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RENOVATION 4.0

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Abbreviations

BPMN	Business Process Model and Notation
BPMN DI	BPMN Diagram Interchange
DES	Discrete Event Simulation
KPI	Key Performance Indicator
PWMA	Process and Workflow Management and Automation

EXECUTIVE SUMMARY

This document introduces renovation process management as one approach within the BIM Ecosystem. Modelling of renovation processes is used to introduce a process-oriented structure into the BIM tools and data with the goal to enable a process-oriented simulation, execution and monitoring to manage costs and times of renovation projects. The process model is conceptually defined as a directed graph with additional attributes that introduce a domain-specific context. Hence, simulation, execution and monitoring can be in general applied to all process models, whereas additional aspects can be added to fit the domain-specific purpose of BIM-based renovation projects.

We apply the well-established Plan-Do-Check-Act framework (Gidey et al., 2014; Meiling et al., 2014; Lundkvist et al., 2014) by introducing a **design phase** (Plan), an **execution phase** (Do), a **monitoring phase** (Check) as well as a **reflection and improvement** phase (Act), in order to provide a decision support environment for renovation project managers.

The renovation process **design phase** and its corresponding tools enable the design, the analysis, the formal verification, the documentation and the transformation into executable formats of renovation processes. We propose full-fletched modelling tools that use standard BPMN notation to design a renovation process. The usage of analysis for queries, formal verifications and assessments ensures the consideration of domain-specific necessities – in our case cost and time relevant probabilities – as well as the documentation and transformation for both – human interpretation of graphical models and workflow engine interpretation of formal correct workflows. We consider renovation process templates in the form of: (a) Facade improvement outside, (b) Facade improvement inside, (c) Roof improvement outside, (d) Roof improvement inside, (e) Window exchange. Those templates are then transformed into processes for a concrete renovation project and if – needed also transformed into an executable workflow that guides the project manager.

The renovation process **execution and monitoring phase** with its corresponding tools support the execution of a renovation process - which is still executed manually on the construction site - with monitoring, simulation and workflow execution tools. The monitoring displays KPIs in form of actual or simulated time and costs. Times are indicated in duration or execution time, whereas costs are indicated as fixed or variable costs. Furthermore, KPIs are defined by planned or target figures, actual or current figures as well as estimated or simulated figures. The monitoring cockpit composes those factors to KPIs in order to present the different actual costs and times compared to the planned figures and provide a continuous simulation of the expected trend of those indicators. This trend calculation is performed by knowledge-based simulations, where past data and expert knowledge is extracted in the form of configuration files for simulations of the process models. This extracted knowledge can be iteratively improved, when creating a digital twin with extended log-files from a workflow engine. Relevant personnel, material and machine-rental costs as well as execution and duration times along the renovation process are continuously monitored and it is predicted how those costs and times will likely develop in the future.

The **reflection and innovation phase** and its corresponding tools support the collaborative reflection of a renovation project. Collaborative platforms enable comments on the decisions taken during the renovation process as well as enable the evolution of the extracted knowledge that is used for simulation and KPI calculation. In case the workflow engine created an enriched digital twin of the renovation process, process mining can identify improvement potentials out of the log-files.

The next steps are (a) lifting the process design to full-fletched modelling, (b) introducing artificial intelligence, (c) enriching the digital twin of the process, and (d) raising the interconnection with other BIM tools, which will be elaborated in the second iteration of this deliverable (D6.3).

1. INTRODUCTION

1.1 OBJECTIVES OF THE DELIVERABLE

This deliverable provides the first set of renovation process, KPI, data and workflow models.

Renovation processes describe the sequence of tasks that are necessary in order to start from the existing building and result in the renovated one. Typically, a process is continuously triggered and runs often in the form of multiple instances of the same process. In the case of the renovation process, we observe the logical sequence of tasks of companies that perform – continuously and in form of multiple instances - the renovation of buildings. The management of those renovation processes can have several objectives like: (a) Raising the quality due to documentation and standardisation, (b) Involving relevant stakeholders for contribution, reflection and knowledge extraction by using semi-formal graphical models, (c) Raising efficiency in form of optimising times and costs, (d) Extracting process-specific knowledge from human domain experts that can be considered and used by smart software as well as (e) Providing a know-how platform across the whole socio-technical ecosystem of a renovation process to design, monitor and innovate the complex dependencies of the ecosystem. However, there is a variety of objectives for the management of renovation processes besides the mentioned ones.

The renovation domain leads to the emergence of some challenges. The **first challenge** is that every renovation project of a building has its own – use case specific – characteristics, hence it has more the behaviour of a "project", which in contrast to a "process" is usually performed only once. In order to apply the aforementioned objectives, the first challenge is hence to abstract the concrete use case specific renovation projects to such a level that process management can be applied. Therefore, the correct level of abstraction, we call it the appropriate "flying height", needs to be identified with the goal to stay concrete enough in order to apply standardised documentation, raise potentials for higher efficacy and apply knowledge-based algorithms. On the other side, we must stay abstract enough in order to keep the processes simple and manageable and not "destroy" any potential benefit of efficiency with the costs of process management.

The **second challenge** is to identify the appropriate part of the overall ecosystem, where the management of renovation processes and process-oriented decision support system using knowledge-based algorithms has the potential to provide sufficient benefit. Analysing the different phases of a renovation project, the "*cost calculation*" during the "*architectural and design phase*" as well as the "*budget control*" during the "*construction renovation implementation phase*" are candidates, where renovation process management is potentially beneficial.

The **third challenge** is to introduce smart algorithms that can interpret the models and the additionally provided knowledge in order to apply so-called "knowledge-based" algorithms. Knowledge can either be provided in human or software interpretable form. Human interpretable knowledge can be the design of graphical models, the entering of assessments and opinions in form of estimated input figures or the description and commenting for instance. On the contrary, semantic specifications, rules, adaptive algorithms, fuzzy logic or machine learning belong to the software interpretable knowledge category.

Concluding the above, the main objectives of this deliverable are:

- Provide the correct level or abstraction to describe the renovation process
- Identify the relevant renovation processes and provide an initial set of process templates

- Indicate how algorithms that process the aforementioned models could provide decision support
- Explain how those findings can be applied in a concrete use case

1.2 Introduction of Taxonomy and Methodology

The process-oriented simulation of times and costs for renovation supports the decision making, based on estimated, simulated and measured times and costs that occur during the process of a renovation. This renovation process management environment is hence part of the overall tool-suite of Building Information Model (BIM) tools. Although the actual process model is not part of the BIM data structure, the process model accesses the data, which are defined in the BIM data structure.

Therefore, we position our process-oriented simulation of times and costs as a "Smart Decision Support Tool" that is specifically configured for the purpose of renovation processes and BIM-based data input.

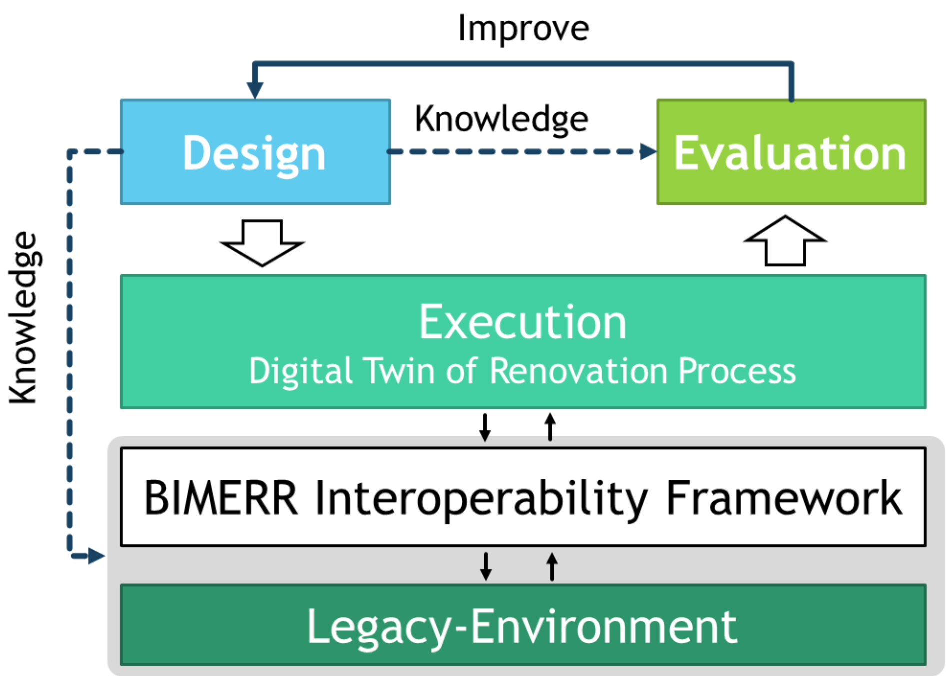


Figure 1: Process-Oriented Management of Times and Costs

Figure 1 introduces the overall approach, where:

1. The process is designed, structured and enriched with domain specific knowledge (Karagiannis & Woitsch, 2010; Woitsch & Karagiannis, 2005), so that the workflow environment is capable of creating a meaningful digital twin of the renovation process.
2. The digital twin is created mainly out of workflow logs – that are structured according to the designed process – and additional information retrieved to document the status, decisions and actions per time are stored.

3. The evaluation unit continuously monitors the process status, enables a forward-looking simulation and offers process mining on the digital twin of the renovation process.
4. In order to enrich the digital twin of the renovation process with real data from the legacy environment, the workflow is constructed in such a way that necessary information is acquired from the BIMERR interoperability framework (upon being extracted from the legacy environment).
5. Improvements and lessons learned are extracted based on the results of the evaluation and the comparison between planned vs. actual renovation process, as well as predicted simulation vs. actual occurrences.

1.2.1 Design of Renovation Processes

In this phase the decision makers create a business process similar to a task dependency plan that will be executed when the renovation process is started. In order to support user-friendly and efficient modelling of such renovation processes, we apply a so-called template repository, which consists of the most common pre-defined renovation processes. Those template processes can be selected for a concrete construction site and remodelled to a concrete business process that describes the renovation process in the same granularity as a project task dependency plan. Although there are conceptual and technical differences between a process and a project task-dependency plan, we consider it on this stage as similar for the purpose of an overall introduction.

1.2.2 Monitoring and Evaluation of the Execution of Renovation Processes

In this phase the aforementioned concrete renovation process is executed. Here we have different application scenarios identified:

a) Costs and times estimation to support "cost calculation" during the "architectural and design phase":

We refer to the overall "Best Practice Renovation Process"[1] that identifies different phases of performing a renovation process. In the second phase "Architectural Design of Renovation" there is an activity called "Cost Estimation for the Client".

In this phase, the contract with the client is not signed yet, but for making a proper offer, the renovation company needs to have a good cost and time estimation. At this stage, the aforementioned process templates are used to compose a renovation process for the concrete offer at hand on an abstract and not too detailed level for an indicative time, cost and risk assessment.

The provided simulation results are considered as a support for decision makers during the offer generation.

[1] D6.1, page 25, Figure 6

b) Preparation of simulation and measurement to support "budget control" during "construction renovation implementation":

We refer to the overall "Best Practice Renovation Process"[2] that identifies different phases of performing a renovation process. In phase 5 "Constructions and Renovation Project Implementation" there is an activity called "Budget Control, Work Progress Monitoring and Quality Inspection".

We support this task with detailed process monitoring in combination with a process simulation. The aforementioned high-level process model, which was used for estimating times and costs during the offer generation phase, is now transformed onto a detailed description level. We consider a similar level of detail like in the task-dependency plan used for the project management. The process model focuses on the logic of the execution, hence the task-dependency plan from the project management is used to provide the necessary input data for the simulation.

Once the correct level of detail has been achieved, the concrete and executable renovation process is exported to the workflow engine.

c) Costs and times simulation and measurement during "construction renovation implementation":

Our aim is to build a digital twin of the renovation process. Therefore, we digitize relevant aspects of the real-world renovation process that is executed on the construction site by using a workflow engine.

We start with actions, times and costs for the first creation of the digital twin and may add additional aspects in case this is considered as useful.

The workflow engine runs in parallel with the real-world renovation and creates a digital twin in the form of log-files. If required, status checking tools are accessed for the provision of information like human resources in hours, used material, used machines or amount of rents.

All those data assets are collected by the workflow engine and provided in form of extended log-files to our process-oriented dashboard.

The process-oriented dashboard can now:

- **Measure the current times and costs per status report**
- **Simulate the predicted times and costs based on potential risks in the future**

1.2.3 Innovation and Reflection of the Renovation Processes

Although the previous monitoring phase introduced a predictive simulation, it has to be stated that the extracted knowledge for this predictive simulation relies on experiences of the past. Hence, it is a valuable experience that can be used to better assess the current status of the renovation process, but still it is not an instrument to pro-actively design future challenges.

