1. Simulation Tools for Renovation Processes

This section demonstrates the knowledge based simulation for the renovation process first and then provide a view on the architecture of the tool.

1.1 Simulation tool demonstration use case

The simulation tool requires as input first of all the renovation process workflow in standard BPMN format. The process to simulate can be exported in BPMN format directly from the renovation process and workflow design tool. Additionally an Excel sheet containing times, costs and decision probabilities is required. This format has been used as a temporary solution to give the user freedom to provide input using complex formulas and will be replaced in the final prototype by an integrated interface.

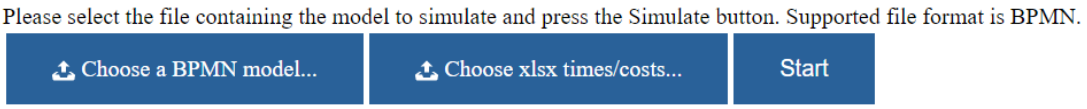


Figure 1 - Renovation process Simulation inputs

The Excel input file must be created accordingly the details described in D6.2 (BIMERR Consortium,2020).

In particular the Excel must contain the following 3 sheets in the proposed order:

1. C_START_EVENT
2. C_TASK
3. C_EXCLUSIVE_GATEWAY

The C_START_EVENT sheet provide information on the number of simulation to run with their starting time and unique identifier. The first column of this sheet must contain the name of the starting event as reported in the BPMN model. The second column must contain the starting time of this specific event while the third column an unique id to associate to the simulation run in order to have a reference later in the simulation results.

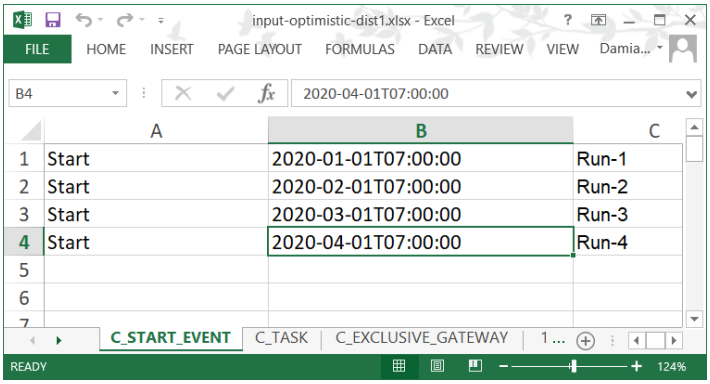
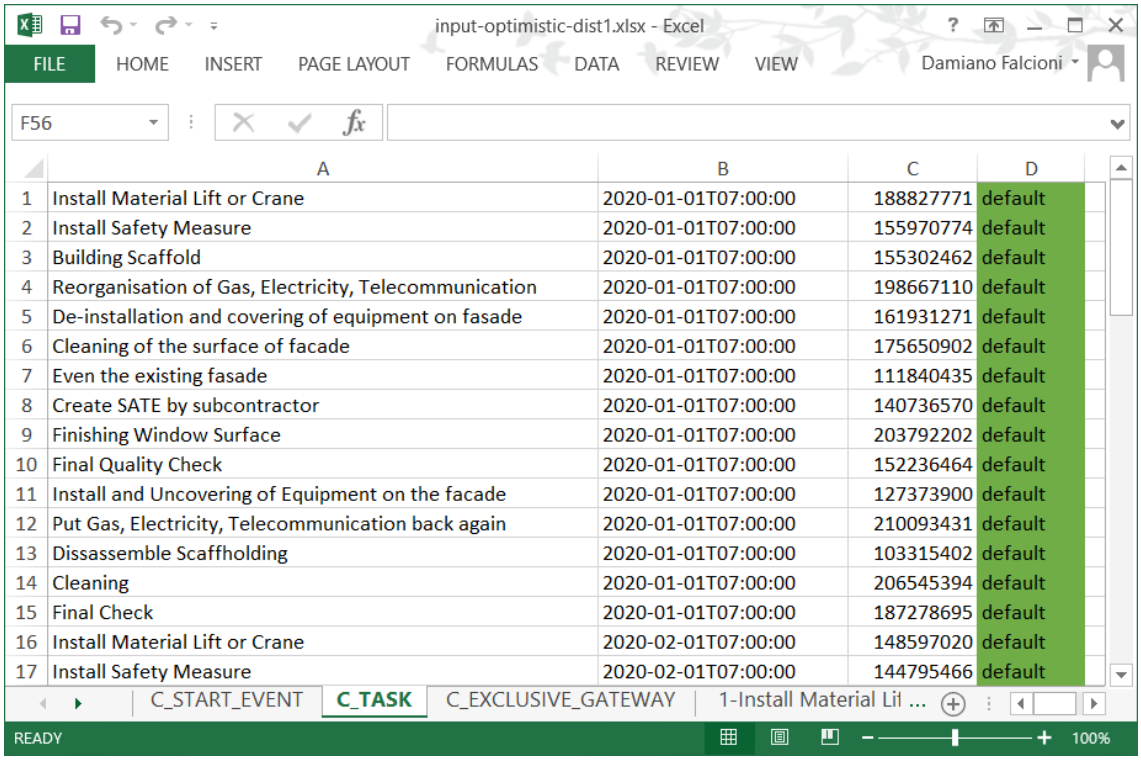


