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1. Why and when to use the AppModel

Once you have decided to implement a sanitation system you'll be confronted with the question of which technologies to use and how to form an appropriate system. There exists a broad range of technology options including such functioning with water, other completely dry, some on-site, some with sewer connection and off-site treatment, or those that require human-powered or motorized sludge emptying and off-site treatment. Each technology option has its own advantages and disadvantages which make it more appropriate for one or another context.

Because there exists an increasingly growing number of technology options and criteria they should fulfill, it is very difficult to decide which technology options might be the best match for a given situation.

This guidance should help to systematically screen for appropriate sanitation options among all potential ones in a given context as an input into the decision-making process. It helps you to reduce the overwhelming number of options to a smaller set which could be looked at more in detail. It does NOT help you to make the final decisions. The final decision should be made in consultation with stakeholders including additional, for the stakeholder important criteria.

The Appmodel is meant to be implemented into CLUES (Community-Led Urban Environmental Sanitation Planning) and should be used to support the "Identification of service options" (step 5).

The model should only be used by a person with technical knowledge about sanitation systems and a good understanding of influencing factors. Furthermore, good communication and insights into the local preferences should be possible.

2. How does the model work?

For a better understanding of the following guidelines, please make yourself familiar with the vocabulary that is used.

Case	The case refers to the location, where the model will be applied. This is could be a Village or a district inside a bigger city. It is Important, that the boundaries are clearly set before acquiring data.
Technology	A Technology is one part of a sanitation System. Technologies are classified in 5 groups: -User Interface (e.g. pour flush toilet) -Collection and storage/treatment (e.g. septic tank) -Conveyance (e.g. solid free sewer) -(Semi-) Centralized treatment (e.g. activated sludge) -Reuse/disposal (e.g. biogas combustion).
Attribute	Attributes are used to describe characteristics (criteria) of technologies and cases. One example for an attribute is the “Temperature range”. For the technology, this describes the performance of that technology regarding a specific temperature. For the case, the attribute “Temperature range” describes the temperature variations in that location (case).
System	A system is any combination of technologies, where all inputs are transformed and reused or disposed. For example: dry toilet + organic waste -> composting chamber -> soak pit + application compost
Appropriateness score	The appropriateness score describes how appropriate (how well adjusted to the case) something is. The score has a value between 0 and 1 (1 means very appropriate, 0 means not appropriate).
Appropriateness profile	The appropriateness profile contains the attributes and their appropriateness scores which are used to calculate the appropriateness score of one technology. For example: *Frequency.of.O&M = 1 , Temperature.range = 1 , Vehicular.access = 0.8563 , Slope = 1 , O&M.skills = 1 , Management = 0.1499 , Spare.parts.supply = 0.85111* → *appropriateness score = 0.72884*
CaseFile	The CaseFile is a .csv file that contains information about the case.
TechFile	The TechFile is a .csv file that contains information about the technologies which will be assessed in the model.

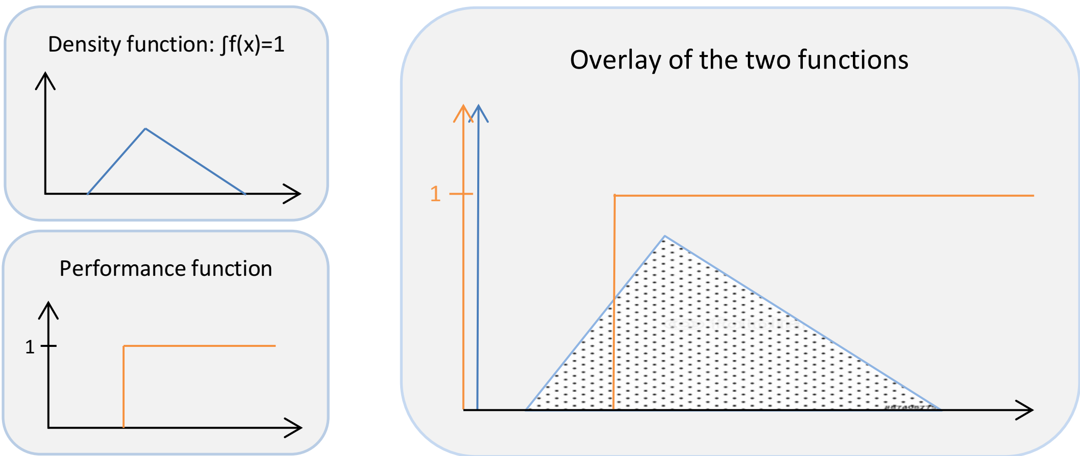
The AppModel uses the data provided in form of the **TechFile** and **CaseFile** to calculate the appropriateness of a single technologies for a given location (case). The output are appropriateness profiles for each technology showing the performance of the technology for different appropriateness criteria as well as an overall score that allows you to easily compare one technology to another.