[2] D6.1, page 25, Figure 6

The next phase targets this issue by reflecting the past experiences, but also by triggering innovation to re-design the processes and to re-consider the experiences that are used for the simulations. In this phase the assumptions that have been taken during all aforementioned phases are reflected with the goal of implementing lessons learned by:

- Improving the process templates and their usage for the offering phase
- Improving the estimations performed in the offering phase
- Improving the transformation into executable processes, especially for simulation relevant artefacts
- Improving the calculations for the status measures
- Improving the expert know-how relevant for the risk assessment

Those improvements are performed using process mining and collective intelligence. Process mining is applied to analyse – after the renovation has been finished – how the renovation process – here we can only refer to the digital twin, hence the virtualized process – was performed and if potential improvements can be identified. Collaborative reflection of the renovation process is performed by using social media – in our case Wiki Pages – to collect expert opinions on the renovation project and extract improvements based on this feedback. The goal is to enlarge, enrich and improve the available process templates and the corresponding simulation relevant information, and hence improve the next life cycle of a renovation process.

1.3 STRUCTURE OF THE DELIVERABLE

The deliverable addresses the aforementioned objectives in form of:

- **Chapter 1** introduces the context of the deliverable and provides an overview of the used terms and the applied methodology for writing this document.
- **Chapter 2** introduces the different abstraction levels of a renovation process and elaborates on which algorithms and consequently which types of results can be expected for each abstraction level of the renovation process model.
- **Chapter 3** introduces in more detail, how renovation processes can be monitored by applying algorithms that interpret models in order to assess the current status of the renovation process and predict the future behaviour using simulation.
- **Chapter 4** introduces in more detail, how renovation processes can be improved by reflecting and innovating the current process instances and how to intellectually and creatively propose changes in the process models or in the extracted knowledge that is used when interpreting the process models.
- **Chapter 5** provides the initial repository of renovation process templates that describe the most common initiatives and hence act as a basis for the use cases. This set includes (a) Roof Improvement Outside, (b) Roof Improvement Inside, (c) Facade Improvement Outside, (d) Facade Improvement Inside, (e) Window Exchange.

- **Chapter 6** demonstrates, how a selected process from the template repository can be prepared for a particular use case in order to apply the monitoring as well as the reflection and innovation of the concrete faced improvement outside process. This section acts as a sample transformation that can be used as a guideline and reference case to transform high-level process templates to specific use cases.
- **Chapter 7** explains the roadmap of the following deliverables and how knowledge-based algorithms are introduced to improve the management or renovation processes.

2. DESIGN OF RENOVATION PROCESS AND WORKFLOW MODELS

Our process-oriented approach puts the renovation process in the centre in order to build a digital twin that is structured considering the renovation process model, and consists of values according to time stamps, cost calculations as well as additional domain-specific information that is provided by domain experts. Consider that the renovation process model is mostly used in the renovation process simulation tool, whereas the renovation workflow model by the adaptive workflow management and automation tool.

2.1 RENOVATION PROCESS TEMPLATE

First, the renovation process model needs to be created. We propose a manual creation of so-called templates that describe the most common renovation actions like: Facade renovation outside, Facade renovation inside, Roof improvement outside, Roof improvement inside, Window exchange, Heating system exchange, etc.

In the following lines, we introduce the different levels of granularity of the processes. The full figures are presented in the Annex, but for comparison reasons the processes are provided in here in one page to demonstrate the different variations.

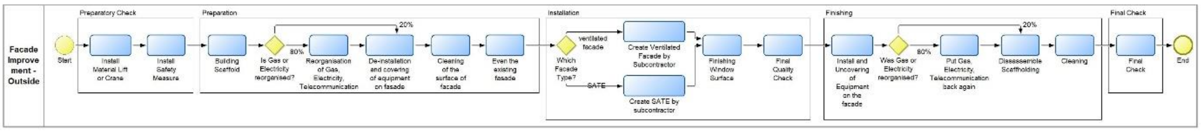


Figure 2: Renovation Process Template of "Facade Renovation Outside"

Figure 2 introduces the renovation process template for "Facade Renovation Outside". Each template consists of five phases, in which process- and phase-specific tasks are performed:

1. Preparatory Check – first preparation tasks on the construction site;
2. Preparation – preparations for the upcoming installations;
3. Installation – main part of the renovation process;
4. Finishing – finishing tasks such as cleaning; and
5. Final Check – final quality check.

The different variations of a process are realised in form of decisions, where those decisions are not on instance level, but describe different variations of possible processes on template level. Figure 3 indicates such a variation, where either a "ventilated facade" or a "SATE" is used for facade improvements. The variation that one of the two facade types can be used, is only on template level, as in a concrete use case, the facade type is defined, and hence there is no need for a decision.

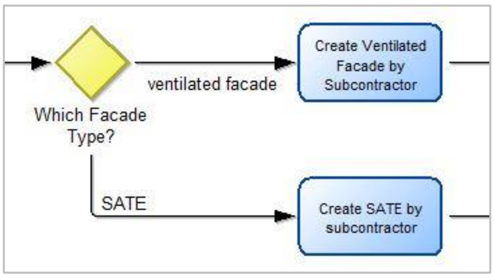


Figure 3: Sample of Process Variation

This template is transformed into a concrete renovation process where: (a) a particular process variation is selected and (b) all relevant templates that are used for a concrete use case are combined to one renovation process.

2.2 Renovation Process Model

The concrete renovation process describes the process for a specific use case on a business level. This means that no technical details and no resource allocations are performed but the sequence of actions that is required is defined.

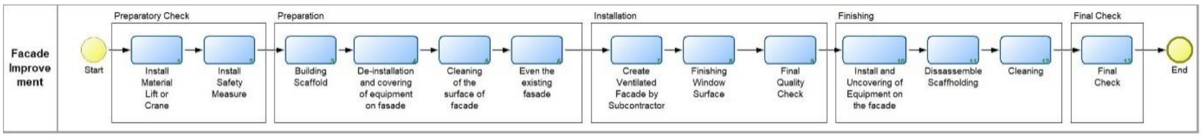


Figure 4: Concrete Renovation Process of “Facade Renovation Outside” (Annex: Figure 50 ff.)

Figure 4 shows a simple transformation from the template to the concrete process. This simplified process representation enables simulations and monitoring of times and costs. As the activities are on a high level, the simulations are rough estimations. However, they can already incorporate expert knowledge for analysing the probabilities of times and costs.

The transformation from the template to the concrete process was performed by deciding which process variation is selected. It has to be stated that more advanced transformations like including additional templates or highlighting a particular part of the process is possible.

2.3 Renovation Workflow Model

Finally, we approach to the most detailed process model that can be used for execution. In case a process model is used for execution, it has to be on the same level of detail, as the actual execution takes place. A simple transformation of our “Facade Renovation Outside” concrete process into an executable process for a three-month period is indicated in Figure 5.

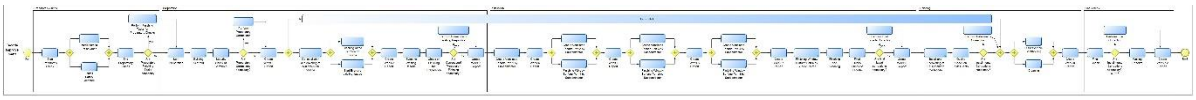


Figure 5: Executable Renovation Process of “Facade Renovation Outside” (Annex: Figure 52 ff.)

The relation between the executable renovation process and Process and Workflow Management and Automation (PWMA) is twofold: its execution (a) **assists the project manager** in observing and managing the renovation process; and (b) accesses data repositories on pre-defined key points in order to **create a digital twin** of the process with status log-files that are enriched with legacy data and pre-defined structure process semantics (Woitsch & Utz, 2015).

2.4 Renovation Process KPI Model

Key Performance Indicators (KPIs) are used to measure the performance of processes. Although a variety of KPIs[3] exists, here we focus on times and costs. Our performance measurement is based on actual data as well as simulation data, which allow a comparison of effective costs and planned costs. KPIs can evaluate a variety of aspects, in the specific case of a "Best Practice Renovation Process"[4] that considers "budget control" for (a) Material, (b) Equipment and (c) Manpower with the goal to control the **times and costs**.

The foundation for the renovation process is therefore to (1) keep the overall costs within a threshold, and to (2) finish the project within a set time limit. The KPI models distinguish between:

- Perspective that groups similar indicators, like grouping all "Financial" indicators or all "Time" or "Quality" dependent indicators. In our sample based on the user feedback, we calculate costs and times.
- Goals and sub-goals that describe the objective to be achieved – in our case "Stay within estimated budget" and "Finish the project within the agreed duration".
- Indicators that 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.

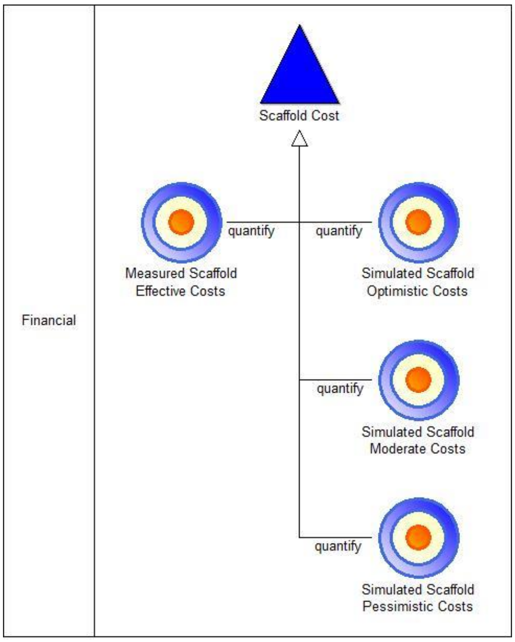


Figure 6: The Key Performance Indicator Model for the "Scaffold Cost"

The KPI model in Figure 6, gives an overview of the goal "Scaffold Cost" and the related KPIs "Measured Scaffold Effective Costs", "Simulated Scaffold Optimistic Costs", "Simulated Scaffold Moderate Costs" and "Simulated Scaffold Pessimistic Costs". For explaining the principle, we select only the scaffold costs of the renovation process, as it is a combination of costs of building the scaffold, costs of renting the scaffold over the duration and costs of removing the scaffold.

Hence the effective costs are initially estimated and considered as planned budget figures. They can be compared to the actual costs that occur when renting the scaffold, which are independent of the planned figures.

Those two values – the planned "should value" vs. the actual "is value" – are compared in the KPI "Measured Scaffold Effective Costs".

[3] D3.3

[4] D6.1, page 25, Figure 6

To improve the monitoring of the costs, the three simulation scenarios – optimistic, moderate and pessimistic – are modelled as additional KPIs, having the same planned value as the "Measured Scaffold Effective Costs" and can be compared with the simulated expected future costs.

The context of a KPI is modelled in the so-called attributes of the KPI, which is depicted in Figure 7.

The context of a KPI consists of its "***description***" like name, frequency of update, if the nature of the data is measured, calculated or estimated as well as if the KPI is an early warning, real-time status or late warning indicator.

Attributes in "***details***" enable the calculation:

The "*Field measure unit*" – in our case "Euro" for the "*Field name*" "costs" influences the format in which the value is displays.

The "*Data aggregation type*" defines, if the incoming data needs to be calculated or – in case of not aggregated – simply used as they come in.

"*Target range*" is the planned or should value and estimated with 20.000 in our sample, whereas the threshold is limited from the top by the "<" operator.

The threshold is set between 15.000 and 20.000 as the alert colour "yellow" indicates in the alert range. This range enables also the indication of a green or red tolerance.

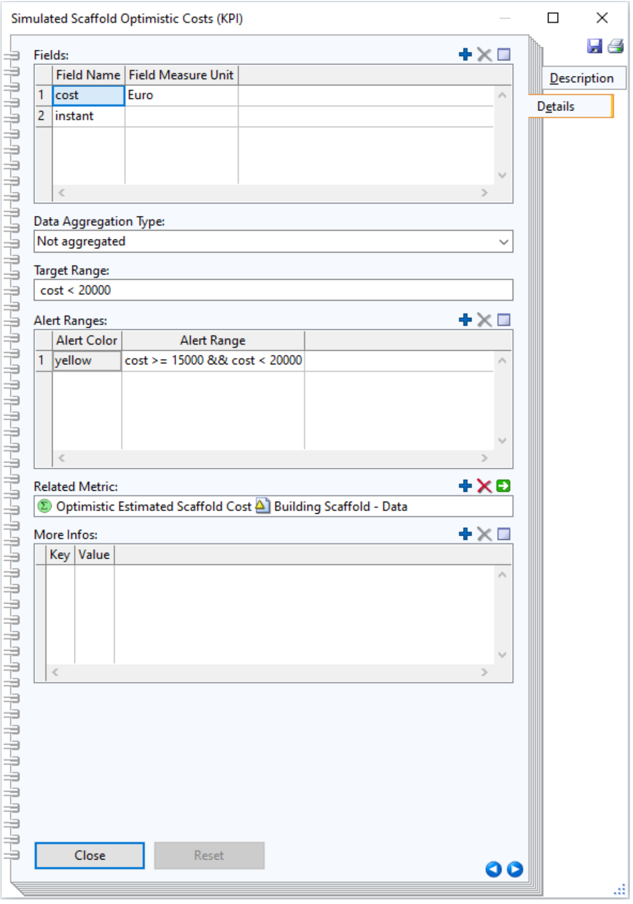


Figure 7: KPI Details

Each KPI is modelled as explained in Figure 7, whereas the "*Target range*" is estimated and the "*Alert ranges*" that describe the thresholds are based on "*experiences*" of experts.

