1. Renovation Process KPI Design Tool

The Renovation process KPI design tool is an application build with ADOxx, a meta-modelling platform that allows to define your own meta-model and automatically generate the modelling environment for you accordingly it. Also in this case, like the renovation process design tool, a community version of the platform is available. The corresponding cloud version will be demonstrated in the final prototype. The community version library allows to create an ADOxx modelling environment as a windows desktop application that everyone can freely setup and redistribute.

In the renovation process KPI design tool the meta-model is based on concepts of the balanced scorecard (Kaplan, Robert S., and Norton, 1992), extended with a data model-type that allow to specify how the KPIs are retrieved and calculated. In the D6.2 (BIMERR Consortium,2020) has been introduced the concept of KPIs for the scaffold cost of the renovation facade scenario. The first meta-model defined is the cause and effect model-type. It allows to define KPIs and Goals with their relations and group them in specific perspective. In particular:

- Perspective group similar KPIs, like grouping all “Financial” indicators or all “Time” or “Quality” dependent indicators.
- Goals and sub-goals describe the objective to be achieved.
- KPIs describe measurable data sets that assess in combination with the indicator context – plan value, real value, thresholds, type of thresholds and meta data about the indicator –, if the corresponding goal can be achieved or not.

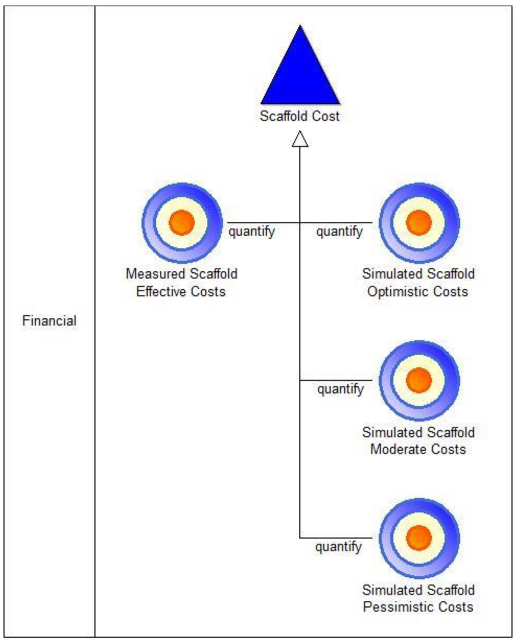
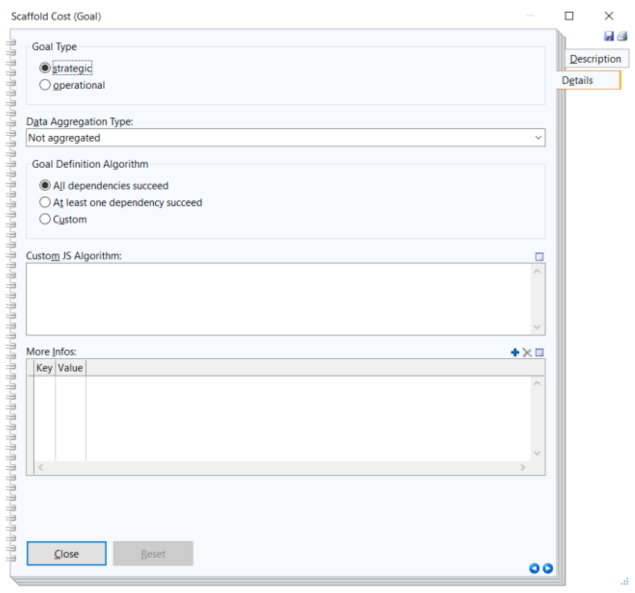

Scaffold Cost
quantify
quantify
Measured Scaffold Effective Costs
Simulated Scaffold Optimistic Costs
Financial
quantify
Simulated Scaffold Moderate Costs
quantify
Simulated Scaffold Pessimistic Costs

Figure 1 KPI model

Every object in the model has a common set of attributes like a name and a description of the object, plus a set of specific attributes that characterize it.

In the case of Goals and Sub-Goals the specific attributes refer to the type of the goal that can be Strategic or Operational and on the aggregation type of the data that represent how often this goal is evaluated. Referring on details of the evaluation of the Goal is possible to specify the procedure used during its evaluation. The goal, therefore, can succeed if all its dependencies succeed or if at least one succeeds. Additionally, if none of these reflect the goal behaviour, it is possible to provide the actual algorithm in JavaScript format needed to evaluate the Goal. In this context the connection flows between the goal and its relevant KPIs and sub-goals that determine the goal dependencies are relevant.



Scaffold Cost (Goal)

Description
Details

Goal Type
[✓ strategic]
operational

Data Aggregation Type:
Not aggregated

Goal Definition Algorithm
[✓ All dependencies succeed]
At least one dependency succeed
Custom

Custom JS Algorithm:

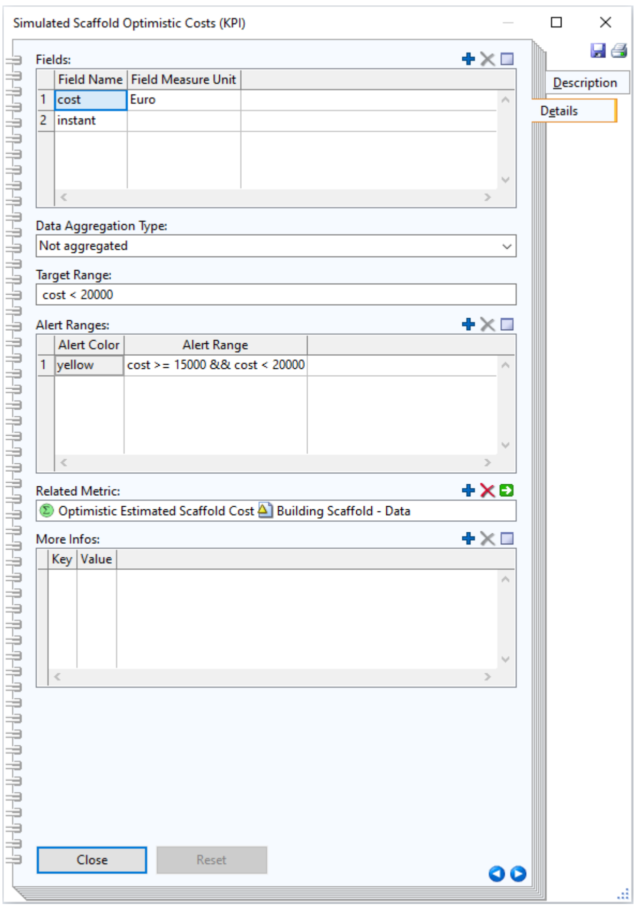
More Infos:

Key	Value

Close
Reset

Figure 2 - Goals attributes

In the case of KPI objects the specific attributes are relative to the fields of data available in the KPI and information on the target and alert ranges of the KPI value.
The Fields represent what kind of metrics are available in this KPIs. Usually there is a value field (cost in this case) that contain the value of the KPI and an instant time field that contains at what time the KPI value has been calculated, but this is not fixed and always valid, so the user can provide as much as he need. Every field can also have a specific measure unit.
Also in this case it is possible to specify the aggregation type of the data representing how often the KPI is calculated. KPIs in order to be meaningful must be associated with thresholding that in this case are represented as target and alert ranges. The target range must contain a formula (as a JavaScript expression) that uses the field name defined above, and that specifies the value range that is the target of our KPI (eg. Cost < 20000).