The model covers three main steps:
Step 1) calculates an attribute appropriateness score for each attribute of each technology and generates an appropriateness profile.

Step 2) uses the appropriateness profiles to calculate an overall technology appropriateness score for each technology.
In step 3), the technologies are associated with entire systems and an overall system appropriateness score is calculated

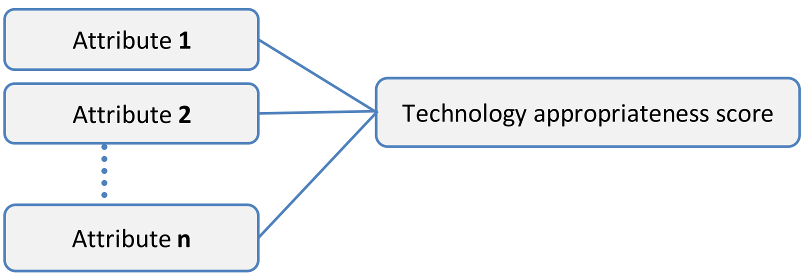
1) <u>Attribute appropriateness score:</u>
   To describe the values that an attribute takes for a given technology or case, probabilistic functions are used. Each attribute is described by one density function and one performance function.
   For example, the "Temperature.range" would be described as a density function for the case (temperature variations in that location) and as a performance function for the technology (how does the technology perform at a given temperature).
   The appropriateness score is calculated by checking how well the two functions match. The more area of the density function overlaps with the performance function, the higher is the score.

$$Attribute\ appropriateness\ score = \int density\ function \cdot performance\ function$$



2) <u>Technology appropriateness score:</u>
   The technology appropriateness score is obtained by combining the attribute appropriateness scores of the attributes describing this technology, using the following aggregation method:

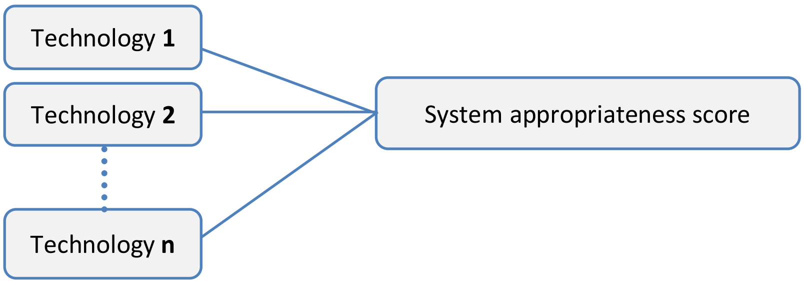
$$Technology\ appropriateness\ score = \sqrt[n]{\prod_{i=1}^{n} Attribute\ appropriateness\ score\ (i)}$$



3) <u>System appropriateness score:</u>

The system appropriateness score is obtained by combining the technology appropriateness scores of the technologies implemented in this system, using the following aggregation method:

$$System\ appropriateness\ score = \sqrt[n]{\prod_{i=1}^{n} Technology\ appropriateness\ score\ (i)}$$



3. How to use the model?

In order to obtain useful results, it is crucial to feed the model with meaningful input data (TechFile & CaseFile). It is therefore recommended to invest some time in collecting this data and follow the steps explained in the sections 3.1 and 3.2. Furthermore, the collected data must be transmitted into a special layout and be submitted to the model (section 3.3). Once the preparation is completed, the model can be run (section 3.4) and the results can be interpreted (section 3.5).