Figure 2 - Renovation process simulation input C_START_EVENT

The C_TASK sheet contain the execution time of every activity in our renovation process. The first column must contain the activity name as reported in the BPMN model. The second column is an optional starting time that can be used to provide an additional waiting time before the activity start. By default the activity start as soon as the previous one is terminated. The third column represent the execution time expressed in milliseconds. This value can be provided directly but the great advantage of using Excel as input source is that you can calculate this value combining different factors together. Additional sheets are used for this scope. The forth column can contain the unique id of the simulation run to be used for or the value default if the activity is valid for every simulation run.



	A	B	C	D
1	Install Material Lift or Crane	2020-01-01T07:00:00	188827771	default
2	Install Safety Measure	2020-01-01T07:00:00	155970774	default
3	Building Scaffold	2020-01-01T07:00:00	155302462	default
4	Reorganisation of Gas, Electricity, Telecommunication	2020-01-01T07:00:00	198667110	default
5	De-installation and covering of equipment on fasade	2020-01-01T07:00:00	161931271	default
6	Cleaning of the surface of facade	2020-01-01T07:00:00	175650902	default
7	Even the existing fasade	2020-01-01T07:00:00	111840435	default
8	Create SATE by subcontractor	2020-01-01T07:00:00	140736570	default
9	Finishing Window Surface	2020-01-01T07:00:00	203792202	default
10	Final Quality Check	2020-01-01T07:00:00	152236464	default
11	Install and Uncovering of Equipment on the facade	2020-01-01T07:00:00	127373900	default
12	Put Gas, Electricity, Telecommunication back again	2020-01-01T07:00:00	210093431	default
13	Dissassemble Scaffholding	2020-01-01T07:00:00	103315402	default
14	Cleaning	2020-01-01T07:00:00	206545394	default
15	Final Check	2020-01-01T07:00:00	187278695	default
16	Install Material Lift or Crane	2020-02-01T07:00:00	148597020	default
17	Install Safety Measure	2020-02-01T07:00:00	144795466	default

Figure 3- Renovation process simulation input C_TASK

In case of choices the C_EXCLUSIVE_GATEWAY sheet must be filled. This allow to specify for every choice in the BPMN process, the probability to use during the simulation. The first column in this case must contain the exclusive gateway name as reported in the BPMN process; the second column an optional waiting time to postpone the choice execution and the third column the probability value of all its outgoing sequence flows.

As introduced previously, additional sheets can be present in order to define the execution time for every task, combining different indicators and risk factors. Different approaches can be used to combine the risk factors as described in D6.2 (BIMERR Consortium,2020). An example is the weighted combination of the normal distribution of five different factors: (1) the normally estimated average task time, (2) the probability of the delay due to payment problems, (3) the delay introduced by bad weather forecast, (4) the delay introduced by sub-contractors problems and (5) the delay introduced by unexpected events.

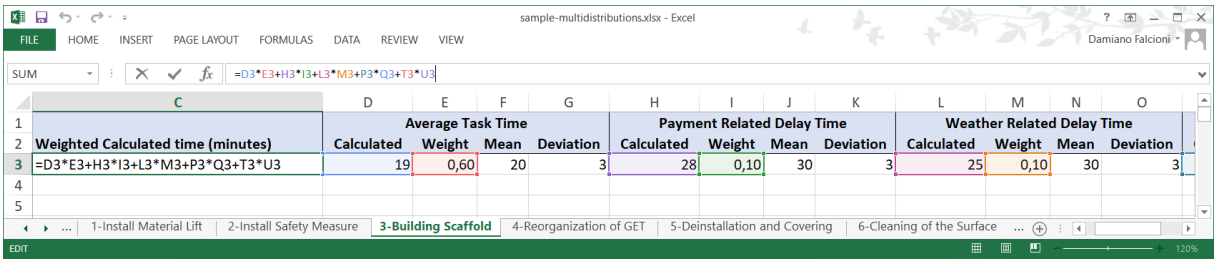


Figure 4 - Renovation process simulation input calculation

As soon as both inputs are ready the simulation can start. Once completed, the results are visualized in two different forms: an overview of times and cost with path probabilities and generic information of the process and a detailed view in form of an execution log that can be used also to perform a comparison with real workflow execution.