The definition of the target range and the threshold is use case specific and depends on experiences of the involved knowledge experts. As a rule, the well-known SMART acronym is stated for completeness reasons (Doran, 1981):

- **S**pecific – not generic but specific to the concrete element that should be measured.
- **M**easurable – the indicators have to be measurable.
- **A**chievable – the goal should be ambitious but still achievable within reasonable effort.
- **R**esult-oriented – the goal should be measured according to results.
- **T**ime-bounded – the goal has to be achieved within a certain time.

The "*Related Metric*" attribute is a technical configuration that links the mentioned KPIs with the relative metrics that are described in the "Data Access Model". Hence, this KPI points to a data set that is further described in the data access model.

2.5 Renovation Process Data Access Model

Data models are required for creating a better understanding and expedited communication between managers, data analysts and other stakeholders (Werner & Woitsch, 2018). The data access model describes how the different metrics are calculated and which data sources are accessed. It consists of (a) the technical necessary data in order to access a data source and retrieve the correct data, but also enables (b) the semantic description of a particular metric that may be needed later on during the usage of those data.

For this purpose, we distinguish two types of objects:

- The "**Data object**" is considered as the "alpha-indicator", similar to the alphabet those objects provide the alphabet of the dashboard, from which "words" – in our case measures – can be composed in order to provide a certain meaning.
- The "**Measure object**" is the composition of alpha-indicators and hence are the "words" of the dashboard. A semantic description may introduce a certain meaning to the measure.

Figure 8 shows how the KPIs from the aforementioned sample "Scaffold costs" are realized on a technical data level. The data is collected, also from external sources, and calculated by defined metrics.

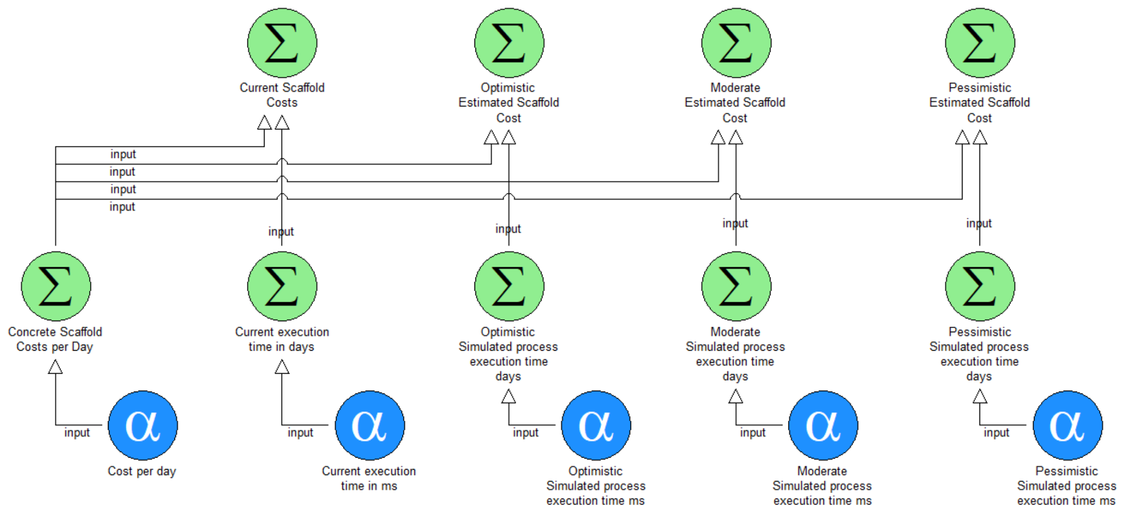


Figure 8: Data Calculation Model

Data objects describe how to access, log-in and retrieve data from specific external data sources.

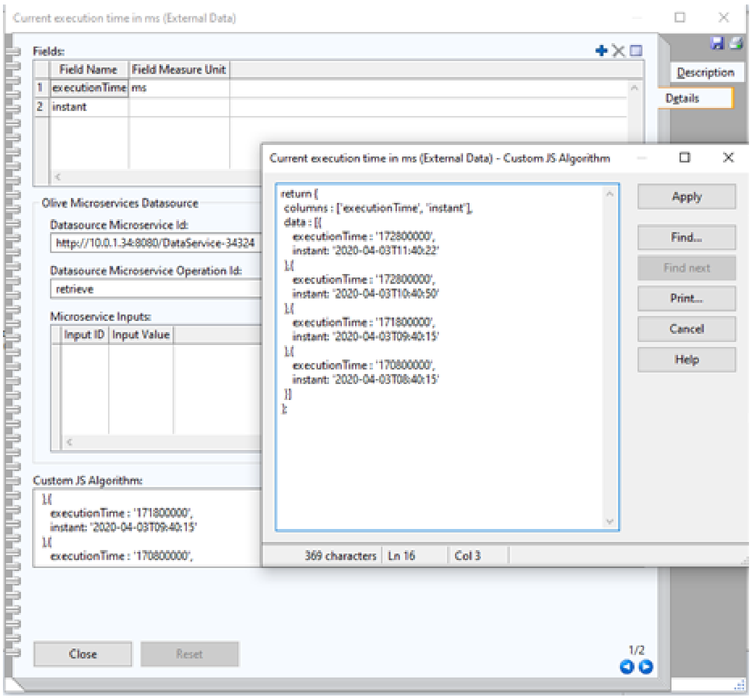


Figure 9: Data Access Specification

Figure 9 illustrates how the aforementioned blue alpha-indicators are configured in detail to access external data sources.

Beside the microservice ID and operation ID, the JavaScript algorithm that is executed at the data service side is configured. The return value is allocated to the "Field Name" in our case "executionTime".

In case an unknown third-party data service is needed, the recommended way is to realize a proxy object, which is described in the model here, and leave the interaction with the third-party data service to the program code in the proxy object.

The calculation and the semantic meaning is provided when modelling the metrics. Figure 10 provides a sample, where "Concrete Scaffhold Costs per Day" are multiplied with "Current Execution Time in Days". First, the inputs are allocated to the variables a and b, whereas the object – the reference written in blue – points to the two measures in the model "Concrete Staffhold Costs per Day" and "Current Execution Time in Days".

The *"Fields"* box then uses JavaScript code to calculate the results based on a predefined formula for the sake of example a.cost*b.executionTime, where "cost" and "executionTime" are the fields of the corresponding measures.

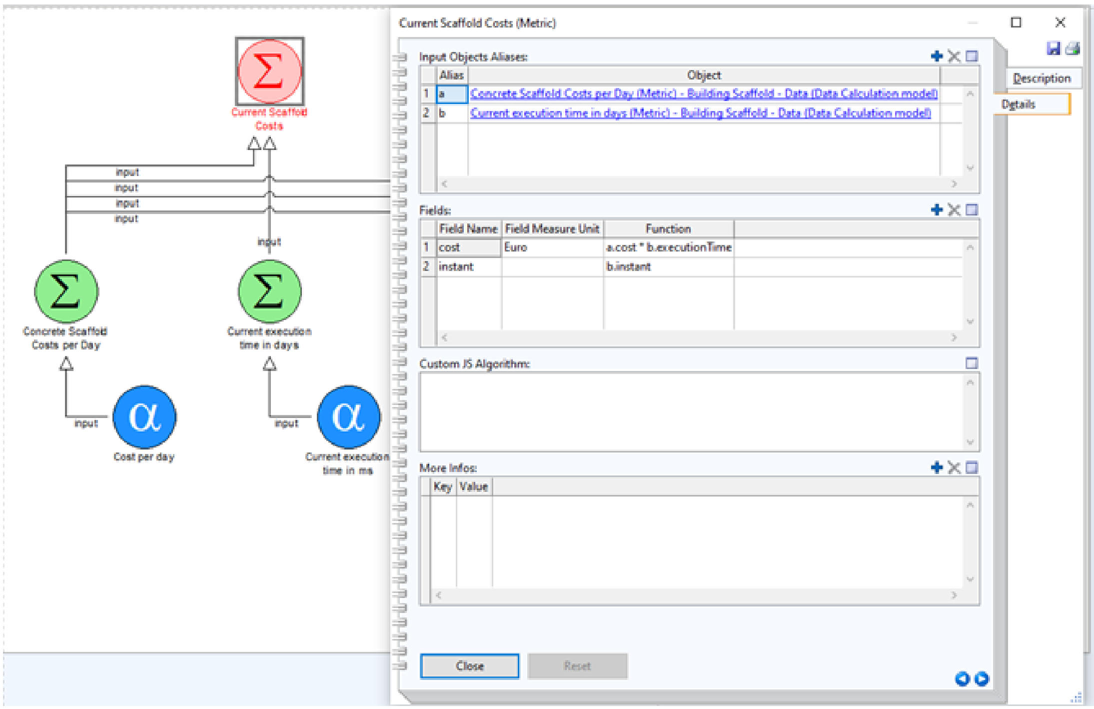


Figure 10: Metric Input and Calculation

Those data access models enable to use the data-sets with intended meaning independently of how the underlying software is programmed or configured. The relevant knowledge to calculate and interpret the data is extracted and stored in a tool-independent way in the model.

3. MONITORING AND EVALUATION OF RENOVATION PROCESS AND WORKFLOW

We applied a process-oriented approach that puts the renovation process in the centre of interest for the creation and usage of a digital twin, which is structured according to the renovation process model. It is composed of time, costs as well as additional domain-specific information provided by domain experts.

This section describes how to use the domain-specific knowledge for:

- Process-Monitoring for Decision Support;
- Process-Simulation for Decision Support;
- Process-Execution for Enrichment of Digital Twin.

In order to see the whole architecture and technical details, we refer to D6.4 Renovation Process Simulation Tool 1.

3.1 RENOVATION PROCESSES-ORIENTED MONITORING

3.1.1 Models-based Monitoring Dashboards

A core element of the decision support tools is to represent the current status in form of a dashboard or alternatively called cockpit to the decision makers. There are several different approaches available that are basically distinguished in:

(a) The capabilities to represent the current status in form of visualizations, filter, compare or search features as well as analysis, drill-down or documentation capabilities and finally the possibility to involve other decision makers to perform cooperative decision making;

(b) the data algorithms that are applied to collect, abstract, calculate and introduce a meaning to the data that are represented, as well as technology-specific characteristics like close-to real-time monitoring, introduction of artificial intelligence or human decision makers in the knowledge provision or interpretation as well as the specific data characteristic and format.

Renovation process-oriented monitoring introduces a complementary process-oriented context to the data algorithms. The aforementioned Renovation Process KPI models introduce the context of indicators and enable additional semantic enrichment on how the indicators are collected, manipulated and interpreted. This information is provided in the form of the trivial KPI model.

In cases where knowledge-based analysis, for instance fuzzy-logic, rule-based algorithms, semantic lifting or similar approaches to introduce artificial intelligence (Nilsson, 2014) into the data algorithms, is requested, the aforementioned KPI models need extensions to also cover these aspects. This deliverable introduces the basic set of KPI models: hence, it provides the data access, data calculation and the basic KPI representation information.

To deliver a complete solution, a dashboard with basic features on how to represent the aforementioned modelled indicators is also provided. The introduced dashboard is entirely based on models that enable the link between externalized knowledge and data. Since the scope of this deliverable is to introduce

the concept of a process-oriented monitoring and not present the technical capabilities of our provided dashboard, the following subsection uses the open source dashboard from the Microservice platform OLIVE[5] just to demonstrate how the modelled concepts can be used for a monitoring dashboard with the aim to support decision makers.

3.1.2 Process-Oriented Monitoring Cockpits

Dashboards are created for each use case, hence the process history for each renovation instance is monitored. We introduce the following concepts, as they are important for monitoring cockpits:

- **Nested Monitoring-Aggregation** by aggregating several cockpits – e.g. several concrete use case cockpits from several sites are aggregated to an organisational wide cockpit.
- **Backward-looking monitoring and forward-looking simulations** using KPIs for the backward-looking monitoring or process-simulations for the forward-looking simulations.
- **Process-Oriented context of cockpits** by introducing different phases and dependencies for each construction site, as well as dependencies between several in parallel running construction sites by running complex process-simulations where the individual construction site process simulations provide the simulation results, which are then aggregated for an aggregated status report of all simulations.