3.1. Technology Data

The technology data contained in the TechFile describes different technologies and their characteristics. The technologies contained in this file will be assessed by the model and will be evaluated on their appropriateness for a specific location (case). All functional groups, as used by the Compendium (http://ecompendium.sswm.info/sanitation-technologies) should be represented plentiful. A basic set of technologies which can be used and edited if wished, can be found in the guidelines folder – *default technology set*. To edit the TechFile see Section: *4.5*

Procedure:

1) Choosing a set of potential technologies:
   The set of Technologies, should contain conventional as well as novel technologies. All functional groups as used by the compendium (http://ecompendium.sswm.info/sanitation-technologies) should be represented plentiful. Furthermore, other (e.g. locally evolved) technologies can be added (see section: *4.5*).
2) Defining attributes for each technology:
   Tech-Attributes describe the characteristics of a technology. They should express possibilities and limits of the technology as well as the performance, given a specific relevant condition (physical, environmental, demographic, legal, cultural, and social). Attributes should be kept simple and independent from stakeholder opinions since they are used at a screening and anticipated elimination should be avoided. A set of technologies and corresponding attributes can be found in section: *4.3.* Furthermore, examples of attributes can be found in section 4.6
3) Choosing attribute functions:

Each attribute is described by a probabilistic function. Which function is used depends on the nature of the attribute itself as well as on the availability of data regarding this attribute. The four types of functions, which are used in this model, are explained in section: 4.1

4) Collect data for the functions of each attribute of each technology:
The kind of data that must be collected depends on the function chosen to describe the attribute and can be found in section 4.1.

3.2. Case Data

The Case Data describes the characteristics of a specific location by so called "Attributes" and is used to calculate the appropriateness scores of technologies. The attributes chosen to represent the case should contain physical, environmental, demographic, legal, cultural, and social characteristics of the area. They should also contain stakeholder's interests, if they are meaningful at a screening stage. The Attributes are represented through functions for which data must be collected. An overview of functions that can be used is given in section: 4.1Types of functions and how to use them. A sample set of attributes and corresponding functions can be found in section 4.6.

Procedure:

1) Define attributes to represent the case:
Case-Attributes describe the characteristics of the area/case to which the model should be applied. Physical, environmental, demographic, legal, cultural, and social aspects should be included. A sample case and corresponding attributes can be found in section: Example of CaseFile. Furthermore, examples of attributes can be found in section: 4.6.
2) Choose a function for each attribute:
Each attribute is described by a function. Which function is used depends on the nature of the attribute itself as well as on the availability of data regarding this attribute. The four types of functions, which are used in this model, are explained in section 4.1.
3) Collect data for the functions of all attributes:
The kind of data that must be collected depends on the function chosen to express the attribute and can be found in section 4.1.

Attention:

- The attributes describing the same characteristic in a technology and in a case, must have the same name →name(Tech-Attribute) = name(Case-Attribute)
- If a Case-Attribute is described by a density/performance function the corresponding Tech-Attribute has to be described by a performance/density function. This ensures, that each attribute is described once as a density- and once as a performance function.
- Category density functions can only be combined with category performance functions with the same categories.

3.3. Submit collected data

To submit the collected data in the correct way, the data needs to be contained in a .csv file. The two excel sheets (Inerface_CaseFile & Interface_TechFile) can be used as a layout and give further information on how to enter data. They can be found in the guideline folder – user interface casefile , user interface techfile. To submit the data correctly into the model, the second work sheet of each file must be saved as a csv. file. So obtained csv. file can then be uploaded into the model. It is of essential importance, that the correct syntax for the corresponding data is used. A quick checklist to prevent errors is given in section 4.2.