Simulated Scaffold Optimistic Costs (KPI)

Fields:

	Field Name	Field Measure Unit
1	cost	Euro
2	instant	

Data Aggregation Type:
Not aggregated

Target Range:
cost < 20000

Alert Ranges:

	Alert Color	Alert Range
1	yellow	cost >= 15000 && cost < 20000

Related Metric:
Optimistic Estimated Scaffold Cost Building Scaffold - Data

More Infos:

Key	Value

Figure 3 - KPI Attributes

Using the same approach, it is possible to define one or more alert range that allow to specify when the KPI is approaching a risky value on the border of the target range. Multiple alert ranges are possible here, so as example if the cost > 15000 there is a yellow/moderate alert while if the cost > 19000 there is a red/important alert because the value is approaching the top border of the target range. Ranges allow to represent information on the threshold of a value (eg. 20000) combined with information of expected directions of the values (so if the threshold is an upper or lower bound), allowing to represent cases of discrete values as well.

At the end, it is important to associate the KPI to a metric in order to be correctly calculated. The metric is defined in the data calculation model that define how the metric value have to be retrieved or calculated.

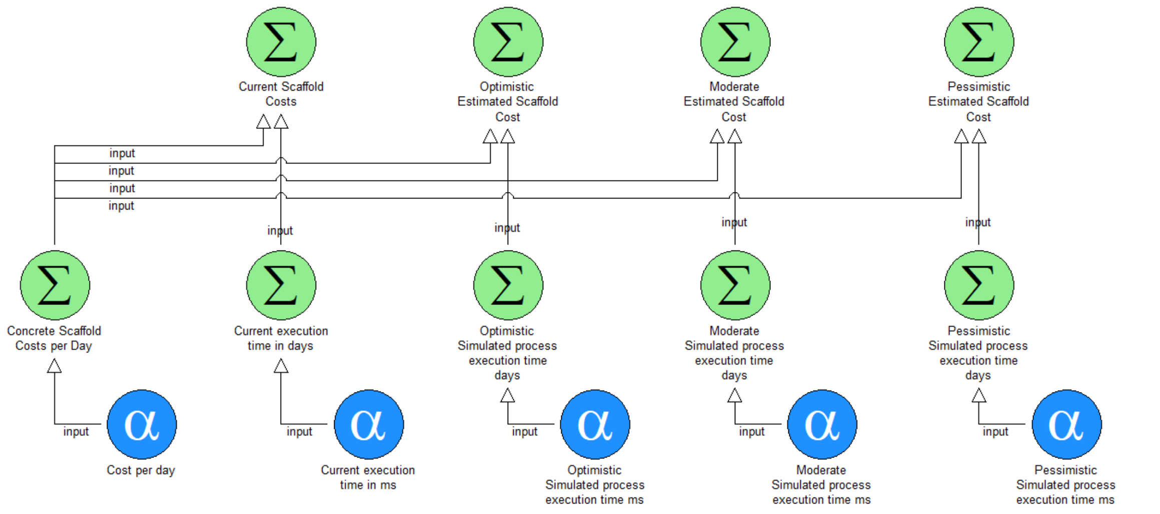

Current Scaffold Costs
Optimistic Estimated Scaffold Cost
Moderate Estimated Scaffold Cost
Pessimistic Estimated Scaffold Cost
input
Concrete Scaffold Costs per Day
Current execution time in days
Optimistic Simulated process execution time days
Moderate Simulated process execution time days
Pessimistic Simulated process execution time days
Cost per day
Current execution time in ms
Optimistic Simulated process execution time ms
Moderate Simulated process execution time ms
Pessimistic Simulated process execution time ms

Figure 4 - Data calculation model

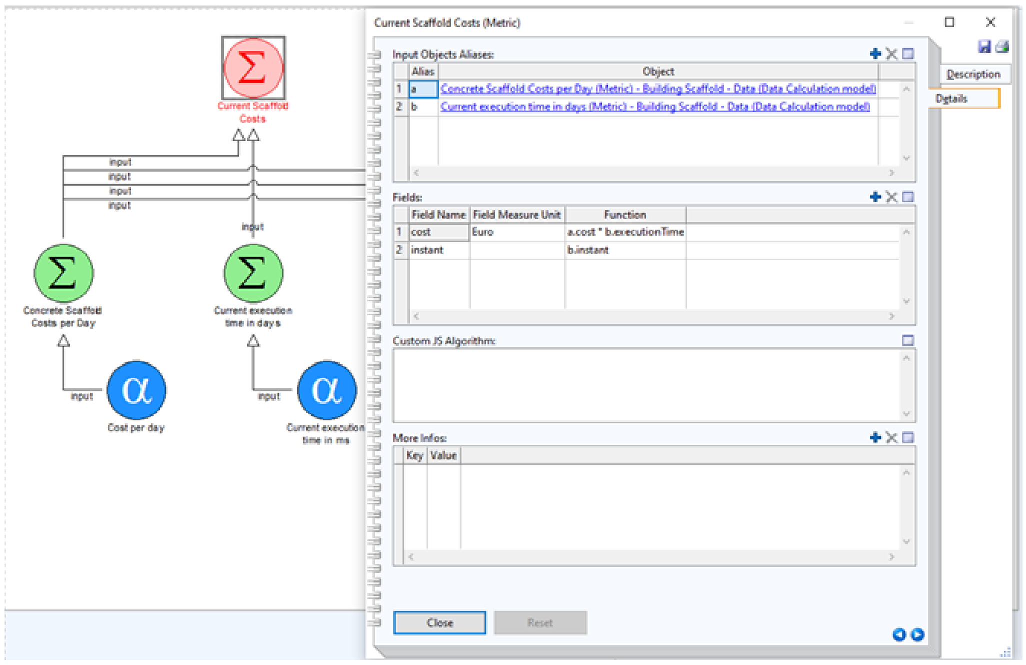
The data calculation model is composed of Metrics and Data Items including dependencies between them. Metrics (represented as green circles) represent a data in a specific format and contain information on how the value of this data have to be calculated using as inputs sub-metrics and data access indicators. The Data Items (represented blue circles) on the other side are able to describe how a data value is retrieved from an external system that can be as example a remote service, a sensor, a database or even an Excel sheet. In this context, the data access indicator is strongly dependent on the Olive microservice framework that is responsible to provide the features to access such external system.

Also in the data calculation model, every object has a common set of attributes like a name and a description of the object, plus a set of specific attributes that characterize it.