Figure 5 - Renovation process simulation general results

The general results in particular contains the following data:

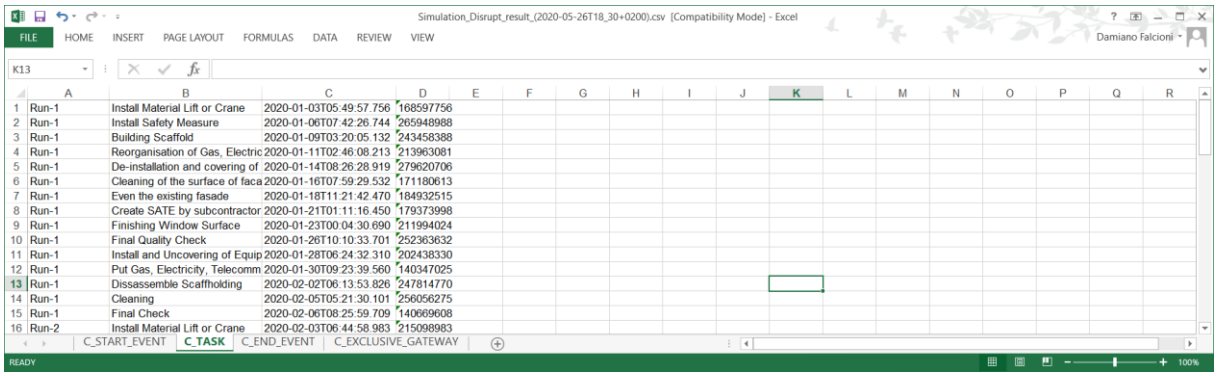
Name	Measure	Details
Average Cost	Average cost during all of the simulation runs	-
Max Cost	Max cost during all of the simulation runs	Trace name that contains this cost
Min Cost	Min cost during all of the simulation runs	Trace name that contains this cost
Total Costs	Sum of all costs during all of the simulation runs	-
Average Executions Time	total execution time / total simulation runs number	-
Max Executions Time	Max execution time during all of the simulation runs	Trace name that contains it
Min Executions Time	Min execution time during all of the simulation runs	Trace name that contains it
Total Executions Time	Sum of all execution times during all of the simulation runs	-
Total Runs	Number of simulation runs	-
Total Traces	Number of Petri Net traces passed through each simulation run	-
Total Paths	Number of Petri Net places passed through each simulation run	-

Table 1 - Renovation process simulation general results details

The detailed results are in form of Excel sheet of the same structure used as input but with detail on the simulated starting and execution times.

The C_TASK sheet in particular will contain in the first column the id of the run involved, in the second column the name of the task performed and in the third column the simulated starting time with the actual execution time in the fourth column.

Additionally a C_END_EVENT sheet is present that contain for every started simulation its ending time.



	A	B	C	D
1	Run-1	Install Material Lift or Crane	2020-01-03T05:49:57.756	168597756
2	Run-1	Install Safety Measure	2020-01-06T07:42:26.744	265948988
3	Run-1	Building Scaffold	2020-01-09T03:20:05.132	243458388
4	Run-1	Reorganisation of Gas, Electric	2020-01-11T02:46:08.213	213963081
5	Run-1	De-installation and covering of	2020-01-14T08:26:28.919	279620706
6	Run-1	Cleaning of the surface of faca	2020-01-16T07:59:29.532	171180613
7	Run-1	Even the existing fasade	2020-01-18T11:21:42.470	184932515
8	Run-1	Create SATE by subcontractor	2020-01-21T01:11:16.450	179373998
9	Run-1	Finishing Window Surface	2020-01-23T00:04:30.690	211994024
10	Run-1	Final Quality Check	2020-01-26T10:10:33.701	252363632
11	Run-1	Install and Uncovering of Equip	2020-01-28T06:24:32.310	202438330
12	Run-1	Put Gas, Electricity, Telecomm	2020-01-30T09:23:39.560	140347025
13	Run-1	Dissassemble Scaffholding	2020-02-02T06:13:53.826	247814770
14	Run-1	Cleaning	2020-02-05T05:21:30.101	256056275
15	Run-1	Final Check	2020-02-06T08:25:59.709	140669608
16	Run-2	Install Material Lift or Crane	2020-02-03T06:44:58.983	215098983