Nested Monitoring-Aggregation:

The management of several use cases, and the management of several renovation initiatives correspondingly, in parallel can be managed by a so-called hierarchy of cockpits.

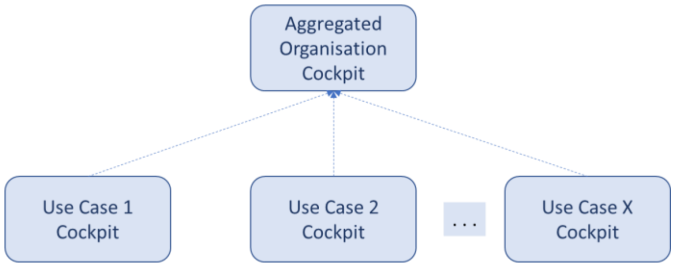


Figure 11: Hierarchy of Cockpits

The hierarchy of cockpits can be modelled by using a KPI from one cockpit and use it as a data source for an aggregated cockpit and so on.

This means that the data access object that defines the input data stream for an aggregated cockpit accesses the resulting KPI from a concrete cockpit.

Figure 11 indicates that several concrete use case cockpits can be aggregated to one "aggregated" cockpit, whereas several aggregated cockpits can again be combined to a higher abstraction and so on.

A simple version of nested KPI cockpit is performed by combining several individual renovation processes, for instance "Facade Renovation Outside", "Facade Renovation Inside" and "Window Exchange", which are three individual processes that are commonly performed in conjunction.

A KPI-cockpit that observes the overall project is possible by accessing the individual KPIs of the various renovation processes and provide a complete status report of the overall site. This principle can be extended to also include several sites and hence monitor dependencies between different construction sites.

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

Backward-Looking Monitoring and Forward-Looking Simulation:

The cockpit for a concrete construction site consists of KPIs that are defined by the decision makers as relevant to make informed decisions. This is demonstrated by the KPI "*Scaffold Cost*", which consists of (a) the construction, (b) the de-construction and (c) the rental costs for the duration of its use at the construction site. As the scaffold is used in a period of the overall renovation, it is a perfect example for monitoring (backward-looking) and simulating (forward-looking) the costs considering the actual time.

The actual costs occur when building the scaffold, whereas the costs of de-construction need also to be considered. The rental costs depend on the actual duration of the construction site, which may deviate from the project plan.

Here, we introduce the process-simulation that forecasts the most likely duration to continuously assess the probable duration to derive the corresponding costs. We propose three simulation scenarios, the optimistic, moderate and pessimistic scenario, that can be adapted to the requirements of the use case. Some KPIs do not need a simulation at all, or are appropriately covered with only one simulation, but there may be a KPI that is best simulated with several simulations.

Figure 12 shows a typical representation of KPIs using a picture from Google Maps of the location of the construction site and including the four KPIs: (a) actual scaffold costs as well as (b) optimistic, (c) moderate and (d) pessimistic scenarios of the simulated duration and the consequently resulting scaffold costs. An alternative representation are the graphs showing the history for each KPI. Colour codes – red, yellow, green – as defined in the KPI model display the status.

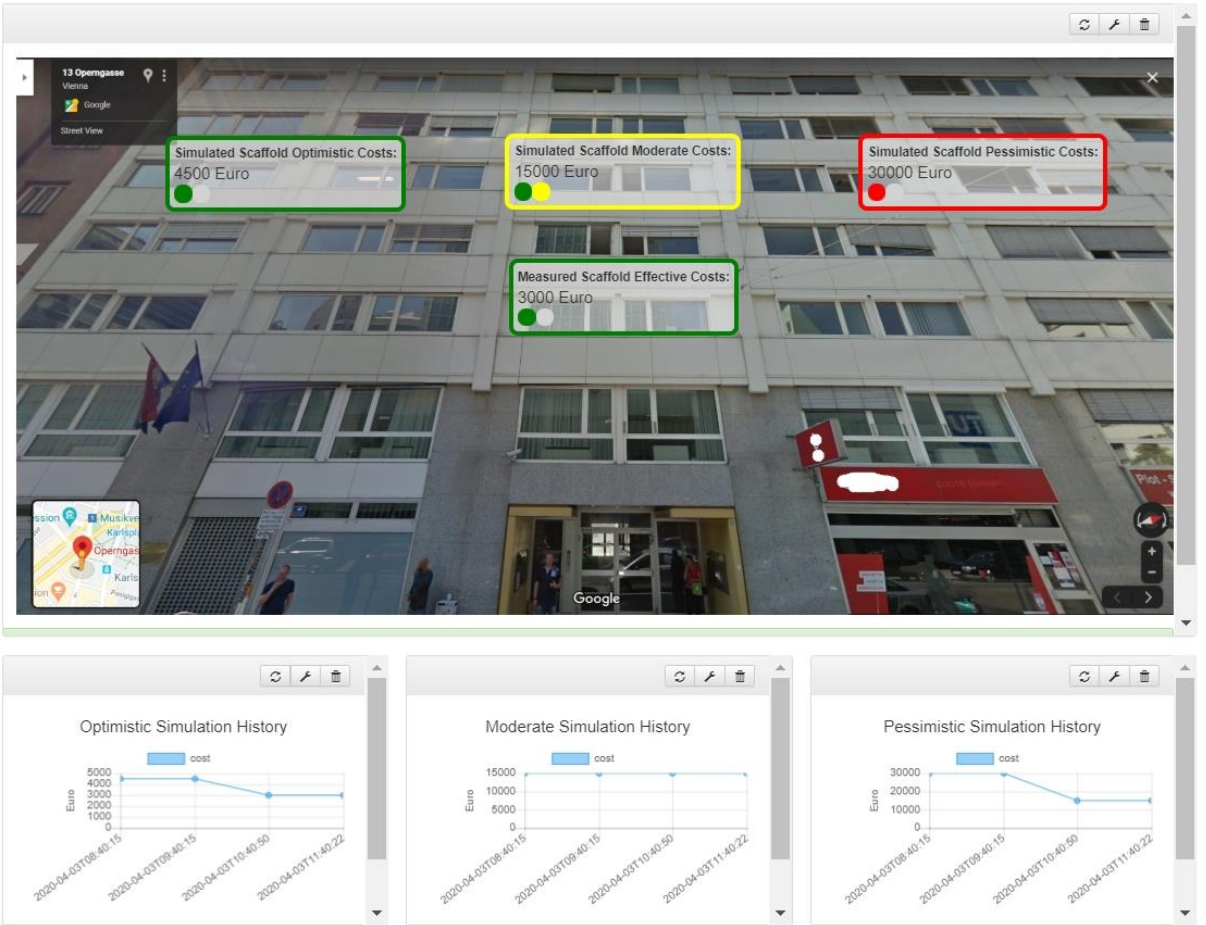


Figure 12: Backward-looking Monitoring and Forward-Looking Simulation of KPI-Scaffold Costs

Process-Oriented Context of Cockpits:

Figure 13 demonstrates the process-oriented context of the cockpit as the capability to link KPIs to different phases of the process. For each time slot, a process can be linked to the actual as well as the simulated KPIs.

The process-oriented representation also allows to drill the KPI down either in the process-oriented view, or as it is displayed at the bottom of the figure using the model-tree, which represents the KPIs as they are modelled in the KPI model.

Hence the process-oriented representation is first an alternative visualization of the cockpit and second the method to additionally introduce the linkage of a process phase to a concrete KPI.

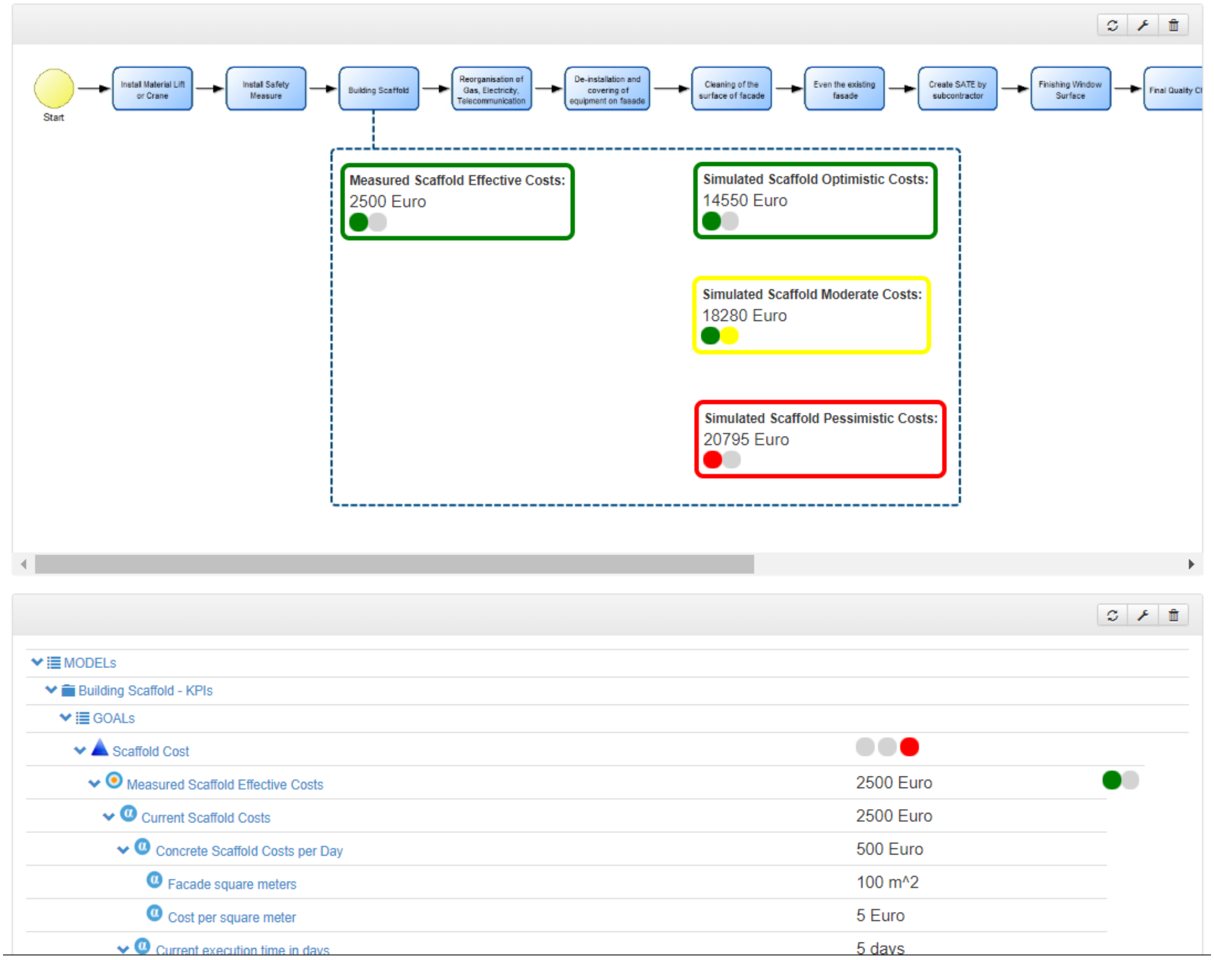


Figure 13: Simulation Output for KPIs

The intension is that a cockpit 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 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 cockpits. A simple simulation of one renovation process for the simulation of one KPI will be introduced in the next section.

3.2 Simulation of Renovation Processes

The simulation of a renovation process complements the monitoring by providing a forward-looking simulation of the renovation process and hence estimates the expected duration and execution time. Consequently, the different costs can be derived using the results of the simulation.

3.2.1 Introduction into Process Simulation

For the explanation of the principle, we focus on time, although other parameters can also be simulated, (Tumay, 1996). Figure 14 shows a traditional Discrete Event Simulation (DES), where the process is interpreted as a directed graph and the time a so-called token needs to pass the directed graph is measured, (Fishman, 1978). Performing this some thousand times, the interpretation of the different results – some tokens need less time, some more – provide a better description of how the process will likely behave in future.

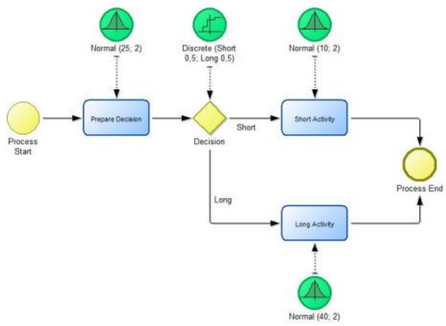


Figure 14: Process Simulation

In our sample, we distinguish different types of distributions, first a normal distribution that indicates that sometimes the activity is performed slower and sometimes quicker, as well as a discrete distribution that indicates that either the short path or the long path has to be performed. Based on the normal distribution on the activities and based on the discrete distribution on the decision, the execution time of the process is different. In a first step, the weights and distributions are estimated. Afterwards, adaptions and improvements can be conducted by applying process mining for instance. Parameters, weights and distributions are changed until they can be externalised in the form of key learnings.