For the Metric objects such attributes refer to the way the metric is calculated on the basis of its dependencies. The Input Object Aliases attributes refer to this and allow to specify for every dependency an alias name to use in the calculation formula. Alias can be any name but must not contain spaces and start with a number.

The Fields represent what kind of data are available in this metric. Usually there is a value field (cost in this case) that contain the value of the metric and an instant time field that contain at what time the metric value has been calculated, but this are not fixed and always valid, so the user can provide as much as he needs. Every field can optionally have a specific measure unit (Euro in the case of the cost field) but must specify the formula used to calculate the specific field of the metric. The function can be described in the form of JavaScript expression and the defined aliases can be accessed and used in the formula. Fields of dependent objects can be accessed using the dot operator, so if we defined an alias for a sub-metric and such sub-metric have a field “cost” defined, in the formula this can be reached writing the alias name followed by a dot followed by the field name (eg. “a.cost”). Every field defined must contain a calculation formula. If there is no need for a formula like in the case of the instant time field, this can be taken directly from the dependency (eg. Specifying “b.instant”). Considering as a sample the metric “Current Scaffold Cost”, that should be calculated multiplying the scaffold cost per day with the current execution time, we can define such behaviour creating first the aliases for the sub-metrics “Concrete Scaffold Costs per Day” and “Current execution time in days” naming respectively “a” and “b”. Then the “cost” field of can be calculated using the function “a.cost * b.executionTime”, where “a.cost” refer to the “cost” field of the “Concreate Scaffold Cost per Day” sub-metrics, while “b.executionTime” refer to the “executionTime” field of the “Current execution time in days” sub-metrics. About the “instant” field we used the formula “b.instant” meaning that we use here the same value of the “instant” field of the sub-metric “Current Execution time in days”.

In case of exotic metrics functions it is possible to provide your own algorithm in JavaScript format that will calculate the metric fields using the “Custom JS Algorithm attribute”.



Current Scaffold Costs (Metric)

Input Objects Aliases:

	Alias	Object
1	a	Concrete Scaffold Costs per Day (Metric) - Building Scaffold - Data (Data Calculation model)
2	b	Current execution time in days (Metric) - Building Scaffold - Data (Data Calculation model)

Fields:

	Field Name	Field Measure Unit	Function
1	cost	Euro	a.cost * b.executionTime
2	instant		b.instant

Custom JS Algorithm:

More Infos:

Key	Value

Figure 5 - Metric Attributes

The Data Items are able to represent how the data values are collected from external systems through the microservice framework Olive[1]. For this purpose the microservice must return the data in a specific format in order to be recognized. The data must be a JSON object that contain a “columns” array containing the list of returned field names (that must match the one defined in the fields attributes) and a “data” array of JSON objects each one containing a key for every field defined in the “columns” with the appropriate value in string format.

An example of a valid JSON that the Olive microservice must return is the following:

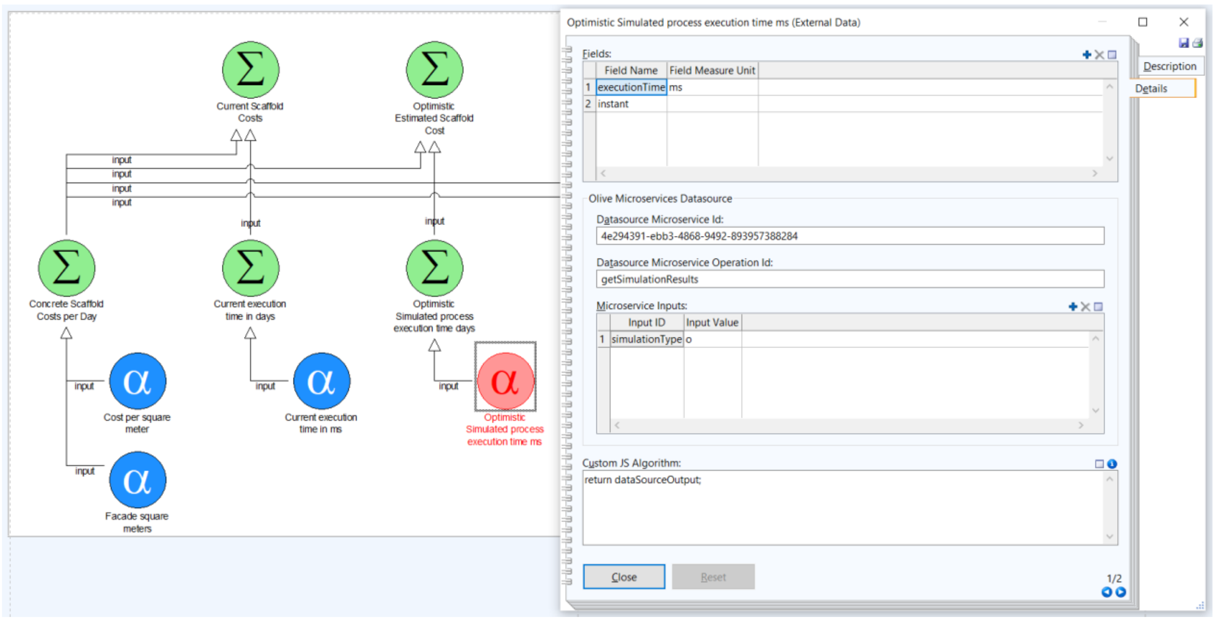
```
{
 "columns" : ["cost", "instant"],
 "data" : [{
    "cost": "2000",
    "instant": '2020-01-30T11:40:22'
 },{
    "cost" : "1900",
    "instant": "2020-01-29T10:40:50"
 },{
    "cost" : "1800",
    "instant": "2020-01-28T09:40:15"
 }]
}
```

[1] https://www.adoxx.org/live/olive

Also in this case is important to define the data fields that the service return with optional information on the measure unit for the specific value in the field.

As soon as the microservice in Olive is ready, it is important to refer to it using its unique id and providing the operation name and its required inputs in terms of input id with appropriate value. This will be the same input that the microservice expect as a JSON format but explicitly defined key by key.

In the case of the Data Items that contain the results of the optimistic simulation ("Optimistic Simulation process execution time ms") the microservice operation used is the "getSimulationResults" providing as input the parameter "simulationType" with value "o" that in the context of the service means "give me the result of the optimistic simulation". The returned JSON contain the fields "executionTime" as milliseconds value and the "instant" time of the simulation.


