		Magnitude= 1 %		
1	addition of RW/H	Description: Adding RWH	Description: Adding GWR	
7	and GWR	scheme in local area	scheme in local area	
	systems at a local	Occurrence type: One-off	Occurrence type: One-off	
	level by 25% of	First occurrence: 2015	First occurrence: 2015	Intervention 3
	households	Location: local area	Location: local area	
	starting from 2015	Variables:	Variables:	
		ID =1	ID =1	
		Name= Storage capacity	Name= Storage capacity	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		Units= m ³	Units= m ³	
		Magnitude= 240,000	Magnitude= 19,500	
		ID =2	ID =2	
		Name= Capital cost	Ivame= Capital cost	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	

Intervention	Intervention	Individual	Individual	Individual
Strategy ID	strategy	Intervention 1	Intervention 2	Intervention 3
	description (name)			
	(name)	Units= Euros	Units= Euros	
		Magnitude= 127,200,000	Magnitude= 29,500,000	
		ID =3	ID =3	
		Name= O&M cost	Name= O&M cost	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		died I	died I Units-Euros/vear	
		Magnitude = 5,760,000	Magnitude = 750000	
		ID =4	ID =4	
		Name= Allocation of green	Name= Allocation of green	
		water from RWH tank for	water from GWR tank for	
		Toilet consumption	Toilet consumption	
		Component ID=	Component ID=	
		area 1	area 1	
		Units=-	Units=-	
		Magnitude =True	Magnitude =True	
		ID =5	ID =5	
		Name= Allocation of green	Name= Allocation of green	
		water from RWH tank for	water from GWR tank for	
		subcatchment 1 and local	Component ID=	
		area 1	subcatchment 1 and local	
		Magnitude =True	area 1	
			Units=-	
		ID =6	Magnitude =True	
		Name= Allocation of green		
		water from RWH tank for	ID =6	
		Component ID-	water from GWR tank for	
		subcatchment 1 and local	irrigation consumption	
		area 1	Component ID=	
		Units=-	subcatchment 1 and local	
		Magnitude =True	area 1	
			Units=-	
-			Magnitude =True	
5	addition of RWH	Description: Adding RWH	Description: Adding GWR	
	systems at a local		Occurrence type: One-off	
	level by 25% and	First occurrence: 2015	First occurrence: 2015	
	50% of	Location: local area	Location: local area	
	households,	Variables:	Variables:	
	respectively,			
	starting from	ID =1	ID =1	
	2015	Name= Storage capacity	Name= Storage capacity	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		Units= m ³	Units= m ³	

Intervention	Intervention	Individual	Individual	Individual
Strategy ID	strategy	Intervention 1	Intervention 2	Intervention 3
	description			
	(name)			
		Magnitude= 240,000	Magnitude= 39,000	
		ID =2	ID =2	
		Name= Capital cost	Name= Capital cost	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	
		Units= Euros	Units= Euros	
		Magnitude= 127,200,000	Magnitude= 59,000,000	
		ID =3	ID =3	
		Name= O&M cost	Name= O&M cost	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	
		Units= Euros/year	Units= Euros/year	
		Magnitude = 5,760,000	Magnitude = 1,500,000	
		ID =4	ID =4	
		Name= Allocation of green	Name= Allocation of green	
		water from RWH tank for	water from GWR tank for	
		Toilet consumption	Toilet consumption	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	
		Units=-	Units=-	
		Magnitude = Irue	Magnitude = True	
		ID =5	ID =5	
		Name= Allocation of green	Name= Allocation of green	
		water from RWH tank for	water from GWR tank for	
		industrial consumption	industrial consumption	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	
		Units=-	Units=-	
		iviagnitude = i rue	iviagnitude = I rue	
		ID =6	ID =6	
		Name= Allocation of green	Name= Allocation of green	
		water from RWH tank for	water from GWR tank for	
		irrigation consumption	irrigation consumption	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	
		Magnitudo -Truo	Magnitudo -Truc	
6	addition of P\//U	Description: Adding PM/H	Description: Adding GM/P	
0	and GWR	scheme in local area	scheme in local area	
	systems at a local	Occurrence type: One-off	Occurrence type: One-off	
	level by 50% of	First occurrence: 2015	First occurrence: 2015	
	households	Location: local area	Location: local area	
	starting from	Variables:	Variables:	