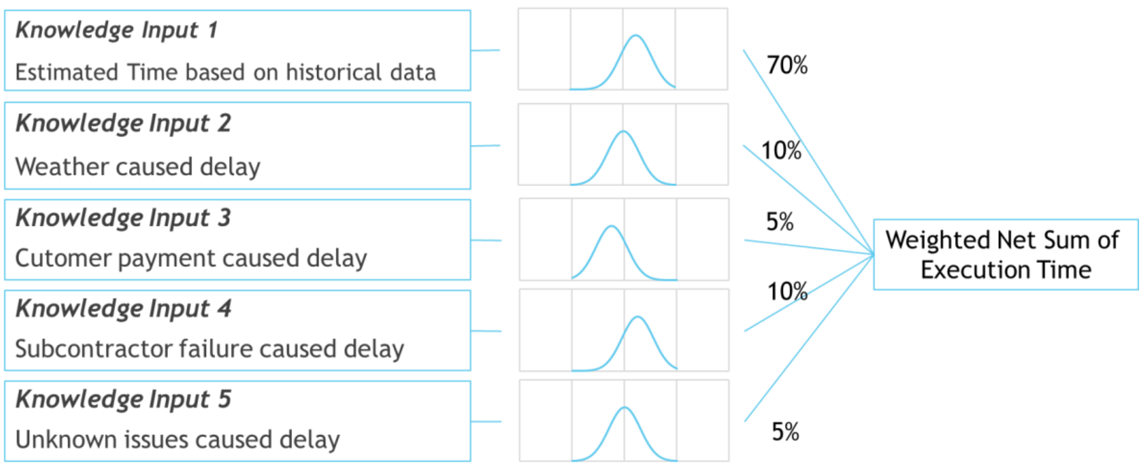


Figure 15: Mechanisms for "Knowledge-based Simulation"

Our "knowledge-based simulation" introduces a finer grained calculation of probabilities and distribution by introducing the concept of "weighted net sum" and applying it on the parameter of interest, as Figure 15 depicts. In our sample case, the "scaffold is in use" time is the parameter of interest as it is the basis to calculate the scaffold rental costs.

To calculate the respective weighted net sum the following inputs are used:

- Input 1 is historical data that provides the base distribution for the expected time;

- Input 2 is an estimation on the weather conditions causing a delay in the facade renovation;
- Input 3 quantifies the potential risk that the customer does not pay and therefore the construction site needs to pause – with the rental costs of the scaffold to be continuing;
- Input 4 refers to the potential risk that the subcontractor does not perform according the contract, hence a substitute needs to be put in place – with the rental costs of the scaffold to be continuing;
- Input 5 indicates the likelihood of unexpected risks that may cause a delay.

Each of the knowledge input assets is described with the mathematical distribution and the weighted net summary calculates to what extend the various effects are considered.

The expert input hence needs to clarify (a) the **mathematical distribution** and (b) the different **weights** for the net summary. Both parameters are estimations that are first plausibly proposed, and continuously improved in form of observations and collaborations among experts to gain a setup that represents the individual expertise of a particular organization.

This process granularity allows forward looking simulations and enables the comparison with backwards looking measures. In case the knowledge needs to be represented on a more detailed level, the concrete process is detailed, hence the corresponding simulation can be detailed.

It has to be stated that detailing the concrete process and the corresponding knowledge-based simulation becomes very complex, hence the benefit of a good simulation that warns for delays can be compensated by the effort of too detailed modelling. Therefore, the level of granularity of the concrete process strongly depends on the costs that arise in case of a threat that is simulated.

3.2.2 Extraction of Expert Knowledge about the Process

The knowledge which is used for the simulation is provided in the form of an input Excel file together with the corresponding renovation process model in BPMN Diagram Interchange (BPMN DI) format. Notice that the Excel file is a basic approach to share the content between various cooperating systems. In particular, here it is a means of intercomponent data sharing. A more advanced option could be a database interface for instance.

For each simulation run, a unique identifier with a corresponding start time is provided. Figure 16 introduces a simple simulation, where a default deviation is applied to the provided time, which is provided as milliseconds for each activity. A loose coupling concept is provided here for the implicit mapping of semantics onto the tasks. In particular, the process tasks are mapped to the tab "C_TASK". Moreover, the row number indicates the order of the tasks of a specific process instance and simulation relevant parameters are mapped to column D.

	A	B	C	D	E	F
1	Install Material Lift or Crane	2019-06-03T07:00:00	1448892	default		
2	Install Safety Measure	2019-06-03T07:00:00	1240270	default		
3	Building Scaffold	2019-06-03T07:00:00	1531233	default		
4	Reorganisation of Gas, Electricity, Telecommunication	2019-06-03T07:00:00	1465932	default		
5	De-installation and covering of equipment on fasade	2019-06-03T07:00:00	1452233	default		
6	Cleaning of the surface of facade	2019-06-03T07:00:00	1542882	default		
7	Even the existing fasade	2019-06-03T07:00:00	1447758	default		
8	Create SATE by subcontractor	2019-06-03T07:00:00	1414080	default		
9	Finishing Window Surface	2019-06-03T07:00:00	1626861	default		
10	Final Quality Check	2019-06-03T07:00:00	1510817	default		
11	Install and Uncovering of Equipment on the facade	2019-06-03T07:00:00	1563641	default		
12	Put Gas, Electricity, Telecommunication back again	2019-06-03T07:00:00	1314383	default		
13	Dissassemble Scaffholding	2019-06-03T07:00:00	1418284	default		
14	Cleaning	2019-06-03T07:00:00	1467456	default		
15	Final Check	2019-06-03T07:00:00	1448293	default		
16						
17						

C_START_EVENT | C_TASK | C_EXCLUSIVE_GATEWAY | 1-Install Material Lift | 2-Install Safety Measure

Figure 16: Process Task List for Simulation

To extend the trivial simulation that introduces a standard deviation for each execution time per activity, Figure 17 shows the realization of the aforementioned knowledge-based simulation. The knowledge-based simulation consists of several columns, whereas each of the columns represents the extracted knowledge of an expert that is combined to calculate a weighted sum of the expected deviation for each activity. The calculated value is based on the mean and the deviation. Currently, we use the standard normal distribution of Excel with a given mean and a given standard deviation of the distribution to generate a random number, more sophisticated tools including the advantages of the design tools can be used in order to fill the Excel sheet.

Each value is multiplied by its corresponding weight to get the weighted value, which is then converted from milliseconds to the time that is appropriate for the use case.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1				Average Task Time				Payment Related Delay Time				Weather Related Delay Time				Sub-contractor Related Delay Time				Unforeseen Related Delay Time				
2		Weighted Caclulated time	Weighted Caclulated time	Calculated	Weight	Mean	Deviation	Calculated	Weight	Mean	Deviation	Calculated	Weight	Mean	Deviation	Calculated	Weight	Mean	Deviation	Calculated	Weight	Mean	Deviation	
3	3-Building Scaffold	1506861,391	25,11	23	0,60	20	3	31	0,10	30	3	28	0,10	30	3	28	0,10	30	3	28	0,10	30	3	
4																								
5																								

... | C_EXCLUSIVE_GATEWAY | 1-Install Material Lift | 2-Install Safety Measure | 3-Building Scaffold | 4-Reorganization of GET | 5-Deinstallation and Covering | 6-Cleaning of the Surface | 7-Even existing Facade

Figure 17: Calculation of weighted time considering risks

3.2.3 Simulation Output Data

The resulting simulation data is provided in an Excel sheet in the same format as the Excel file that is used for the input data – same tabs and columns. Having the same output format as the input format allows to run cascading simulations and use the results from one simulation to following simulations. Paths and traces both represent a sequence of actions. The difference between paths and traces is the presence of parallel tasks.

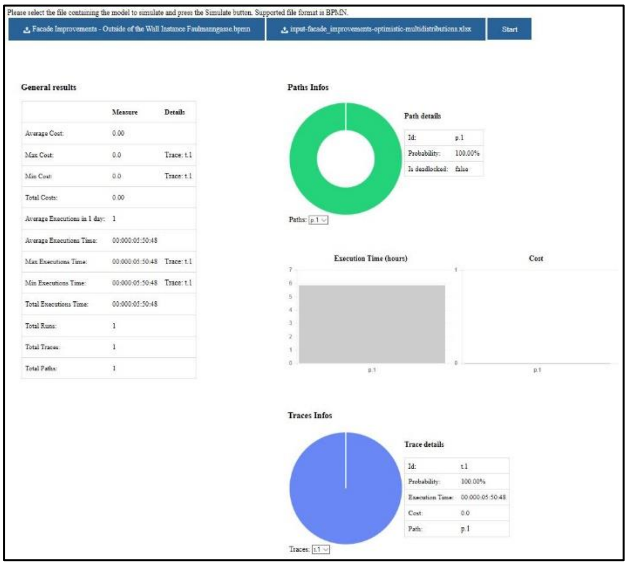


Figure 18: Visual Simulation Output

The trace shows the tasks ordered in a sequence, whereas the path considers parallel tasks in the same sequence. So, if there are two tasks in parallel, they belong to the same path. However, there can be two traces, as one task can be in front of the other in the trace sequence and vice versa.

In case of the renovation process this detail is important to distinguish between tasks that are performed by multiple sub-contractors – then the simple path analysis is sufficient, or performed by the same group of people like the same sub-contractor – then the more detailed view on traces needs to be considered.

Similarly, costs or dependencies may need detailed reflection via traces, in case the simple path analysis does not explain sufficiently the dependencies that occur in a certain sequence of actions. The simulation results shown in Figure 18 are used as an input for the monitoring cockpit in order to present the simulated KPIs. The drill-down of such a simulated KPI enables a more detailed analysis of the simulations results – e.g. the analysis of the paths and traces – by referring to the simulation result pages.

3.2.4 Trustworthiness of Simulation Results

Simulation results are estimations based on assumptions of possible future behaviours of a system. The challenge of trustworthiness is therefore twofold:

- To clearly indicate in the representation of the KPI, reliability displays of monitoring cockpits are worked out. The relevant figures for the KPIs can be based on three main data streams that might be compared for a higher trustworthiness:
  - **Measures** are straight forward. A sample would be that simply the occurrence of something, for instance the number of rainy days, is counted. The counts normally do not change, also if various people are counting the same occurrences.
  - **Estimations** are more complex, as those require specific knowledge. In most cases, domain experts might be responsible for the estimations, as those can narrow down the possible alternatives for figures best. Predictions and estimations cannot only be conducted by humans but also supported by artificial intelligence. The interpretations are taken over by a machine working with black-box (deep learning, neural networks) and white-box models (linear regression, decision trees)[6]. Black-box models tend to have observable input and output, however the procedures inside are not transparent.

[6] https://blog.dataiku.com/white-box-vs-black-box-models-balancing-interpretability-and-accuracy

On the contrary, white-box models can be better understood and observed, hence they are often less performant.

- **Calculations** can be supported by tools like a simulator. Keep in mind that such a simulator might lead to varying results for different simulation runs.

- To improve the reliability of the estimations and assumptions, a digital twin or the process is created, and the assumptions and estimations are approved using reflection techniques like process mining.

3.3 Creation of Digital Twin with Workflow Execution

Workflow execution is a crucial part of the whole process, since it is the real instance of the template, where all the effort with modelling and simulation is transformed to the real reconstruction work. The workflow is executed by the workflow engine, which creates the digital twin of the renovation process, so every real reconstruction activity has its own digital representation.

The transformation from the BPMN process including specific knowledge to a meaningful digital twin is conducted within the workflow environment. As already mentioned, a workflow engine is used for the digitisation. This workflow engine runs in parallel with the real-world renovation. The digital twin is mainly created by using workflow log files. Starts, ends of tasks and other required attributes are written to the log files, where attributes can be dynamically added, so every task can have own attributes, or predefined standard pack. This fact gives us the ability to create structured log file, which can be used for the next simulation phases. Real data from the legacy environment is used to enrich the digital twin by extracting information via the BIMERR interoperability framework.