3.4. Run the model

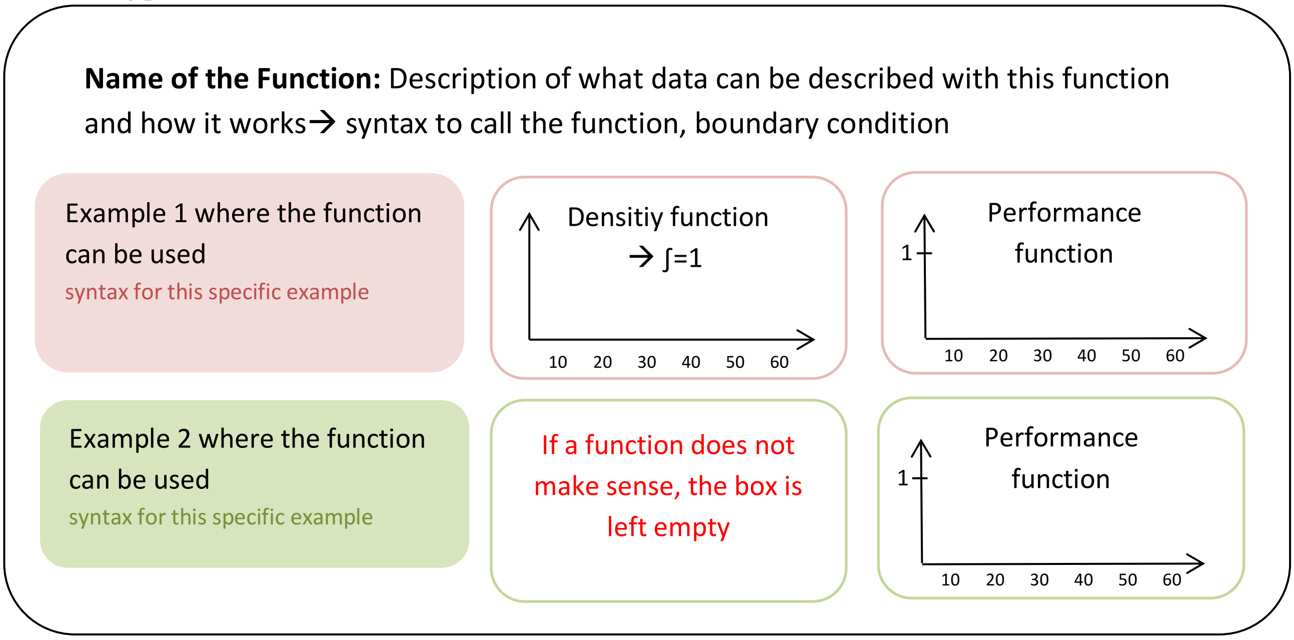
To run the AppModel, the following website can be used:
https://gujoel.shinyapps.io/appropriateness_model/
The TechFile and CaseFile can be submitted by using the upload buttons for the specific file. Once both files are uploaded correctly, use the "run model" button to run the model on a shiny server. The results can be saved as a .csv file to the local hard drive by pressing the "download button".

3.5. Interpreting the results

The results will be presented in a csv. file containing the appropriateness score and profile of each technology (an example can be found in the guideline folder – example results (Katarniya).
The interpretation of the results should be done carefully and with a critical mindset. The technologies will be sorted by their obtained appropriateness score. However, simply taking the "best" option of each functional group is not the idea of this model. As not only the overall score for each technology but also their appropriateness profile is being shown, it can be traced where the score comes from. This can help to focus on specific attributes during the following detailed assessment. Adjustments in the model (on inserted data) can be made if an attribute has led to an unjustified high or low score throughout all technologies. After having analyzed a broad range of technologies and their scoring, a selected few should be taken into a detailed study phase. In this stage, stakeholder and communities should get involved and discuss further steps bevor reaching a final decision.