Intervention	Intervention	Individual	Individual	Individual
Strategy ID	strategy	Intervention 1	Intervention 2	Intervention 3
	description			
	(name)			
	2015			
		ID =1	ID =1	
		Name= Storage capacity	Name= Storage capacity	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	
		Units= m ³	Units= m ³	
		Magnitude= 480,000	Magnitude= 39,000	
		2	2	
		ID =2	ID =2	
		component ID=	component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		died 1	died 1	
		Offics- Euros	Magnitudo- E0 000 000	
		Magnitude= 254 400 000	wagiiituue- 59,000,000	
		Wagintude= 234,400,000	ID =3	
		ID =3	Name= 0&M cost	
		Name= 0&M cost	Component ID=	
		Component ID=	subcatchment 1 and local	
		subcatchment 1 and local	area 1	
		area 1	Units= Furos/vear	
		Units= Euros/vear	Magnitude = $1.500.000$	
		Magnitude = 11,520,000		
			ID =4	
		ID =4	Name= Allocation of green	
		Name= Allocation of green	water from GWR tank for	
		water from RWH tank for	Toilet consumption	
		Toilet consumption	Component ID=	
		Component ID=	subcatchment 1 and local	
		subcatchment 1 and local	area 1	
		area 1	Magnitude =True	
		Units=-		
		Magnitude =True	ID =5	
			Name= Allocation of green	
		ID =5	water from GWR tank for	
		Name= Allocation of green	industrial consumption	
		water from RWH tank for	Component ID=	
		industrial consumption	subcatchment 1 and local	
		Component ID=	area 1	
		subcatchment 1 and local	Units=-	
		area 1	Magnitude =True	
		Units=-		
		iviagnitude = i rue	ID =0	
			watter from CMD to all for	
		Namo- Allocation of groom	water from GWK tank tor	
		water from DM/H task for	subcatchmont 1 and local	
		irrigation consumption in	area 1	
		subcatchment 1 and local	Linits=-	
		area 1	Magnitude =True	
		Units=-		

Intervention	Intervention	Individual	Individual	Individual
Strategy ID	strategy	Intervention 1	Intervention 2	Intervention 3
	description			
	(name)			
		Magnitude =True		
7	addition of RWH	Description: Adding RWH	Description: Adding GWR	Description:
	and GWR	scheme in local area	scheme in local area	Increase in annual
	systems at a local	Occurrence type: One-off	Occurrence type: One-off	pipeline
	level by 25% of	First occurrence: 2015	First occurrence: 2015	rehabilitation rate
	households and	Location: local area	Location: local area	Occurrence type::
	0.5% additional	Variables:	Variables:	Recurring
	rehabilitation			First occurrence:
	annually starting	ID =1	ID =1	2015
	from 2015	Name= Storage capacity	Name= Storage capacity	Frequency:
		Component ID=	Component ID=	once a year
		subcatchment 1 and local	subcatchment 1 and local	Time period: 25
		area 1	area 1	years
		Units= m ³	Units= m ³	Location:
		Magnitude= 240,000	Magnitude= 19,500	Distribution mains Variables:
		ID =2	ID =2	
		Name= Capital cost	Name= Capital cost	ID =1
		Component ID=	Component ID=	Name= Leakage
		subcatchment 1 and local	subcatchment 1 and local	Rate
		area 1	area 1	Component ID=
		Units= Euros	Units= Euros	subcatchment 1
		Magnitude= 127,200,000	Magnitude= 29,500,000	Units=%
				Magnitude= 0.5
		ID =3	ID =3	
		component ID=	component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		died I	died 1	
		Magnitudo = E 760.000	Magnitudo = 750.000	
		Magnitude = 5,760,000	Magnitude = 750,000	
		ID =4	ID =4	
		Name= Allocation of green	Name= Allocation of green	
		water from RWH tank for	water from GWR tank for	
		Toilet consumption	Toilet consumption	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	
		Units=-	Units=-	
		Magnitude =True	Magnitude =True	
		ID =5	ID =5	
		Name= Allocation of green	Name= Allocation of green	
		water from RWH tank for	water from GWR tank for	
		industrial consumption	industrial consumption	
		Component ID=	Component ID=	
		subcatchment 1 and local	subcatchment 1 and local	
		area 1	area 1	
		Units=-		
		Magnitude =True	Magnitude =True	
		ID =6	ID =6	