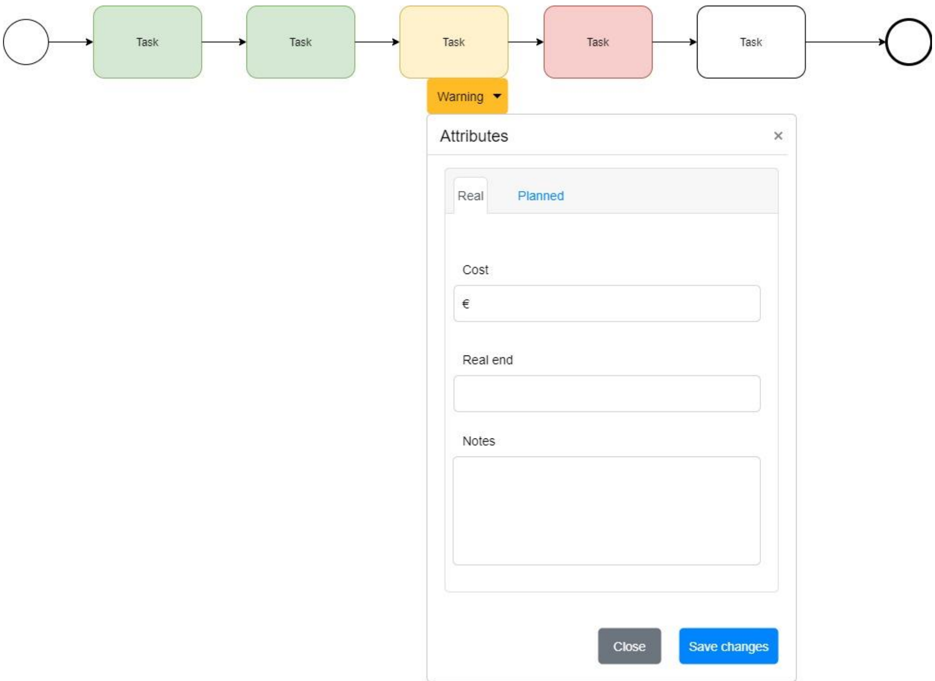


Figure 19: Mock-up of Workflow Execution

One main benefit of the workflow is that the reconstruction process can be tracked by the stakeholders in-time. This means that the project manager has an overview of the tasks, their assignments and their status. As visualized in Figure 19 (high-level) data for each task is collected and compared to the KPIs.

This enables the indication of problems at an early stage. The data, continuously collected and stored in execution logs, can be later used as a valuable source for analysis and better planning of future reconstructions. Moreover, automation in general and devices like smart glasses in specific can be used as a facilitator for generating value by using workflows.

As various abstraction levels might be required for explaining the concerns of company, domain and information technology, different workflows seem to be reasonable. In the following subsections, a first draft of the specific business and IT workflow for the facade renovation process can be found.

The main differences between the workflow focusing on business aspects and abstract workflow (Cloud-Socket Consortium, 2016) are shown in Table 1.

	Business Workflow	Abstract Workflow
Design Granularity	focus on performing activities, granularity depends on the expressiveness level	focuses on user interactions, depends on the technical detail and systems granularity
System vs. Role Lane	lanes represent roles	lanes represent systems (user role is stored as an annotation)
Task Type	not included	includes following task types: manual, service, user, send, receive, business rule and script tasks
Data Objects	included in high-level	more detailed regarding activity correspondence, additional information about data creation and interaction as well as data privacy
Sample Services	not included	references for service tasks are included to describe their intended functionality

Table 1: Business vs. Abstract Workflow

3.3.1 Business Workflow

The following aspects should be considered for the business workflow (Cloud-Socket Consortium, 2016):

1. **Person who executes** – All workers and other stakeholders executing the tasks have roles or organizational units. Lanes in BPMN are used to indicate the different players in the renovation process.
2. **Place of execution** – The construction site reflects the physical location, where the business process is performed.
3. **Time of execution changes** – Activities are performed continuously. In case of interruptions, for instance caused by the weather conditions, dividing the task in two activities with different starting and execution times might be reasonable.
4. **System change** – A separation of activities might be required due to changes in the working environment of the performers. For instance, if one construction worker gets ill and another has to cover for him.

5. **Data Object change** – Similar to the system change, the object that is manipulated – usually data objects – defines the activity border.

In specific, the business workflow should indicate the different actors in form of lanes and consider the aforementioned aspects.

The first draft of a business workflow belonging to the facade renovation process is shown in Figure 20. As explained above, lanes were created to show the roles and organizational units. Here, we have four in total: construction workers, management and controlling, reporting and subcontractors. The physical execution of the renovation takes place on the construction site. For sure, subcontractors have their own company location and there are additional office facilities for the reporting units for instance. A specific task with waiting reserve indicates that there can be interruptions due to weather conditions or other factors. The data objects, like report or check lists, are yet quite general for the business workflow.

In particular, talking about the usage of the scaffold, this might be seen as a task lasting for a period of time in the renovation process. However, this task must be divided based on the perspective. For the business-oriented workflow, one task for the whole period could be used. On the contrary, it is more reasonable to separate the usage of the scaffold in subtasks for the abstract workflow, as the systems should interact due to regular reporting statuses.

Currently, the physical reporting and the monitoring are sequential tasks in the business as well as the abstract workflow. There are two main options for the reporting: (1) sequential and (2) continuous. The sequential monitoring means that for instance the status at the construction site is controlled at the end of each week, whereas devices might support the continuous monitoring. Special monitoring devices or software on mobile phones could provide data about the location of the construction workers continuously, for example. More details how such apps can be integrated in the workflow will be elaborated in D6.4 Renovation Process Simulation Tool 1. Hence, one main question is, if sequential or continuous reporting and monitoring is more reasonable in the renovation domain and if there are differences considering specific construction sites.

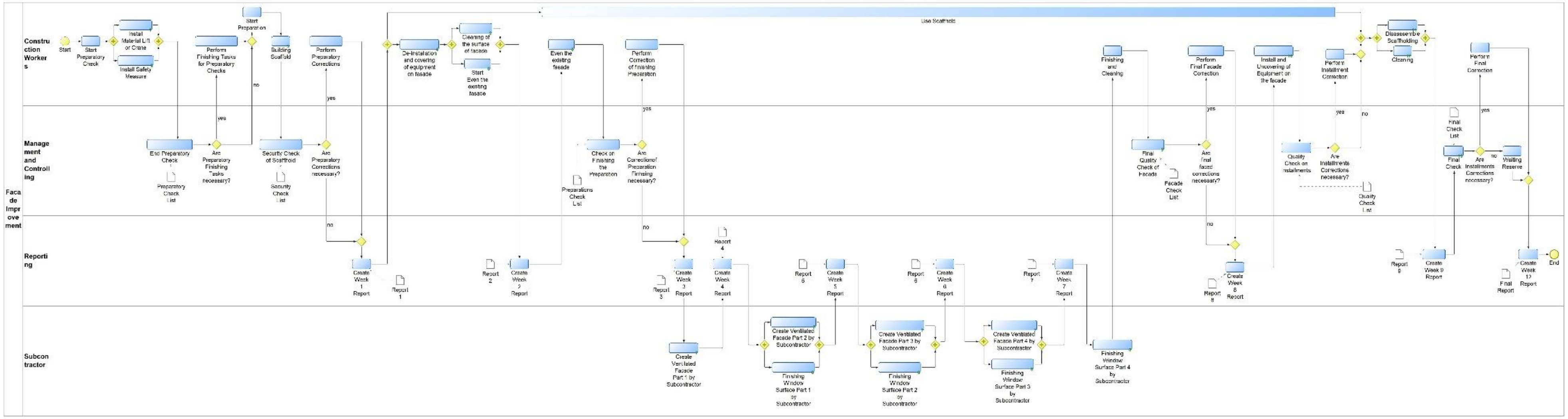


Figure 20: Business Workflow for the Facade Renovation (Annex: Figure 56 ff.)

3.3.2 Abstract Workflow

In the IT workflow, the so-called abstract workflow, more technical details are incorporated (CloudSocket Consortium, 2016). Descriptions on user, user interaction, key functionality, software, interactions, data objects, sequence flow as well as a description indicating the deployment or SLA information on a high level are provided.

In particular, the following aspects should be considered for the abstract workflow:

1. **User who interacts** – The different tasks are separated by different user accounts interacting with the user interface.
2. **User Context (Interface)** – The user context describes the user interaction with a software application as a separator of different abstract workflow activities.
3. **Event-based trigger** – Interruptions of events – a timer, a message, or any other form of interruption – can also be a separator of activities.
4. **System change** – The change of a system, modeled as lane, normally requires a separation of activities related to different lanes.
5. **Data Object change** – Changing data object usually requires separating activities. The data objects here are in more detail and rather technically oriented.

Summarizing, an abstract workflow lane represents a system and the activities stand for user interactions or processing including the corresponding user role. Events represent communication between systems or users. Name, usage and creation are used to detail the data objects (electronic file, collection of data or physical document).

Figure 21 (higher resolution can be found in Annex) represents a first draft of the abstract workflow for the facade renovation process. For creating the abstract workflow, four system lanes were used: construction and status tracking environment, decision support system and quality control, reporting system and subcontractor communication system. The systems send status and information messages to interact with each other. Those were introduced and indicate that the task sequence finished in one system is further processed in another system. Compared to the business-oriented workflow, the data objects are much more detailed. Their representation indicates, whether some data is an input, an output or belongs to a data store. Notice, that this is a first version of the abstract facade workflow. It might be necessary to specify it for the execution with the workflow engine.

Currently, we use decisions and loops to incorporate a notion of adaptiveness in the workflow. Adaptive workflow management[7] is reasonable to cope with aspects like interruptions due to weather conditions. The aim is not to remodel the whole process if there is an interruption in week eight and the process takes a week longer, but rather conducting this adaption dynamically by using adaptive workflow management.

[7] will be further discussed in D6.6

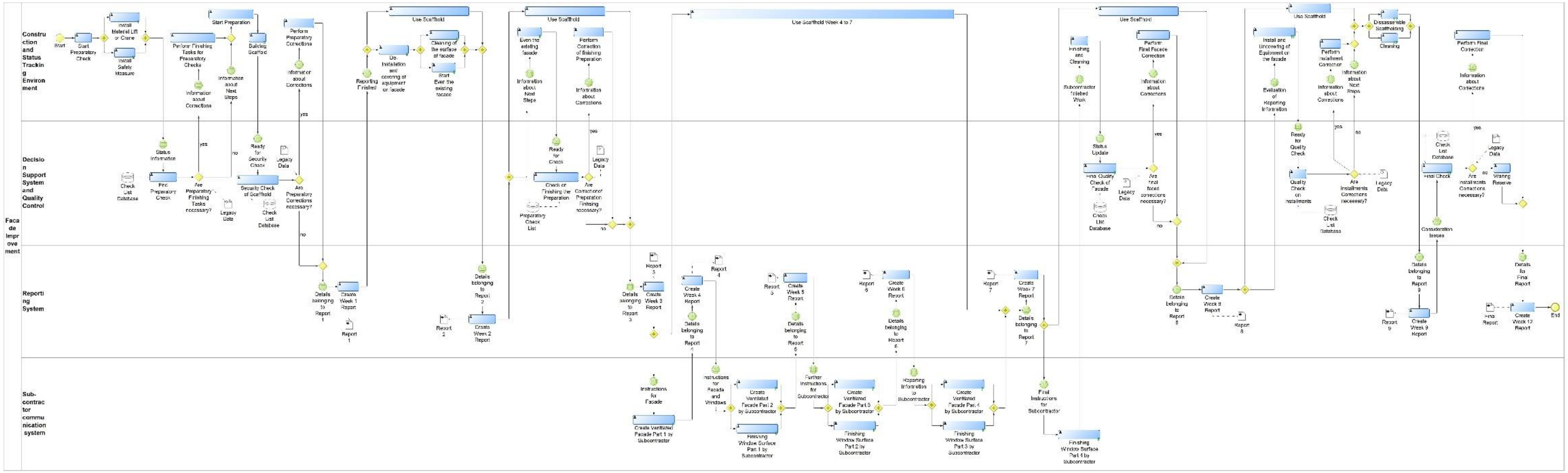


Figure 21: Abstract Workflow for the Facade Renovation (Annex: Figure 59 ff.)

4. Reflection and Innovation of Renovation Processes

After the renovation work has been finished, the project manager as well as the involved stakeholders derived insights on how the extracted and designed knowledge was capable to support decision making during the execution of the renovation process.

Hence, after finishing the renovation initiative the relevant stakeholders are invited to reflect the renovation process as well as the assumptions that have been made and adapt the externalized knowledge, which were estimations in the first place and are now – after each run of the process – improved.

In particular, we aim to:

- Improve the process templates and their usage for the offering phase;
- Improve the estimations performed in the offering phases;
- Improve the transformation into executable processes, especially for simulation relevant artefacts;
- Improve the calculations for the status measures; and
- Improve the expert know-how relevant for the risk assessment.