Figure 6 - Renovation process simulation detailed results

1.2 Simulation tool architecture

The BIMERR Renovation process Simulation provides a fast and extendible service able to simulate renovation process executions. The service use the Petri Net logics in order to simulate processes and workflow provided in BPMN2.0 formats and it is flexible enough to support the simulation of other kind of models through the definition of their appropriate mapping rules to Petri Net. The service is provided as REST API with a graphical HTML client that show the results in a user friendly way.

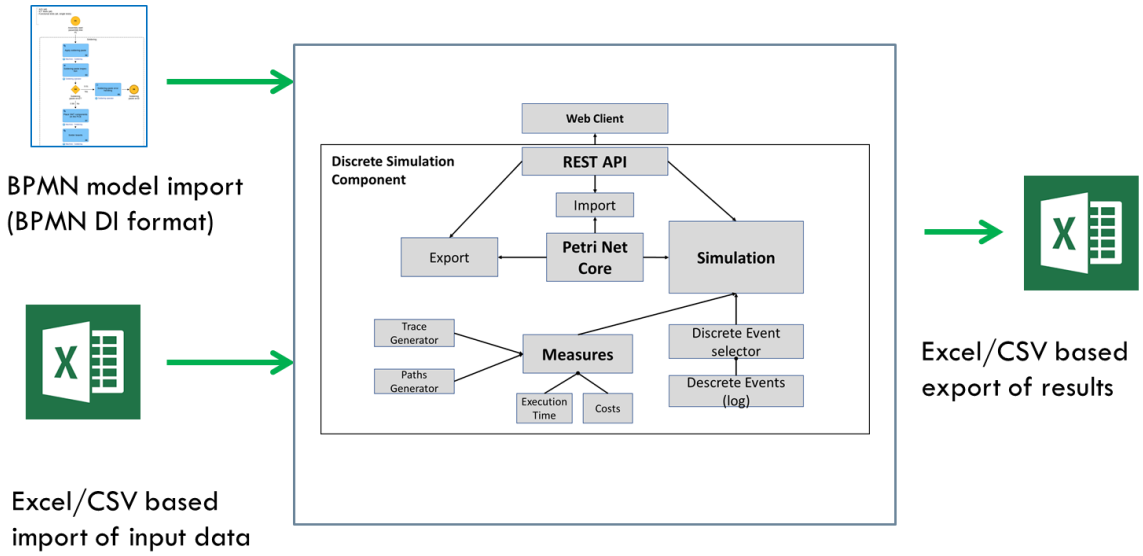


Figure 7 - Renovation process simulation engine architecture

A description of the main component of the simulator are provided in the following:

The ***petri net core module*** is the component that contain the main logic of a petri net and manage its semantic. The simulation service use this component in order to evaluate at each step which transition can be enabled.

The ***import module*** is an easy to extend component that is able to automatically recognize the format of the provided model and convert it in the internal petri net structure. It manage separately the logic of document parsing and of object mapping in order to reuse the same mapping logic for multiple file format (like in the case of BPMN and ADOxx BPMN). This is also responsible to associate the input from the Excel sheet to the right BPMN object.

The ***export module*** is for diagnostic only. It give the possibility to export the internal petri net structure in PNML standard format in order to be visualized in any supported editor.

The ***simulation measures module*** is an easy to extend component that give the possibility to define listeners for the simulation event. Each listener produce a measure or a result from a single simulation, like a trace, a path, the waiting times or the execution costs. The resulting indexes can then be collected in a special container in order to calculate some final indexes (like average values).

The ***discrete event selector module*** is the component that perform the choice of the transition to execute between the available one. The module provide a base mechanism that perform a fear choice between parallel transitions and a user defined probabilistic choice between concurrent transitions. The base mechanism has been also extended in order to support dynamic probability evaluation using a scripting system.

The ***simulation module*** is the component that manage all the simulations, invoking the functionalities of the measures module and of the transition choice. It is also responsible for the generation of the simulation output in a structured format.

The full documentation including the source code and example of features extension is available to the community through the ADOxx portal https://www.adoxx.org/live/dashboard-version-2.