Intervention Strategy ID	Intervention strategy description (name)	Individual Intervention 1	Individual Intervention 2	Individual Intervention 3
		Name= Allocation of green water from RWH tank for irrigation consumption Component ID= subcatchment 1 and local area 1 Units=- Magnitude =True	Name= Allocation of green water from GWR tank for irrigation consumption Component ID= subcatchment 1 and local area 1 Units=- Magnitude =True	

In the fourth step of the input data in the **Configuration** ribbon button, metrics are defined. Similar to other input data, a new performance metric can be added in the DSS by clicking **Add** button in the **Configuration** ribbon button. In the new form (Fig. 8), WaterMet2 metrics can be selected from a dropdown box once the checkbox of Use-supplied metric is unchecked. The user also needs to specify the three parameters related to the processing (i.e. Aggregation type, resampling type and consolidation) of performance indicators required when assessing with respect the metrics (Fig. 8).

Metric	-									
Settings										
User ID:	Reliability		 Include in ranking							
Description:	Demand ful	and fulfillment ser-supplied metric .12 71. Fraction of water demand delivered								
Metric:	User-supplied metric Metric: S21,12 71. Fraction of water demand delivered									
Type:	Target (adva	nced) 👻								
Processing)									
Aggregat	tion	Resampling	Consolidation							
None		None (Daily)	None							
Minin Maxin	num	Weekly	Minimum Maximum							
Mean	num	 Annual 	Maximum Mean							
User-supplied metric Metric: S21,12 71. Fraction of water demand delivered Type: Target (advanced) Processing Aggregation None None None None None None Minimum Maximum Maximum Mean Sum Sum User-supplied metric Metric: S21,12 71. Fraction of water demand delivered Consolidation Minimum Maximum Sum Mean Sum Sum Mean Sum Mean Sum Mean Sum Mean Mean Mean Sum Mean Me										
O Produ	ıct		Product							
Final	value		Final value							
 Sum Produ Final 	ıct value	Determinar	 Sum Product Final value 							

Fig. 8 A performance metric (reliability) populated for the case study problem in the DSS

O TRUST WP54 DSS							
Configuration	Evaluation						0
Add Edit Clor	WP54 DSS Load Configuration Evaluation East Cone East Cone Cone Delete Add East Cone Delete Demo Demo Demo Demo						
Scenario			Metric	Alternative	Debug		
	_	1		1			
General	Metric no.	User ID	Description	TRUST Criterion	WaterMet ² Metri	іс Туре	
	M0.	Leakage	Total Leakage		5. Total leakage		
Scenarios (2)	M1.	CSO	Total CSO Outflow		31. Total CSO Ou	utflow	
	M2.	GHG	Total GHG Emissions		39. Total GHG em	nission	
Metrics (6)	МЗ.	Cost	Total Cost		56. Total cost (ca	pital + operational)	
	M4.	Reliability	Demand fulfillment		71. Fraction of w	vater demand delivered	
Alternatives (7)	M5.	Social	Social acceptability	n/a	User-supplied m	etric	
Ranking							

The populated table of performance metrics for the case study problem in the DSS is shown in Fig. 9.

Fig. 9 Populated performance metric table for the case study problem in the DSS

After completing the four steps of the input data in the Configuration ribbon menu, the assessment and then ranking of intervention strategies are conducted. Assessment of the intervention strategies are carried out in two distinct steps of automatic and manual population. The first step is to automatically calculate the metrics which can be quantified by WaterMet². This can be done by clicking **Populate Matrix** button. Other metrics which need to be quantified manually using either external tools or in a qualitative method. These metrics are those which the user has checked them when defining them in the relevant metric form. The manual metrics are clearly recognised by their distinct pink colour in the Decision Matrix Table. In the case study problem, five out of six metrics are quantified automatically by WaterMet2 and the only qualitative metric (C_6) is quantified by relevant experts and the quantified values incorporated in the DSS. Instead of using qualitative categories (linguistic terms) for metric C_6 , these are rated as scoring on a scale of acceptance ranging from 1 to 10, being: extremely low (1-2), low (3-4), medium (5-6), high (7-8) and extremely high (9-10). Finally the Quantified performance metrics for each intervention strategy in the case study problem in the DSS is obtained as shown in Fig. 10.