Current Scaffold Costs
Optimistic Estimated Scaffold Cost
input
input
input
input
input
input
Concrete Scaffold Costs per Day
Current execution time in days
Optimistic Simulated process execution time days
input
input
input
Cost per square meter
Current execution time in ms
Optimistic Simulated process execution time ms
input
Facade square meters
Description
Details
Close
Reset
1/2

Optimistic Simulated process execution time ms (External Data)

Fields:

	Field Name	Field Measure Unit
1	executionTime	ms
2	instant	

Olive Microservices Datasource

Datasource Microservice Id: 4e294391-ebb3-4868-9492-893957388284

Datasource Microservice Operation Id: getSimulationResults

Microservice Inputs:

	Input ID	Input Value
1	simulationType	o

Custom JS Algorithm:

```
return dataSourceOutput;
```

Figure 6 - Data Items Attributes

The community version library allows to create an ADOxx modelling environment as a windows desktop application that everyone can freely setup and redistribute. The renovation process KPI design tool in this case is based on ADOxx v1.5 and allow to model the renovation process KPIs using the previously described meta-model in terms of KPIs and Data access models. Additional features are in this case provided by the ADOxx Community in terms of add-on that the user can install from the ADOxx community portal www.adoxx.org.

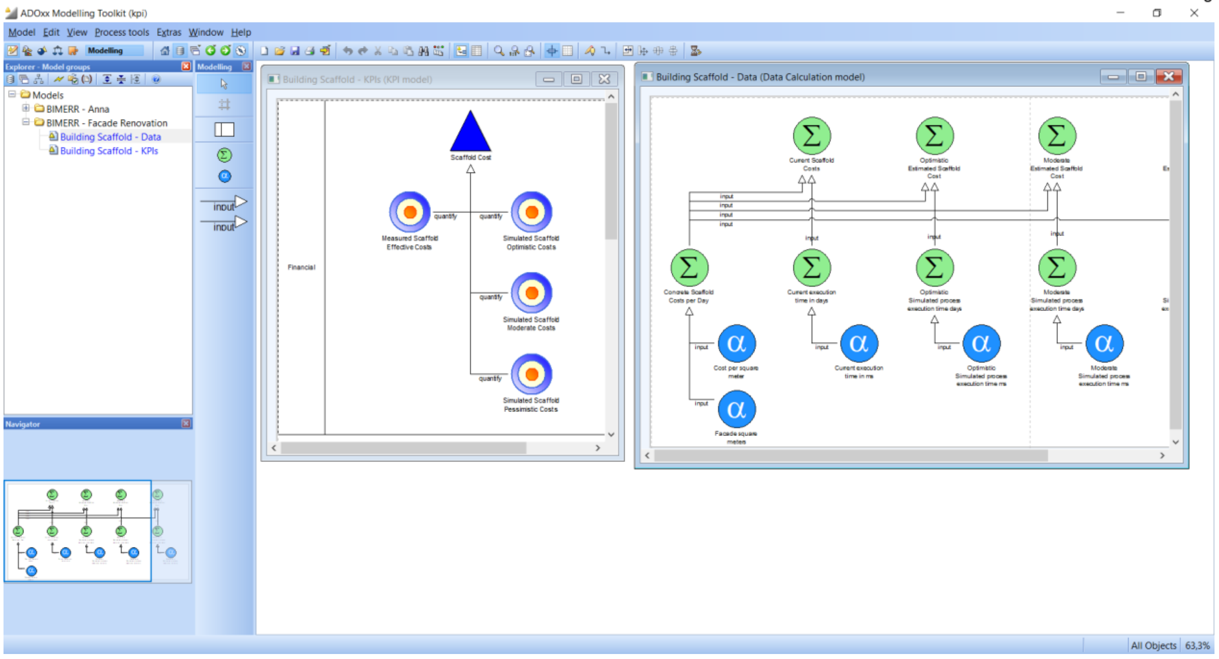

ADOxx Modelling Toolkit (kpi)
Model Edit View Process tools Extras Window Help
Explorer - Model groups
Models
BIMERR - Anna
BIMERR - Facade Renovation
Building Scaffold - Data
Building Scaffold - KPIs
Navigator
Modelling
Building Scaffold - KPIs (KPI model)
Scaffold Cost
Financial
Measured Scaffold Effective Costs
Simulated Scaffold Optimistic Costs
Simulated Scaffold Moderate Costs
Simulated Scaffold Pessimistic Costs
quantify
Building Scaffold - Data (Data Calculation model)
Current Scaffold Costs
Optimistic Estimated Scaffold Cost
Moderate Estimated Scaffold Cost
Concrete Scaffold Costs per Day
Current execution time in days
Optimistic Simulated process execution time days
Moderate Simulated process execution time days
Cost per square meter
Current execution time in ms
Optimistic Simulated process execution time ms
Moderate Simulated process execution time ms
Facade square meters
input
All Objects
63,3%

Figure 7 Renovation process KPIs design tool community version

2. Monitoring and Evaluation Tool for Renovation Processes

The monitoring and evaluation tools for the renovation process are used to support the user in the evaluation of the current status of the process and on the future behavior.

In the following sections the demonstration of the monitoring cockpits first and of the renovation process simulation later, are reported.

2.1 Renovation Processes-Oriented KPI Dashboards

The KPI dashboard visualize in a combined view both the backward looking monitoring with the forward looking simulation results. The dashboard interface is based on configurable widgets where the KPIs can be visualized in different formats accordingly to the widget features. The KPIs definitions are taken directly from the renovation process KPIs design tool that is able to export them in a format recognized by the dashboard. The dashboard use the KPIs information reported in the model in order to automatically evaluate them, calculating the relative metrics and retrieving the data from the data sources using the right Olive microservice.