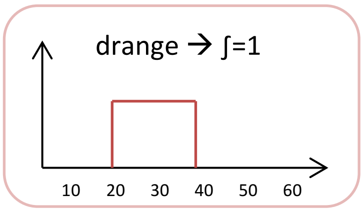
4. Appendix

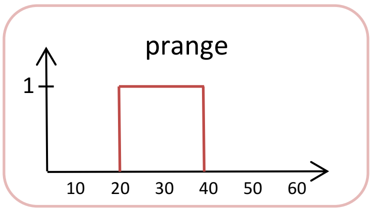
4.1. Types of functions and how to use them



Range: The range function can describe a value range. It can be used if a range or a threshold is needed → range(lower, upper) , lower<upper

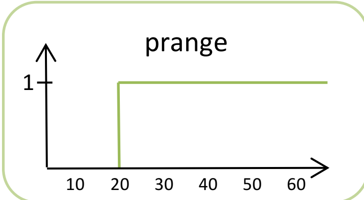
A technology only works with a temperature between 20 and 40 degree Celsius.
range(lower=20,upper=40)





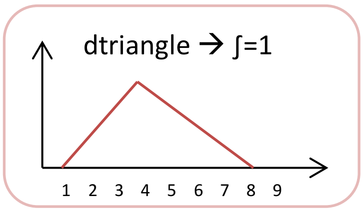
A minimal surface area of $20m^2$ is required
range(lower=20, upper=+inf)

A density function does not make sense in this case (cannot have infinite values)



Triangle: The triangle function can describe values where a linear interpolation between three points is assumed → triangle(a,b,c) , a<=c<=b

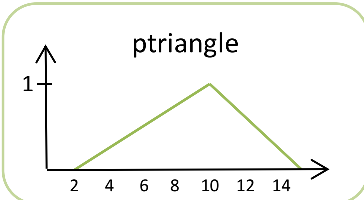
The groundwater level varies between 2m and 8m with an average of 4m
triangle(a=2,b=8,c=4)



A performance function does not make under this statement

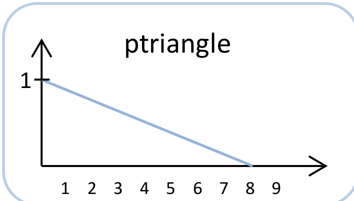
The technology works with a slope between 2% and 15% with a optimal slope of 10%
triangle(a=2,b=15,c=10)

A density function does not make sense under this statement



Technology performance depending on electricity outages per month
triangle(a=0,b=8,c=0)

A density function does not make sense under this statement



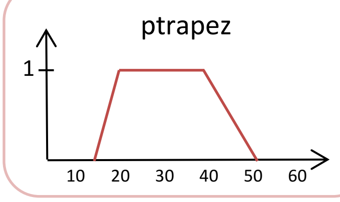
Trapez: The trapez function can describe values where a linear interpolation between four data points (min, 1st optimum, 2nd optimum, max) is assumed

→ trapez(a,b,c,d) , a<b<c<d

The technology starts working at a temperature of 15°C reaches its optimum at 20-40°C and does not work over 50°C

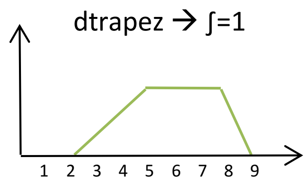
Trapez(a=15,b=20,c=40,d=50)

A density function does not make under this statement



The groundwater in this area is minimal 2m, mostly 5-8m and max. 9m deep.

trapez(a=2,b=5,c=8,d=9)



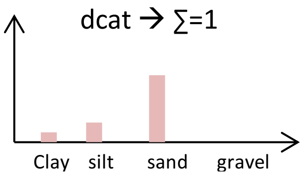
A performance function does not make under this statement

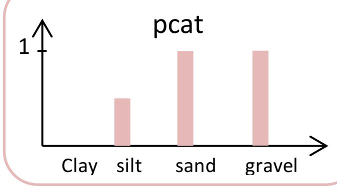
Category: The category function allows us to give values to a specific categories.

→ cat(category 1, category 2, category 3, ...)