TRUST WP54 DSS														
Configuration	Evaluatio	n												
Populate Matrix Recalc.	Add De	elete Is G												
General	Decision	Matrix Weightings Overall R	anking Ri	sk-related Ra	nking								1	
	Alterna	tive	M0. Leakag	ye	M1. CSO		M2. GHG		M3. Cost		M4. Reliab	ility	M5. Social	
Scenarios (2)	No.	ID	SO. Low	S1. High	SO. Low	S1. High	SO. Low	S1. High	SO. Low	S1. High	SO. Low	S1. High	SO. Low	S1. High
	A0.	Business as Usual	26.0	28.5	275.2	288.5	252.4	273.3	52.41	53.21	99.4	94.9	5	5
	A1.	Additional Resource	26.2	30.1	276.0	300.7	254.7	285.0	72.39	73.60	100.0	99.9	8	8
vietrics (6)	A2.	Additional Rehabilitation 1%	20.4	22.5	275.9	293.2	253.0	276.8	56.65	57.55	99.9	96.9	7	7
	A3.	RWH 25%, GWR 25%	21.3	24.4	217.2	230.3	249.5	276.1	59.79	60.80	99.9	97.9	3	3
Alternatives (7)	A4.	RWH 25%, GWR 50%	20.0	23.3	213.2	226.3	249.5	278.1	61.02	62.11	100.0	98.8	2	2
	A5.	RWH 50%, GWR 50%	19.5	22.8	191.5	202.6	249.2	278.2	67.72	68.81	100.0	98.9	1	1
Panking	A6.	RWH 25%, GWR 25%,	18.8	21.5	217.3	231.1	249.4	277.3	61.81	62.85	100.0	98.6	з	3
hanking														

Fig. 10 Quantified performance metrics for each intervention strategy in the case study problem in the DSS

Then, the DSS needs to have associated target/goals and preferences, described in the following sections. The three sets of weighting schemes are populated in the **weighting** tab of the **Ranking** section in the DSS (Fig. 11). A new set of weighting scheme can be added by clicking Add button in the **Evaluation** ribbon menu. The List of the three weighting schemes populated for the case study problem in the DSS is shown in Fig. 11.

O TRUST WP54 DSS					
Configuration	Evaluation				
Populate Matrix Recalc.	Add Dele	tte			
General	Decision Ma	trix Weightings Overall Ra	anking Risk-related I	Ranking	
	Metric		Equal Weighting	Public	Water
Scenarios (2)	No.	ID			Company
	M0.	Leakage	1.00	1.00	4.00
Motrice (6)	M1.	CSO	1.00	3.00	1.00
Wetrics (0)	M2.	GHG	1.00	3.00	2.00
	М3.	Cost	1.00	1.00	3.00
Alternatives (7)	M4.	Reliability	1.00	4.00	5.00
	M5.	Social	1.00	5.00	4.00
Ranking					

Fig. 11 List of the three weighting schemes populated for the case study problem in the DSS

Finally the ranking of the intervention strategies is obtained for all scenarios in the DSS by clicking Recacl. Button in the Evaluation ribbon menu. This is shown in Fig. 12 for the case study problem in the DSS. This ranking is obtained based on the Compromise Programming (CP) MCDA method (Zeleny 1973). A colour scale has been used to recognise the ranking of intervention strategies such that the high ranked intervention strategies are seen by a darker colour.