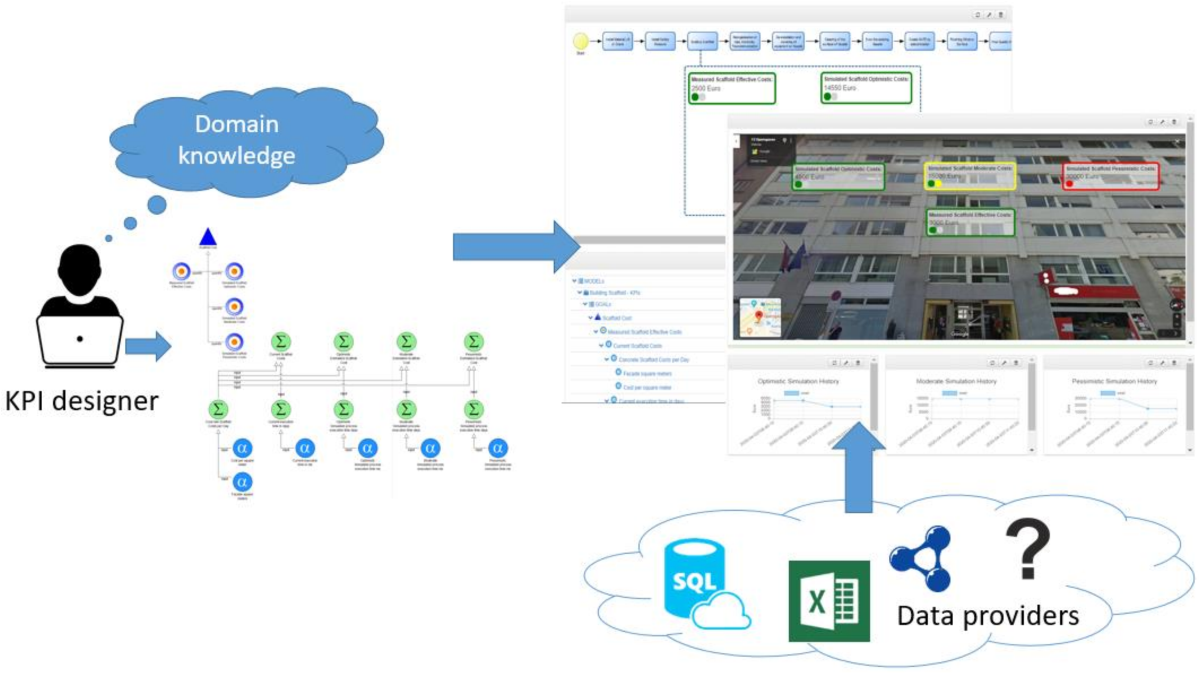


Figure 8 Renovation KPI cockpit use case

2.1.1 Models-based Monitoring Dashboards demonstration

The KPI dashboard is strongly based on the KPI and data model used. A detailed description of the models created for the BIMERR demonstration is available in the D6.2 (BIMERR Consortium,2020). This models are focused on the scaffold costs and contain the definition of the following KPIs including their relative metrics and data sources:

- **Measured Scaffold Effective Costs**: Is a backward looking KPI that monitor on a scheduled based time the scaffold current costs.

- **Simulated Scaffold Optimistic Costs**: Is a forward looking KPIs that show the results of the last simulation performed with optimistic risks evaluation on the scaffold estimated costs.
- **Simulated Scaffold Moderate Costs**: Is a forward looking KPIs that show the results of the last simulation performed with moderate risks evaluation on the scaffold estimated costs.
- **Simulated Scaffold Pessimistic Costs**: Is a forward looking KPIs that show the results of the last simulation performed with pessimistic risks evaluation on the scaffold estimated costs.

Two dashboards are currently available that support a product view of the KPIs and a process dependent view.

The first dashboard use four widget to visualize the KPIs: one image map widget and three line chart widgets. The image map visualize the building facade to renovate using an image from Google Street View and overlay the values of the previously described KPIs using a color code that immediately reflect the KPI status (green for KPIs with value in the target range, yellow for KPIs with value in the alert range and red for KPIs with value outside the target range). The three line chart widgets are used to display the historical trend of the three simulation results visualizing in a Cartesian chart the estimated scaffold cost for every performed simulation over time, allowing to analyze the alignments of the simulation inputs with the real data in the past.

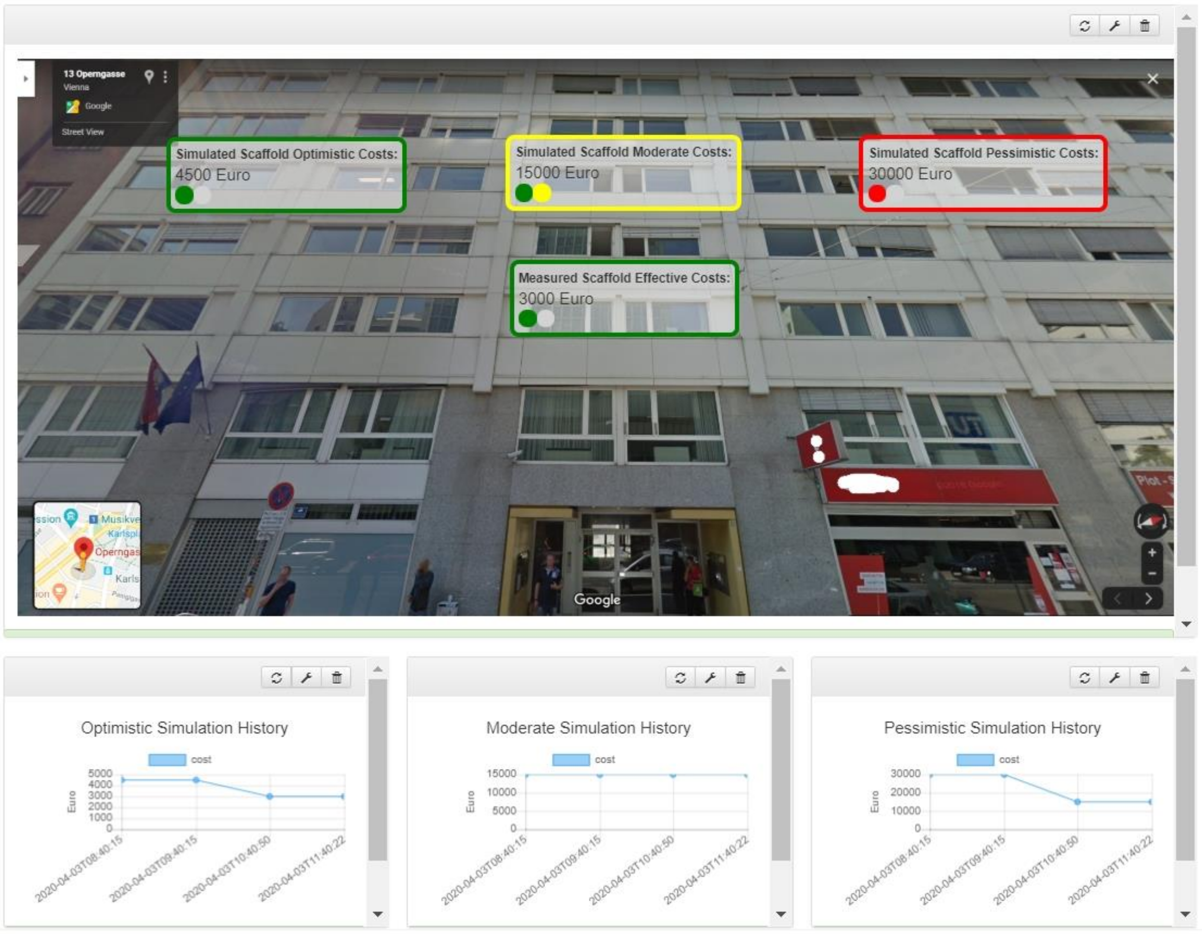
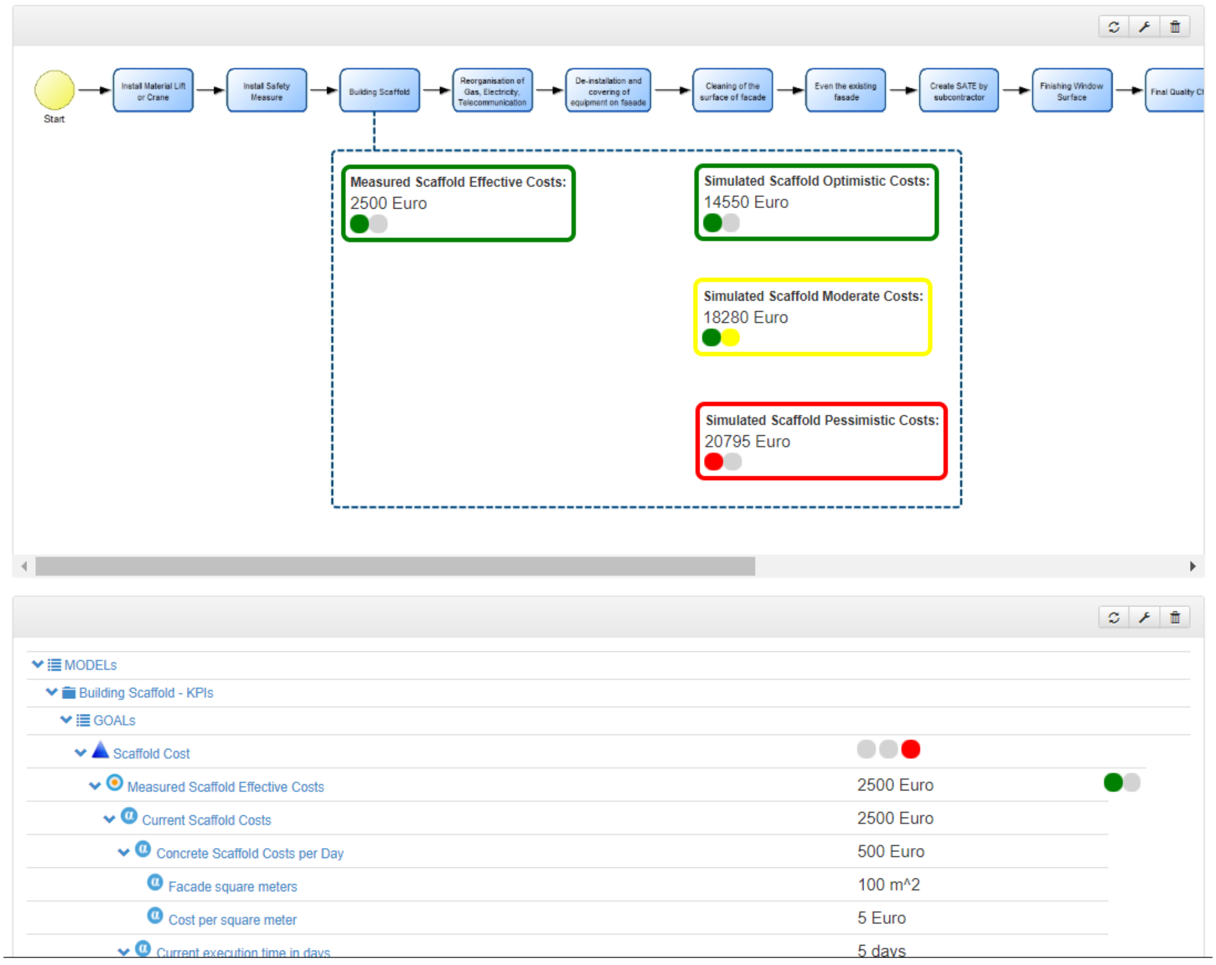