Type of soil

cat(clay=0.1,silt=0.2,sand=0.7 ,gravel=0)





O&M skill

cat(low=,medium=,high=)

4.2. Checklist to submit data

- ☐ Attribute names are the same in the TechFile & CaseFile
  (e.g. for Temperature: Tech-attribute name= Temp ; Case-attribute name = Temp)
- ☐ Each attribute is described by a density and by a performance function. →one in TechFile, the other in CaseFile
  (e.g. Temperature: Tech-function = performance function = prange(lower=10, upper=30) ; Case-function = density function = dtriangle(a=5,b=20,c=28))
- ☐ An attribute can only be described by a continuous function or by a category function →if the density function is continuous, then the performance function must be continuous too. The same applies to category functions.
- ☐ **Names** (Technology name, Case-attribute name, Tech-attribute name) - should be short and self-explaining. They should not contain blanks or special symbols.
- ☐ **Functional groups –** are described by the capital letter of the corresponding functional group.
  - **U**-user interface
  - **S**-collection and storage/treatment
  - **C**-conveyance
  - **T**-(semi)-centralized treatment
  - **D**-use and/or disposal
- ☐ **Products -** the in-, and outputs are described using the following syntax.
  input1, input2, …, inputn -> output1, output2, …, outputm
- ☐ **Functions and Parameter –** for functions and parameter the syntax as shown below must be used (for examples see section 4.1).

drange	lower=,upper=
prange	lower=,upper=
dtriangel	a=,b=,c=
ptriangel	a=,b=,c=
dtrapez	a=,b=,c=,d=
ptrapez	a=,b=,c=,d=
dcat	c(cat1=,cat2=,…,catn=)
pcat	c(cat1=,cat2=,…,catn=)

- ☐ Matching parameters sets are used for the corresponding function (as explained in section 4.1)
- ☐ The input/output relationship are defined with the following syntax:
  - NA (there are no inputs (user interface) or outputs (disposal))
  - AND (the in-/output consist of all the defined products)
  - OR (the in-/output can only consist of one of the defined products)???????
  - XOR (the in-/output can consist of one or several of the defined products)???????
  - > (during the transport we assume mixing of the input products. Therefore we define a hierarchy of the products and define the output as the highest ranked input: e.g. blackwater > greywater > effluent > stormwater)
- ☐
- ☐
- ☐

4.3. Example of TechFile

This is, how a the TechFile use interface looks like. It can be found in the Guideline folder – user interface techfile, and is used to submit the technology data. A techfile in the right format to submit to the model can be found in the guideline folder – default technology set.

		Example	Technnology 1	Technnology 2	Technnology 3	…	Technnology m
	Name: please enter the technologys name. Make sure the name does not contain blanks or special symbols.	single.pit					
	Functional group: please enter the letter corresponing to the functionel group of this technology **U**-user interface **S**-collection and storage/treatment **C**-conveyance **T**-(semi)-centralised treatment **D**-use and/or disposal	S					
	Products: please enter the in-, and output using the following syntax: input**1**, input**2**, …, input**n** -> output**1**, output**2**, …, output**m**	faeces, excreta -> sludge					
Input - output relationship	**Input relationship:** please use the notation as explained in (giudlines: 4.5 Adding a technology)	OR					
Input - output relationship	**Outout relationship:** please use the notation as explained in (giudlines: 4.5 adding techfile)	NA					
Attribute 1	**Tech-Attribute name:** please enter the first attribute regarding this technology. Make sure the name does not contain blanks or special symbols.	Frequency.of.O&M					
Attribute 1	**Function:** pleae enter the function with which you want to discribe the corresponding attribute. Support to the function can be found at XXXX. Make sure to use the following syntax for the different functions:	drange					
Attribute 1	**Pareameter:** please enter the parameters discribing the data for the corresponding function. Make sure you use the following syntax for the different functions:	lower=0,upper=1					
Attribute 2-n please enter a all attributes regarding this technology using the same instructions as for **attribute 1.**		Temperature.range					
		ptrapez					
		a=10,b=20,c=50,d=50					
Attribute 3		Vehicular.access					
		ptrapez					
		a=1,b=3,c=100,d=100					
Attribute 4		Soil.type/hydraulic.conductivity					
		pcat					
		c(clay=0.5,silt=1,sand=1,gravel=0.5)					
Attribute 5		Groundwater.depth					
		ptrapez					
		a=4,b=8,c=100,d=100					
Attribute 6		Excavation					
		pcat					
		c(easy=1,hard=0.5)					
Attribute 7		Population.density					
		prange					
		lower=0,upper=10000					
Attribute 8		Construction.skills					
		dtriangle					
		a=0,b=2,c=1					
Attribute 9		Design.skills					
		dtriangle					
		a=2,b=4,c=3					
Attribute 10		O&M.skills					
		dtriangle					
		a=1,b=3,c=2					
Attribute 11		Management					
		pcat					
		c(household=1,shared=1,public=0)					
Attribute 12		Spare.parts.supply					
		dcat					
		c(low.tech=1, technical.parts=0, specially.manufactured=0)					
Attribute 13		Surface.area					
		ptrapez					
		a=1,b=3,c=10000,d=10000					
Attribute 14		Surface.area.onsite					
		ptrapez					
		a=1,b=3,c=10000,d=10000					