TRUST WP54 DSS									- 0	
Configuration	n Evaluation									
opulate Matrix Recalc.	Add Delete									
General	Decision Matrix Weightings Overal	I Ranking Risk-relate	d Ranking							
	Alternative	W0. Equal Weighting		W1. Public		W2. Water Company		Sum of	um of Overall	
Scenarios (2)		S0. Low Growth	S1. High Growth	S0. Low Growth	S1. High Growth	S0. Low Growth	S1. High Growth	Ranks	Rank	
	No. ID	Rank Distance	Rank Distance	Rank Distance	Rank Distance	Rank Distance	Rank Distance			
Antoine (C)	A0. Business as Usual	5 0.33	5 0.32	5 0.32	5 0.31	5 0.30	5 0.29	30	5	
vietrics (6)	A1. Additional Resource	7 0.37	7 0.37	7 0.39	7 0.39	7 0.36	7 0.36	42	7	
	A2. Additional Rehabilitation	6 0.33	6 0.33	6 0.36	6 0.36	6 0.30	6 0.30	36	6	
Alternatives (7)	A3. RWH 25%, GWR 25%	4 0.29	4 0.29	4 0.26	3 0.25	4 0.25	4 0.25	23	4	
	A4. RWH 25%, GWR 50%	2 0.28	2 0.28	2 0.24	2 0.24	1 0.24	1 0.24	10	2	
Ranking	A5. RWH 50%, GWR 50%	1 0.28	1 0.28	1 0.23	1 0.22	2 0.24	3 0.24	9	1	
unung	A6. RWH 25%, GWR 25%,	3 0.29	3 0.28	3 0.26	4 0.25	3 0.24	2 0.24	18	3	
≀anking	A6. RWH 25%, GWR 25%,	3 0.29	3 0.28	3 0.26	4 0.25	3 0.24	2 0.24	18		

Fig. 12 Ranking table of intervention strategies including overall ranking obtained for all scenarios in the case study problem in the DSS

5. Summary

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This document illustrates briefly, on a real-life example, how to use the TRUST DSS for the long-term planning of integrated urban water systems. A more comprehensive description of the DSS methodology, software tool and demonstration on a real-life example will be provided in the final report (Deliverable 54.3) which is due later on (end of project).

References

- Alegre, H., Cabrera jr., E., Hein, A. and Brattebø, H. (2012), Framework for Sustainability Assessment of UWCS and development of a self-assessment tool. Deliverable D31.1. TRUST Project.
- Behzadian K., Z. Kapelan, G. Venkatesh, H. Brattebø, S. Sægrov, E. Rozos, C. Makropoulos,. "Quantitative UWS Performance Model: Watermet2", TRansition to Urban water Services of Tomorrow (TRUST) project report, 2014.
- Zeleny, M., (1973). Compromise Programming. In: Multiple Criteria Decision Making, Cochrane and M. Zeleny (Editors), University of South Carolina Press: Columbia, South Carolina.

6. Appendix. DSS Software Installation

Before installing the software, the user needs to check the system requirements to ensure that it is fully compatible with the software requirements. After a successful installation, the user can start working on either a new model or existing model. The software tool is freely available for the users and can be accessible through either upon request from the developers or the TRUST website.

6.1 System requirements

The system requirements for installing the software are as follows:

- Operating System: Windows 8, Windows Server 2012, Windows 7, Windows Vista SP1 or later, Windows XP SP3, Windows XP SP2 x64 Edition, Windows Server 2008 (Server Core not supported), Windows Server 2008 R2 (Server Core supported with SP1 or later), Windows Server 2003 SP2
- DSS uses Windows[™] based screens, and navigational devices such as buttons, dropdown menus and toolbars. The Minimum Screen Resolution is 1152x864 but a resolution of 1680x1050 or higher is highly recommended.
- Windows Regional Settings: any language is allowed when installing the software. However, for using the examples in the case study section, it is recommended to set for those languages (e.g. English) which recognises "." as decimal sign in Windows and Microsoft Office.
- Microsoft Excel 2000 or later English Edition for viewing output files

6.2 Installation and running

The DSS software model is designed to run under a Windows[™] operating system. It is distributed in as a compressed folder which includes a WP54DSS.EXE file which runs the program on Windows. The contents of the compressed folder should be extracted to the same directory. In order to run this executable file, the user merely needs to double-click on the WP54DSS.EXE file (Fig. A.1). Note that the two DLL files in the distributed folder (borlndmm.dll and cc32140mt.dll) must be kept in the same folder when running the DSS tool.



Fig. A.1 The initial appearance of the DSS software tool on start-up