13 Operngasse
Vienna
Street View
Simulated Scaffold Optimistic Costs:
4500 Euro
Simulated Scaffold Moderate Costs:
15000 Euro
Simulated Scaffold Pessimistic Costs:
30000 Euro
Measured Scaffold Effective Costs:
3000 Euro
Google
Optimistic Simulation History
cost
Euro
2020-04-03T08:40:15
2020-04-03T09:40:15
2020-04-03T10:40:50
2020-04-03T11:40:22
Moderate Simulation History
Pessimistic Simulation History

Figure 9 - Backward-looking Monitoring and Forward-Looking Simulation of KPI-Scaffold Costs

The second dashboard demonstrates the Process-Oriented Context of the dashboard by the possibility to link KPIs to different phases of the process. For each time slot of a process can be linked to the actual as well as to the simulated KPIs.

The process-oriented representation also allows to drill the KPI down either in the process-oriented view, or using the model-tree, which represents the KPIs as they are modelled in the KPI-model. This help to understand the cause of a failing KPIs checking how its dependencies behave, finding the root of the problem.

Hence the process-oriented representation is first an alternative visualization of the dashboard and second the possibility to additionally introduce the linkage of a process phases to a concrete KPI.


Start
Install Material Lift or Crane
Install Safety Measure
Building Scaffold
Reorganisation of Gas, Electricity, Telecommunication
De-installation and covering of equipment on fasade
Cleaning of the surface of facade
Even the existing fasade
Create SATE by subcontractor
Finishing Window Surface
Final Quality C

Measured Scaffold Effective Costs: 2500 Euro

Simulated Scaffold Optimistic Costs: 14550 Euro

Simulated Scaffold Moderate Costs: 18280 Euro

Simulated Scaffold Pessimistic Costs: 20795 Euro

MODELs	
Building Scaffold - KPIs	
GOALs	
Scaffold Cost	
Measured Scaffold Effective Costs	2500 Euro
Current Scaffold Costs	2500 Euro
Concrete Scaffold Costs per Day	500 Euro
Facade square meters	100 m^2
Cost per square meter	5 Euro
Current execution time in days	5 days

Figure 10 - Simulation Output for KPIs

The intention is that a dashboard can be created where KPIs are linked to different phases of the process that can be simulated and hence dependencies between phases can be considered on an aggregated view. In case a complex process is described by several in parallel running construction sites and each process for each construction site uses simulated KPIs, the aggregating complex process is the simulated using the dependencies of the underlying processes.

Such complex scenarios require complex modelling and knowledge externalization in the design phase, and hence may only be appropriate for specific dashboard. A simple simulation of one renovation process for the simulation of one KPI will be introduced in the next section.

2.1.2 Models-based Monitoring Dashboards architecture

The KPI dashboard is a component that is able to perform a marriage between models and data resulting in a customizable web dashboard. The models contain information about how to retrieve the data and how to combine them in order to form metrics, and how to use such metrics to evaluate KPIs and goals. The data are external and obtained through specifics microservices, created with the Olive framework, able to connect with different type of data sources. At the end the results are displayed using a widget based interface that is able to display the KPIs and metrics in different formats depending on the domain and the user experience.