Therefore, we propose two approaches:

1. **Collaborative Reflection of the Renovation Process** by using collaboration tools to discuss, comment and vote the relevant aspects of the renovation process model and incorporate the suggestions into the new renovation process for the next run.
2. **Process Mining** of log-files may lead to findings after analysing the different execution paths and traces. In case the log-files are enriched with additional information, we create a so-called digital twin of the renovation process, which has the potential to enable more sophisticated knowledge extraction of a process mining. Hence the potential of the process mining depends on the enriched log files.

In the following sections, we introduce the two approaches in more detail.

4.1 Collaborative Reflection of Renovation Process

Feedback and learning are collected by using a Wiki, where the renovation process model is published for a particular instance of a renovation process on a Wiki page. The corresponding stakeholders – project managers, sub-contractors, renovation domain experts, etc. – are invited to collaboratively reflect the execution of the process and comment, vote or provide additional contributions to the process model. For this reason, a model wiki based on XWiki[8] allows commenting models and retrieving comments.

The Wiki pages are structured according to the context of the process model, hence comments to particular phases can be directly related to the renovation process model. Figure 22 shows a sample of a Wiki page, starting with the key figures of the renovated object. The corresponding renovation process is automatically extracted and the graphic as well as additional descriptions are published on a Wiki page. Each activity is described in a sub-page. Comments addressing a particular activity – in our sample we introduce a comment about budget forecasts – can be imported into the model, as the context of the renovation process is implicitly provided in the structure of the Wiki-page.

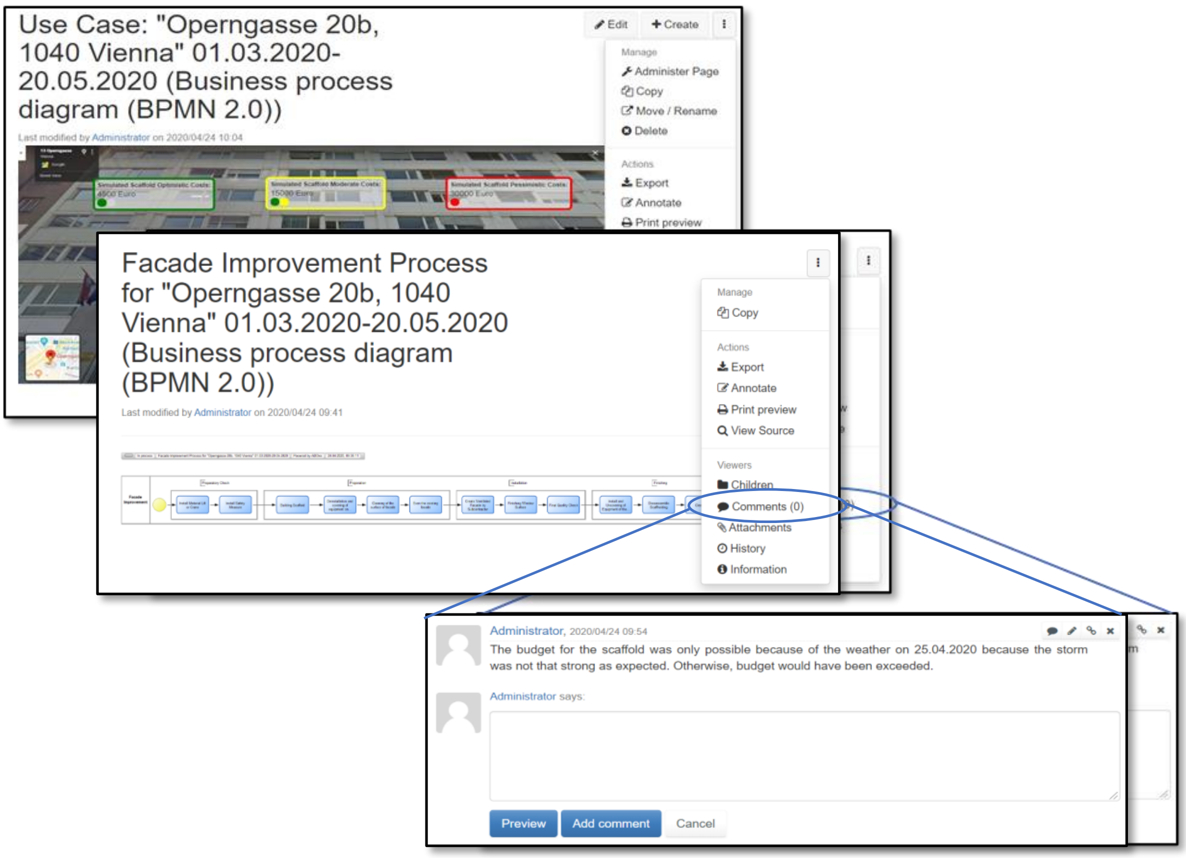


Figure 22: Collaborative Reflection of Renovation Process

After collecting all comments, the externalized knowledge can be retrieved back into the model. With this mechanism we propose lessons learned in order to improve the knowledge that is externalized in the models and in the different configurations of the simulation.

[8] https://www.xwiki.org/xwiki/bin/view/Main/WebHome

4.2 Process Mining of Renovation Process

Process mining is used to support the analysis and evaluation of business processes. Trends and patterns in the process data are interesting for the improvement of processes. Therefore, data mining algorithms are applied on the process data. Not only the efficiency of processes should be improved by process mining, but also the understanding, especially dependencies and interconnections should be clarified. It might not only be necessary to improve specific tasks regarding their execution time, sometimes a restructuring of the whole process is more reasonable. For mining the renovation processes, the process mining platform Celonis[9] was used. In the following subsection, a description of the preparations, the creation of an analysis workspace and the results are provided based on our outside facade renovation process sample.

A new workspace for analysis is created by importing the relevant process data. Within this analysis, we can choose the process explorer, were we can see a snapshot of the identified process. Various tabs provide detailed information about throughput times or the analysis for example. In Figure 23 the analysis tab for our sample workspace is shown.

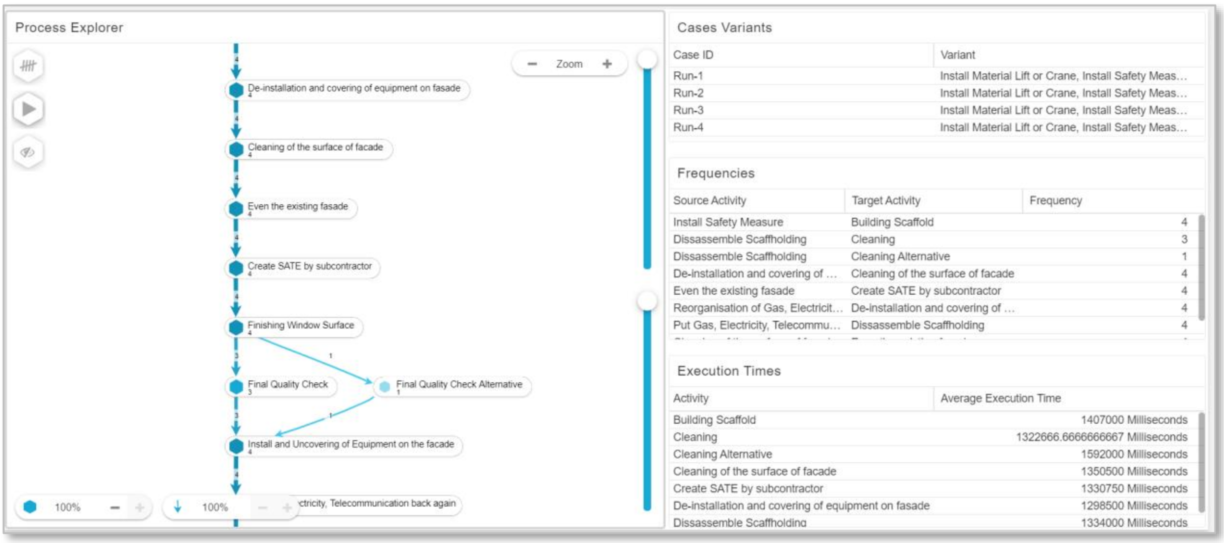


Figure 23: Celonis Analysis Workspace

The results of the process mining strongly depend on the available log data that are mined. The design of the renovation workflow which generates those log files, influences the quality of the log-file. Hence the knowledge that can be extracted from process mining depends on the construction of the workflow and how the so-called digital twin of the renovation process – in form of the log file – is created and enriched by enriching the workflow log with complementary information.

The effort in producing such an enriched digital twin needs to be in a relation to the resulting added value as additional lessons learned. Stepwise enriching the digital twin of the renovation process enables the lessons learned that result in a reasonable added value.

[9] https://www.celonis.com/

5. Repository of Renovation Process Templates

5.1 Renovation Processes

In collaboration with the domain expert partners in BIMERR, the main tender scenarios for concrete use cases were collected in a process landscape, shown in Figure 24. Four major categories of processes were identified:

1. Improvement of Accessibility
2. Improvement of Thermal Envelope
3. Improvement of Installation
4. Other Customer relevant Aspects

Renovation processes focusing on specific areas, are sorted to one of those categories. Notice, that this is a first draft and may be extended in future project phases. It is also important to mention that not all processes in the mentioned are conducted at every construction site. The selection of processes depends on the customer, the building and expert evaluations and suggestions. For example, not every building has a balcony, so this process is not obligatory. It might also be the case that some parts of the building are in good shape, whereas others are not.

For the first category, improvement of accessibility, especially two renovation issues are relevant. Therefore, there are two processes: (1) adding a ramp and (2) installing an elevator. Both might be essential so that the building is accessible also by handicapped persons. In particular, the obligation is the elimination of architectural barriers to ensure accessibility.

Second, there is a variety of improvements regarding the thermal envelope. Beginning at the bottom of a building, the ground slab can be improved. Furthermore, there are also processes for improving the first level slab and all other levels. There is an additional process for decks, floor and slab improvements. Two more processes aim at improving a balcony and the windows. Especially, two kinds of facade improvements (1) outside and (2) inside may be essential to resolve thermal issues, as well as the renovation of the roof. Although the renovation of the carpentry might not have such a high influence on the thermal aspects of a building as the facade, smaller improvements can also be reached with this aspect.

Third, the installation can be improved through attaching additional features or adapting existing ones. Changing the heat system or the air condition might improve the installation a lot throughout all seasons of the year. As saving the environment is getting more important, adding photovoltaic or solar panels increase the environmental friendliness of power production and might decrease the electricity bill in the long run.

Moreover, there are also other relevant aspects for customers. For instance, it is reasonable that a customer wants to improve the fire protection system. In the context of companies dealing with hazardous materials, this seems to be a big issue.

