Urban Wastewater and Reuse Network Optimization Model User's Manual Version 1.0

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1. Command line format

The Urban Wastewater and Reuse Network Optimization Model (UWRNOM) should be run from the command line using the following command. A batched run of the model can be achieved by .bat files or by calling the system's command line by any other programming language.

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UWRNOM.exe [A] [B] [C] [D] [E]
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[A]: system type and the number of objectives

This input is a 2-digit number specifying both the system type, i.e. wastewater system or stormwater system, and the number of objectives used in the optimization. If not specified in the command line, the user will be asked to type it in manually.

The potential system modes (see Zhang et al. (2022) for definition) which can be considered under each system type and each number of objectives are also shown in the table.

Model version 1.0 supports the optimization of a wastewater and reuse system as described in Zhang et al. (2022) *A holistic model for the multi-objective design of urban wastewater and reuse network: a case study in China's Xiong'an New Area*. (to be published). The optimization of stormwater systems is not fully developed.

Input code	System type	Objective(s)	Potential system modes
11	Wastewater and reuse	Capital cost	CN*
12	Wastewater and reuse	Capital cost & Energy consumption	CN
13	Wastewater and reuse	Capital cost & Energy consumption & Water reuse capacity	CN, CR
14	Wastewater and reuse	Capital cost & Energy consumption & Water reuse capacity & Pollution discharge	CN, CR, SS
21	Stormwater	Capital cost	

22	Stormwater	Capital cost & Energy consumption

* system modes - CN: centralized treatment without water reuse; CR: centralized treatment with water reuse; SS: source-separated collection with on-site treatment, in which greywater is reused in-situ and anaerobic digestion of combined urine and feces to recycle energy;

[B]: (optional) display option

Input code	Displayed contents
0	Averaged and optimal objective function values of the archive[1]. If not specified in the command line, this is the default.
1	The above contents + a diversity metric[2]
2	The above contents + the objective function values and selected attributes[3] of typical solutions[4] in the archive.
3	The above contents + selected pheromone concentrations after each iteration.

1: the archive stores the global best *N* solutions after non-dominated sorting at the end of every iteration. (*N* is the archive size specified in *control.txt* (see section 3)).

2: the diversity indicator is the "Δ" defined in Deb, et al. (2002) *A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II*. IEEE Transactions on Evolutionary Computation, Vol. 6, No. 2.

3: the selected attributes include (for wastewater systems): (1) the number of WWTPs, (2) the total length of sewage pipelines (m), (3) the total length of recycled water pipelines (m), (4) the number of pumps, (5) the value of the objective functions. For stormwater systems, only (2), (4), and (5) are displayed.

4: the typical solutions are chosen as those in the archive which perform best under a single objective.

[C]: (optional) output option

Input code	Output contents
0	None. If not specified in the command line, this is the default.
1	*result_sum.txt* - The information displayed in "display option 1". A series of *.csv* files and *.inp* files* - the details of typical solutions, renewed every iteration.
2	The above contents + *ObjFunc.*xxx*.txt* - the objective function values of all solutions in the archive after each iteration.
3	The above contents + A series of *.csv* files and *.inp* files - the details of all solutions in the final archive.

* The *.inp* file is an input file to the EPA Storm Water Management Model (SWMM) v5.1.015 (see https://www.epa.gov/water-research/storm-water-management-model-swmm), which can be used in further analysis of the generated solutions. Note, however, that SWMM is not required to run the UWRNOM.

[D]: workspace

The path in which input files are stored. The output folder will also be created under the same path. If not specified in the command line, the user will be asked to type in manually.

[E]: (optional) result folder name

If a string is entered, it will become the second part of the name of the result folder. The first part of the name will be the system's type chosen in [A]. For example, if [A] is entered as "11" and [E] as "run1", the result folder name will be "Waste_run1".

If [E] is not specified in the command line, the current time (as in GMT+8) will be marked on the result folder's name.