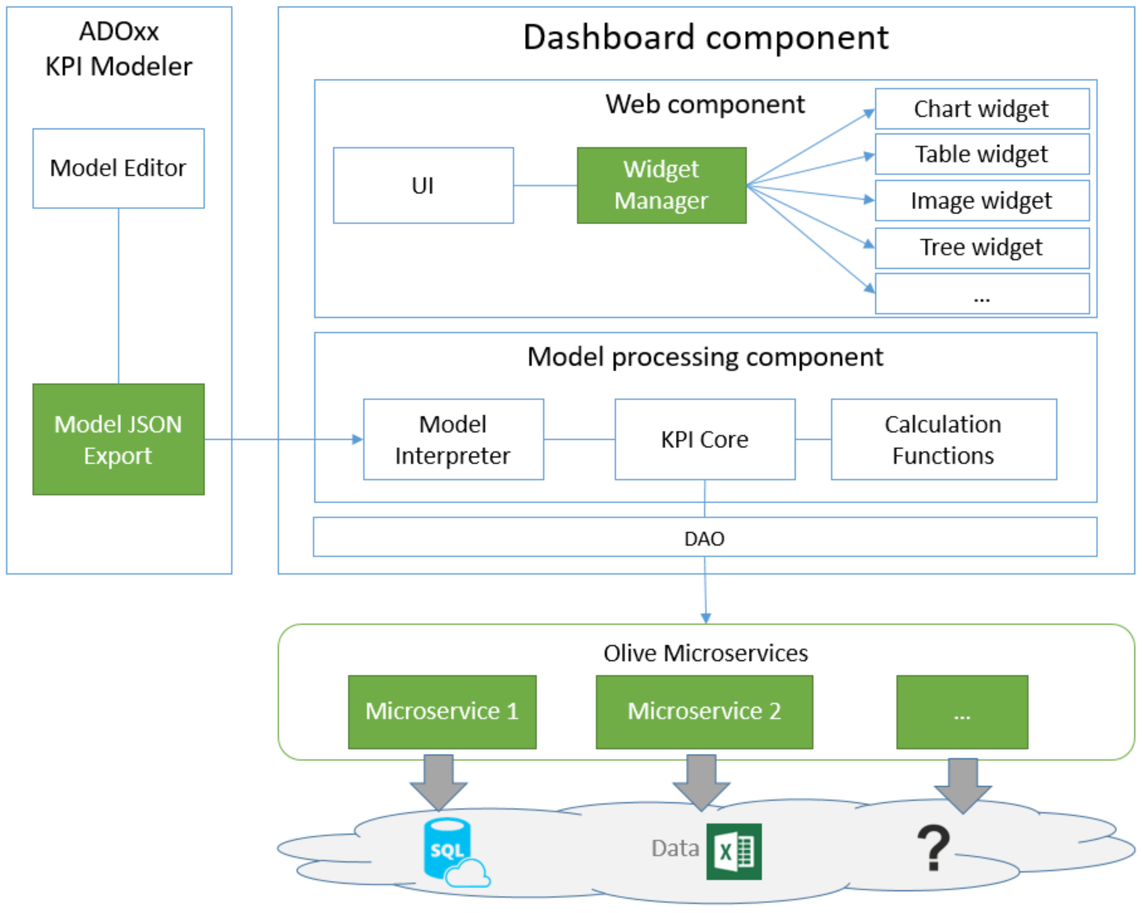


Figure 11 - KPIs Dashboard architecture

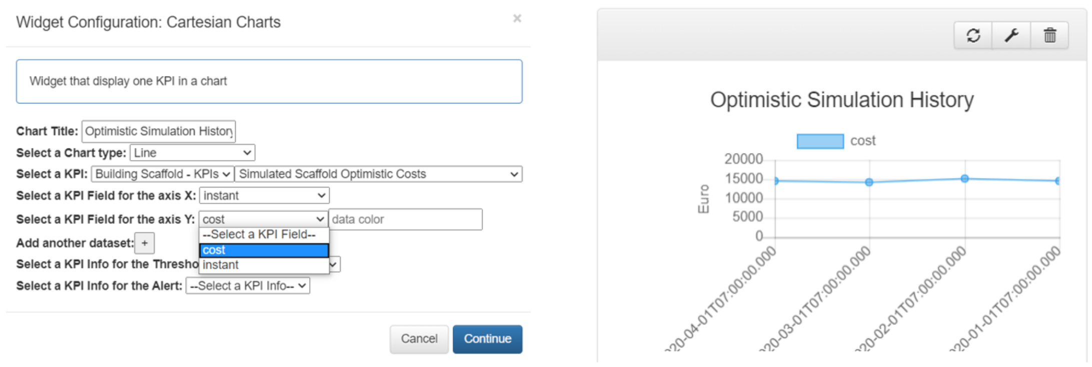
The dashboard accept KPIs models provided in a specific JSON format. The Renovation process KPIs design tool provide a feature to export the KPIs and data model in such specific JSON format. This model is processed by the model interpreter component that have the responsibility to create an internal representation of the model collecting all the dependencies, the calculation methods and the data sources for all the KPIs, goals and metrics in the model.

Such model information are processed by the KPI core component that is responsible to call the microservices described in the model in order to retrieve the data, apply the calculation functions as described in the model and make the resulting values available for the user interface. The interaction of the KPI core with the different microservices is helped by a DAO component that provide also caching features and an optimized microservice communication. The functions are evaluated in a component that is able to interpret and validate them in order to avoid security issues.

When the evaluated KPIs and Goals are available will be provided to the UI component on widget request. The widget manager component is responsible to manage the interface for the creation and configuration of the different widgets giving them also access to the calculated data.

The dashboard provide out of the box four most commonly used widgets but extension are possible through a plug-in based mechanism:

- **Chart widget**: is able to visualize a KPI value in a Cartesian chart. The user can configure the type of chart to use, choosing between horizontal bar chart, vertical bar chart, line chart, curve chart and radar chart and after that can specify which KPI field show for every axis and an optional threshold line. As example the “Simulated Scaffold Optimistic Cost” KPI containing the data fields “cost” and “instant” can be visualized in a line chart selecting for the X axe the “instant” field and for the Y axe the “cost” field.


Widget Configuration: Cartesian Charts

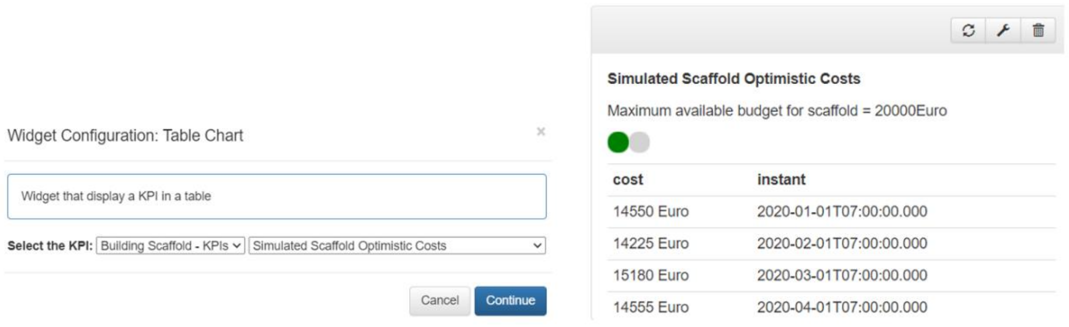
Widget that display one KPI in a chart

Chart Title: Optimistic Simulation History
Select a Chart type: Line
Select a KPI: Building Scaffold - KPIs | Simulated Scaffold Optimistic Costs
Select a KPI Field for the axis X: instant
Select a KPI Field for the axis Y: cost | data color
--Select a KPI Field--
cost
instant
Add another dataset: +
Select a KPI Info for the Thresho
Select a KPI Info for the Alert: --Select a KPI Info--

Cancel | Continue

Figure 12 - KPI dashboard chart widget

- **Table widget**: this widget allow to visualize all the details of a configured KPI in a table format. All the values will be visualized as well as evaluation of the KPI status with a green, yellow, red indicator.