4.4. Example of CaseFile

This is, how the user interface of the CaseFile looks like. It can be found in the "Guideline" folder and is used to submit the case data into the model.

	Case-Attribute name please enter the attributes you would like to avaluate your case for. Only select each Attribute once. Make sure the name does not contain blanks or special symbols.	Function please enter the function with which you want to discribe the corresponding attribute. Support to the function can be found in the Gudelines in section: Types of functions anf how to use them. Make sure to use the following syntax for the different functions: drange prange dtriangel ptriangel dtrapez ptrapez dcat pcat	Pareameter please enter the parameters discribing the data for the corresponding function. Make sure you use the following syntax for the different functions: lower=,upper= a=,b=,c= a=,b=,c=,d= c(cat1=,cat2=,...,catn=)
Example	Vehicular.access	dtrapez	a=0.5,b=5,c=7,d=8
Attribute 1			
Attribute 2			
Attribute 3			
:			
Attribute n			

4.5. Adding a technology

If you want to add a technology to the TechFile, the following information is required:

1. Name of the technology
   - The name should be short, self-explaining and without special characters or blanks
2. Functional group
   - As used by the compendium (http://ecompendium.sswm.info/sanitation-technologies)
3. Products
   - The products of a technology define the in-, and outputs. The following syntax must be used: input**1**,input**2**,...,input**n**->output**1**,output**2**,...,output**m**
     (e.g. blackwater, greywater -> sludge, effluent)
   - Hereby it is important to use the same product-names consistently in all technologies.
4. Input & Output relation
   - The input/output relationship must be defined. The following possibilities exist:
     - NA (there are no inputs (user interface) or outputs (disposal))
     - AND (the in-/output consist of all the defined products)
     - OR (the in-/output can only consist of one of the defined products) ???????
     - XOR (the in-/output can consist of one or several of the defined products)???????
     - > (during the transport we assume mixing of the input products. Therefore we define a hierarchy of the products and define the output as the highest ranked input: e.g. blackwater > greywater > effluent > stormwater)
5. Attributes
   - The Attributes are used to describe the characteristics of the technology. For more information on how to choose and define attributes, please see section: *Technology Data*

To add the technology to an existing set or create a new set please use the Excel sheet (LINK)!

	uddt
functional.group	U
products	-> urine, faeces
inrel	NA
outrel	AND
techappscore	1
attr1	
attr2	temp
	prange
	lower=-5, upper=Inf
attr3	omskill
	prange
	lower=2, upper=Inf