2. Input files

Five or six input files are required. These files should be space- or tab-separated *.txt* files, stored under the workspace specified in [D] (section 1). The file names and contents should be as follows:

(1) Point.txt

Four columns:
- Point index;
- X coordinate;
- Y coordinate;
- Ground elevation (m).

(2) Road.txt

Four or five columns:
- Road index;
- Index of adjacent point 1;
- Index of adjacent point 2;
- Length (m);
- A 0-1 variable indicating whether this road is considered separately as a sub-catchment in designing the stormwater system. If not entered, the default is 0.

(3) Block.txt

Five columns:
- Block index;
- Area (hectare);
- Type; this input is not effective in this version of the model. Therefore, it can be an arbitrary integer.
- Wastewater discharge rate (L/s);
- Recycled water demand (m^3/day).

(4) Block_Point.txt

Two columns:
- Block index;
- Point index, indicating the points to which this block is adjacent. It is where the block connects to the sewage collection and/or recycled water distribution system. Each block can be adjacent to more than one point, in which case the connecting point will be optimized in the model.

(5) WWTP.txt (required if optimizing wastewater systems)

One column:

- Block index, where WWTPs can be built.

(6) Outfall.txt (required if optimizing for stormwater systems)

One column:

- Point index, indicating the potential outfalls of stormwater systems.

3. Reference files

Four reference files are required when running the UWRNOM. These files should be stored under the same directory as UWRNOM.exe. The file names and contents should be specified as follows:

(1) control.txt

The contents are a series of control parameters of the optimization algorithm. They should be space- or tab-separated, arranged in the following sequence:

① $N_{archive}$, the size of the archive;
② $N_{iteration}$, the maximal number of iterations;
③ $N_{unchange}$, if the optimal and averaged objective functions in the archive are no longer changing for this number of iterations, the optimization is stopped;
④ α;
⑤ β;
⑥ ρ;
⑦ q_0;
⑧ p_{best}. The meaning of parameters ④ through ⑧ can be seen in Zhang et al. (2022)

(2) DRangeWaste.txt

The contents are in four columns, indicating the designed flow rate (L/s) and the corresponding feasible pipe diameters (m), and the minimal and maximal slopes. Modification to its default content is not recommended.

(3) DRangeStorm.txt

The contents are in two columns, indicating the designed flow rate (L/s) and the corresponding minimal pipe diameter (m). Modification to its default content is not recommended.

(4) SWMMHeadline.txt

This file includes the [TITLE], [OPTION] and [REPORT] parts of the output SWMM *.inp* files. Users can modify its content according to SWMM User's Manual v5.1.015.

4. Output files

(1) result_sum.txt

This file may contain 6 ~ 15 columns, depending on the number of objective functions. The columns are:

- The number of iterations;
- The number of solutions in the archive;
- The maximum, average, and minimum of each objective function. This may occupy up to 4 * 3 = 12 columns;
- The diversity metric.

(2) ObjFunc.xxx.txt

The columns in this file are:

- The index of the solution;
- The selected attributes of the solution:
  For wastewater systems, ① the number of WWTPs, ② the total length of sewage pipelines (m), ③ the total length of recycled water pipelines (m), ④ the number of pumps, ⑤ the value of the objective functions.
  For stormwater systems, only ②, ④, and ⑤ are displayed.

(3) Six *.csv* files for each solution

Totally six *.csv* files will be produced for each solution. The file names are **x_block.csv**, **x_node.csv**, **x_pipe.csv**, **x_pump.csv**, **x_wwtp.csv**, and **x_reuse.csv**.

"x" is either "obj1/2/3/4" or an integer, where "obj1/2/3/4" indicates the typical solutions in "output option 1", and an integer indicates the index of the solution in the final archive in "output option 3". The content of these *.csv* files will appear as the first line in each file, therefore will not be described here.

(4) One SWMM input file (*.inp*) for each solution

An additional *.inp* file will be produced for each solution, named **x.inp**. Refer to SWMM User's Manual v5.1.015 for the meaning of its contents.