Widget Configuration: Table Chart

Widget that display a KPI in a table

Select the KPI: Building Scaffold - KPIs | Simulated Scaffold Optimistic Costs

Cancel | Continue

Simulated Scaffold Optimistic Costs

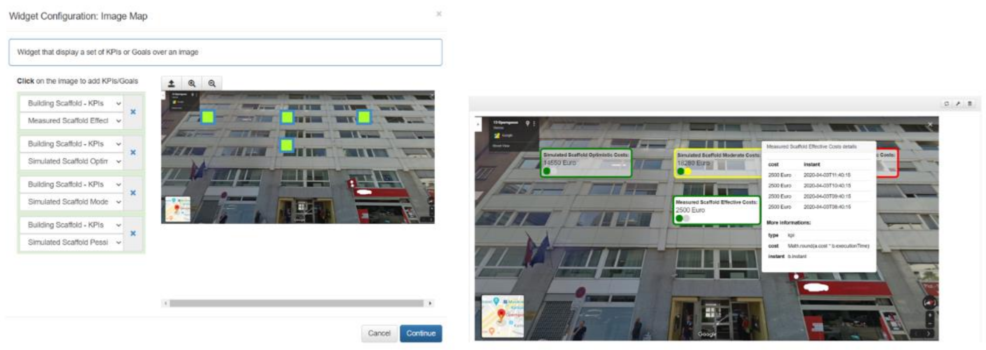
Maximum available budget for scaffold = 20000Euro

●

cost	instant
14550 Euro	2020-01-01T07:00:00.000
14225 Euro	2020-02-01T07:00:00.000
15180 Euro	2020-03-01T07:00:00.000
14555 Euro	2020-04-01T07:00:00.000

Figure 13 - KPI dashboard table widget

- **Image widget**: This widget allow to overlay one or more KPI details over an image. The KPIs are displayed with a color code that reflect the KPI status and details are visualized moving the mouse over the indicator.



Widget Configuration: Image Map

Widget that display a set of KPIs or Goals over an image

Click on the image to add KPIs/Goals

Building Scaffold - KPIs	Measured Scaffold Effect
Building Scaffold - KPIs	Simulated Scaffold Optim
Building Scaffold - KPIs	Simulated Scaffold Mode
Building Scaffold - KPIs	Simulated Scaffold Pessi

Simulated Scaffold Optimistic Costs: 14550 Euro

Simulated Scaffold Moderate Costs: 18280 Euro

Measured Scaffold Effective Costs: 2500 Euro

Measured Scaffold Effective Costs details

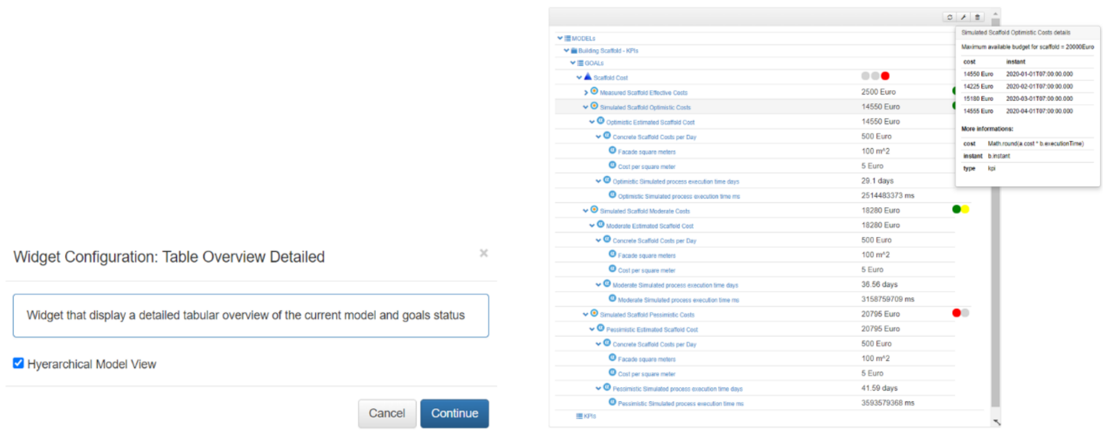
cost	instant
2500 Euro	2020-04-03T11:40:15
2500 Euro	2020-04-03T10:40:15
2500 Euro	2020-04-03T09:40:15
2500 Euro	2020-04-03T08:40:15

More informations:

type	kpi
cost	Math.round(a.cost * b.executionTime)
instant	b.instant

Figure 14 - KPI dashboard image widget

- **Tree widget**: This widget allow to visualize all the KPI in a collapsible tree view organized hierarchically or linearly on their dependencies. In this way is possible to identify the root cause of a problematic KPI or goal simplifying the behavior analysis.



Widget Configuration: Table Overview Detailed

Widget that display a detailed tabular overview of the current model and goals status

[✓] Hyerarchical Model View

```
MODELs
  Building Scaffold - KPIs
    GOALs
      Scaffold Cost
        Measured Scaffold Effective Costs                     2500 Euro
        Simulated Scaffold Optimistic Costs                   14550 Euro
          Optimistic Estimated Scaffold Cost                  14550 Euro
            Concrete Scaffold Costs per Day                   500 Euro
              Facade square meters                            100 m^2
              Cost per square meter                           5 Euro
            Optimistic Simulated process execution time days  29.1 days
              Optimistic Simulated process execution time ms  2514483373 ms
        Simulated Scaffold Moderate Costs                     18280 Euro
          Moderate Estimated Scaffold Cost                    18280 Euro
            Concrete Scaffold Costs per Day                   500 Euro
              Facade square meters                            100 m^2
              Cost per square meter                           5 Euro
            Moderate Simulated process execution time days    36.56 days
              Moderate Simulated process execution time ms    3158759709 ms
        Simulated Scaffold Pessimistic Costs                  20795 Euro
          Pessimistic Estimated Scaffold Cost                 20795 Euro
            Concrete Scaffold Costs per Day                   500 Euro
              Facade square meters                            100 m^2
              Cost per square meter                           5 Euro
            Pessimistic Simulated process execution time days 41.59 days
              Pessimistic Simulated process execution time ms 3593579368 ms
  KPIs
```

Simulated Scaffold Optimistic Costs details

Maximum available budget for scaffold = 20000Euro

cost	instant
14550 Euro	2020-01-01T07:00:00.000
14225 Euro	2020-02-01T07:00:00.000
15180 Euro	2020-03-01T07:00:00.000
14555 Euro	2020-04-01T07:00:00.000

More informations:

cost	Math.round(a.cost * b.executionTime)
instant	b.instant
type	kpi

Figure 15 - KPI dashboard tree widget

At the end the UI component is responsible for the rendering of the configured widgets in a docked layout that the user can configure resizing and moving the widgets around the page with a drag and drop mechanism.