4.6. Attributes – overview

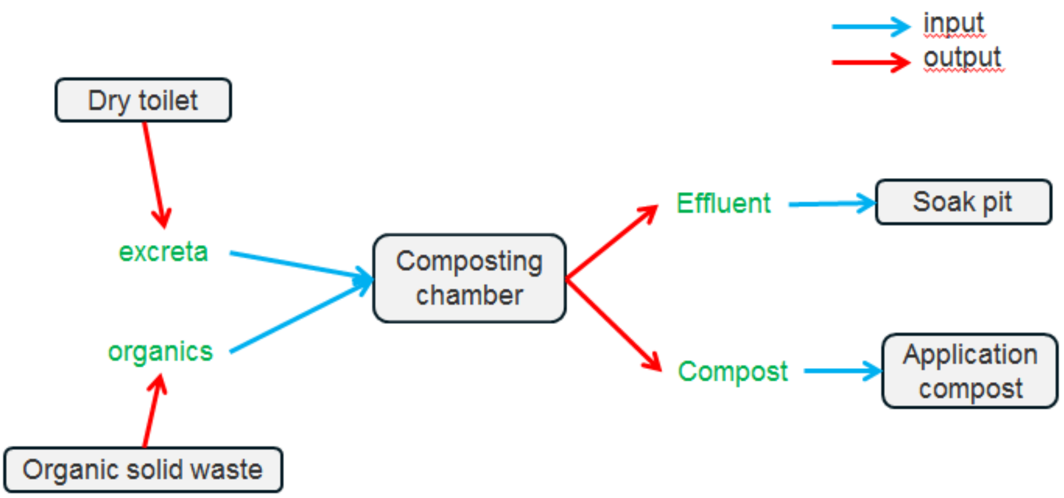
An attribute describes a design characteristic which is used to evaluate a technology. Each attribute needs to be defined as Tech-attribute and as Case-attribute.

Here are examples of several attributes and how they could be represented in the model. However, these are examples and not suggestions. Other attributes can be used and/or examples can be edited.

4.7. How sanitary systems are formed in this model

To form sanitary systems as a combination of individual technologies, the defined in and outputs of each technology are used. Every system starts with one or more technologies from the "user interface" group. These technologies have no defined input and only create an output. Based on that output, other technologies are added to the system (input in the new technology must equal the output of embedded ones). Hereby inputs can come from different sources and outputs can be diverted into different technologies (as the defined input- output relation for the products of each technology allows). A system is complete once there are no more unused products that means, all products are converted and reused or disposed in a safe manner. Technologies of the functional group "reuse/disposal" only have inputs and no output. Therefore they create the end of each system.

Example of a simple system:



Aussortierstes:

Appropriateness criteria such as temperature or groundwater table are of central importance. Each criterion comes with two attributes to measure it: one for the technology and one for the case (e.g. temperature requirements and the temperature distribution in the given application case). For more information about attributes, how to choose them and how to use them, please see section 4.6.
The information contained in the TechFile is also used to forms sanitation systems. By considering the in-, and output(s) of each technology (as defined in the TechFile), possible technology combinations are found. For a detailed description of how systems are formed see section 4.7.

Calculate attrappscore

To calculate the attribute appropriateness score, the model looks at the functions describing this attribute for the specific technology and case. It then determines which one is the density and which one the performance function. Using the density function as a probability distribution, N sample values are drawn and plotted into the performance function. The Fraction of sample points inside the performance range, represents the attribute appropriateness. If e.g. ¾ of the sample points lay within the performance function, an appropriateness score of 0.75 would be obtained.

CaseFile User-Inderface

	Case-Attribute name please enter the attributes you would like to avaluate your case for. Only select each Attribute once. Make sure the name does not contain blanks or special symbols.	**Function** please enter the function with which you want to discribe the corresponding attribute. Support to the function can be found in the Gudelines in section: Types of functions anf how to use them. Make sure to use the following syntax for the different functions: drange prange dtriangel ptriangel dtrapez ptrapez dcat pcat	**Pareameter** please enter the parameters discribing the data for the corresponding function. Make sure you use the following syntax for the different functions: lower=,upper= a=,b=,c= a=,b=,c=,d= c(cat1=,cat2=,...,catn=)
Example			
Attribute 1			
Attribute 2			
Attribute 3			
:			
Attribute n			