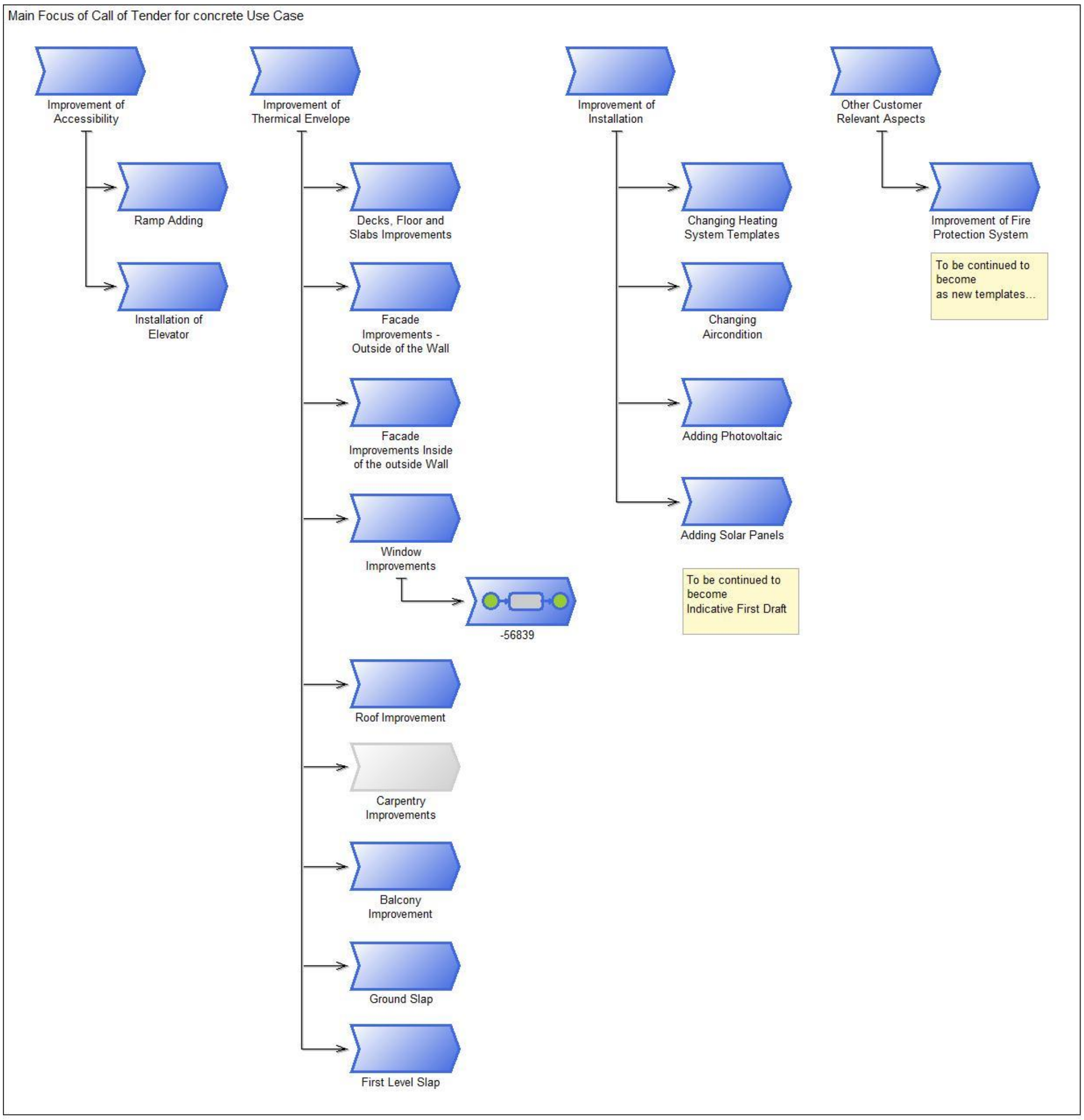


Figure 24: Process Landscape

The following subsections describe the five template processes required for a common building renovation. The template processes are created in BPMN with the ADONIS Business Process Management Toolkit. They are exported as BPMN DI for further processing steps. These template processes are valid for various construction sites. The processes include start and end events, gateways (parallel and/or exclusive) and tasks. The decision points, like exclusive gateways, in the template processes are only used on the template level. When a template process is transformed into a concrete use case, there is no need for a decision, as they are already defined. As already mentioned, the template processes are valid for a variety of construction sites, for example only limited to European countries. Therefore, additional information and parameter configuration is necessary for transforming a template process into a concrete use case. For instance, the facade in Greece might have a thickness of five centimetres by law, whereas the thickness in Austria must be at least ten centimetres. However, here the introduction of knowledge filters as well as rule-based systems enable the transformation of template processes into concrete use cases by checking various parameters. A detailed description of each template process can be found in the subsections below.

5.1.1 Roof Improvement – Outside

The roof improvement outside process, shown in Figure 25, explains the tasks required for external insulation. The box around the process, also called pool, indicates that the process is fully conducted by one organization. In this case, a common construction company or an enterprise specialized in outside roof insulation may take over this part of the renovation.

The start event indicates the start of the process. A parallel gateway follows. This means that the following two paths are conducted in parallel.

The first path starts with **installing safety measures**, which is required to ensure the safety of the construction workers and other passers-by. This task might include blocking the street or sidewalks that are close-by.

Afterwards, for easing the construction work the **scaffold is built-up**. This task includes the installation of handrails, the usage of a crane and various other security equipment. Meanwhile in the second path, it is **checked whether everything is prepared**, so that the real roof renovation can start.

A converging gateway merges the two parallel paths. Moreover, two more tasks are conducted in parallel. First, the existing **roof layer is cleansed and removed**. This step is necessary, as the new layer requires a smooth surface. Also, all broken layers, for instance, they might be drenched or mouldy, must be removed to guarantee the correct functioning of the new installations. Second, in parallel the **waste** resulting from the cleansing task is separated and disposed in accordance with the regulations. Again, both paths are merged. As the temperature inside the building and/or the attic is usually different compared to the outside temperature throughout the year, an installation for coping with vapor is required.

Therefore, the next task of the process is the **placement of a vapor layer**. Some characteristics should be fulfilled for classifying a roof as good. For instance, the heat, produced by the heating inside of the building should not be given off through the roof. For this reason, an insulation panel is placed that should provide insulation. In particular, in seasons with cold weather the insulation panel can save heating costs. A variety of insulation material, like fiberglass, mineral wool, cellulose, or foam, can be used for this task. However, not only the roof surface area must be insulated, but also the parapet wall.

So, the next process task is the **insulation of the parapet wall**. There are two different tasks, which are one after the other, for the insulation, as the roof surface and the parapet wall might require other insulation material as well as different equipment. One major function of the roof is to keep everything below dry. Hence, another additional layer is placed – the **waterproof layer**. For the installation of the waterproof layer, it is common to use bitumen. Bitumen is a mixture of sticky, viscous and waterproof organic substances.

Although this material is mainly used for road constructions, the characteristics are also beneficial for waterproofing roofs, especially flat roofs. A **sheet metal roof** is used for finishing. The additional layer of metal on top is exposed to weather and should prevent most influences from outside. For instance, it must withstand a storm, rain, sunshine or hail.

The next task, which is **the installation of a drainage module**, is also very important considering weather and environmental influences. Before ending the roof renovation on the outside, everything is **cleaned** and cleared up.

This task includes the disposal of waste, the packing of equipment and the removal of raw material that was not needed. Finally, a **final quality check**, especially considering the water proofing issues, is conducted. When the quality check was successfully, the roof improvement can be completed, which is indicated by an end event in the process.

Notice, that the scaffold is not removed at the end of this process, as it might be required for other renovation sub-processes after the outside roof improvement.

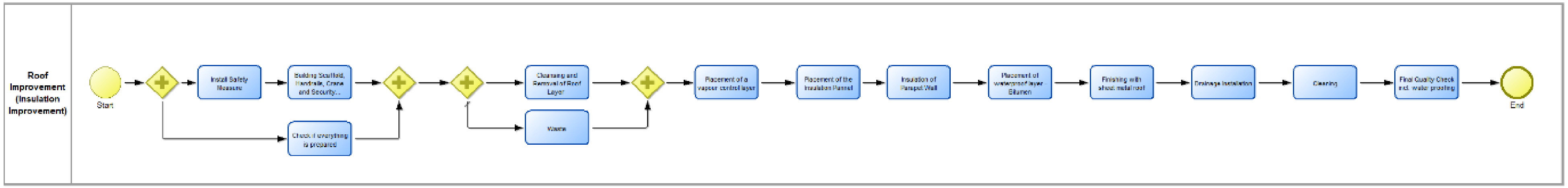


Figure 25: Roof Improvement Template – Outside (Annex: Figure 39 ff.)

5.1.2 Roof Improvement – Inside

The roof improvement inside process, shown in Figure 26, describes the tasks required for internal insulation. The box around the process, also called pool, indicates that the process is fully conducted by one organization. In this case, a common construction company or an enterprise specialized in attic roof insulation may take over this part of the renovation.

The process start is shown by the start event. A preparation task follows. The reason for this task is to **check if everything is prepared**. For instance, the attic must be accessible, and anything stored in the attic must be relocated for the improvement period.

A decision follows after making sure that all required preparations are finished. It has to be decided whether the existing layers must be removed, or if their condition is good enough so that they can be kept. Following two tasks are conducted in case the existing layers must be removed, otherwise they are skipped.

First, the **existing roof layer is removed** and the surface as well as the area around is cleansed. All broken elements are sorted out and parts in good condition might be recycled for other purposes. Second, the **waste** resulting from the cleansing task is separated and disposed in accordance with the regulations.

Afterwards, one more decision, which is based on the existing layers and their conditions, has to be taken. The question is, if a vapor control layer is required. If yes, one additional task, explained in the following is conducted, otherwise this task is simply skipped. As the temperature inside the building and/or the attic is usually different compared to the outside temperature throughout the year, an installation for coping with vapor is required, if not available.

Therefore, the next task of the process is the **placement of a vapor layer**. Some characteristics should be fulfilled for classifying an attic as good insulated. For instance, the heat, produced by the heating inside of the building should not be given off through the attic. For this reason, an **insulation panel** is placed that should provide insulation.

In particular, in seasons with cold weather the insulation panel can save heating costs, as normally, the attic is only used for storing things and therefore not heated or cooled. A variety of insulation material, like fiberglass, mineral wool, cellulose, or foam, can be used for this task. However, not only the attic surface area must be insulated, but also the knee wall.

So, the next process task is the **insulation of the knee wall**. The knee wall is not higher than a meter and should support the roof construction, regarding stability. Normally knee walls can be found in older buildings, which rather require renovation compared to newer ones. These older buildings do often have an attic, which is the ceiling of the top floor.

The space emerging with the knee wall is quite small, so usually it is not high enough for a person to stand up there. There are two different tasks, which are one after the other, for the insulation, as the roof surface and the knee wall might require other insulation material as well as different equipment. **Case specific finishing** is carried out after the insulation.

This might for instance include the dealing with special parts, as not every attic has a perfect rectangular or quadratic shape. Also, chimneys ranging from inside the building, over the attic to the roof, must be considered. Before ending the roof renovation in the attic, everything is **cleaned** and cleared up. This task includes the disposal of waste, the packing of equipment and the removal of raw material that was not needed.

Finally, a **final check**, especially considering the various layers and their attachment, is conducted. When the final check was successfully, the roof improvement of an unheated attic can be completed, which is indicated by an end event in the process. Notice, that the scaffold is not removed at the end of this process, as it might be required for other renovation sub-processes after the outside roof improvement.

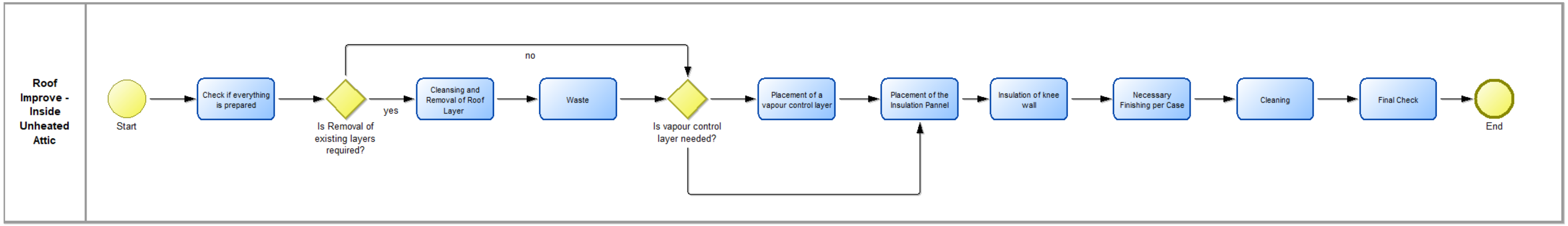


Figure 26: Roof Improvement Template – Inside (Annex: Figure 41 ff.)

5.1.3 Facade Improvement – Outside

The facade improvement outside of the wall, as visualized in Figure 27, describes the required tasks for the renovation of the facade. The box around the process, also known as pool, indicates that the process is fully conducted by one organization.

In this case, a common construction company or an enterprise specialized in facade renovation may take over this part of the building improvements. A start event indicates the start of the improvement process. The first task that must be conducted is the **installation of a material lift or crane**.

As most buildings are higher than a person, the required material for the renovation must be lifted. As the material as well as the tools can be quite heavy, large and impractical, a lift eases the job of the construction workers.

The next task is the **installation of safety measures**, which are essential for the construction workers as well as passers-by. This task might include blocking the street or sidewalks that are close-by. Also blocking the construction area might be reasonable that nobody is injured in case if anything falls down. As already mentioned, most buildings are higher than one story, so a supportive structure is needed. For this reason, a **scaffold** is built up.

The scaffold allows the construction workers to easily reach each story of the building from outside. The scaffold is usually standing till the end of the renovation process. After finishing the scaffold, a decision about the reorganization of gas, electricity of telecommunication must be taken. In loads of cases a reorganization is necessary, if not, the next task is simply skipped.

Various changes on the outside of the building might require the **reorganization of gas, electricity of telecommunication**. Also, if the condition of the existing installations is not the best, it might be more reasonable to exchange and reorganize them during the renovation, as to have another renovation project in the near future.

The **deinstallation and equipment covering on the facade** outside follows. This includes for example removing loose parts of the facade or protecting equipment from external influences. It is usually the case that the pre-processing steps resulted in some dirt and waste. For this reason, the next task is about **cleaning the facade**. The main dirt and dust are removed in this task. This is necessary that new layers and installations can be attached on the existing facade. It is often the case that the facade is not a hundred percent smooth and even. Therefore, the **facade is evened**.

After conducting this correction of the facade surface, the facade type must be chosen. There is either a **ventilated facade or a SATE system**. Only one of those two types can be chosen. The ventilated facade system is also known as double-skin facade. It consists of two layers that are separated by a hollow space filled with air.

The main purpose of this space is to keep out rainwater and cope with the temperature differences. Benefits of the ventilated facade are that the amount of heat absorbed by the building is reduced in summer and heat inside is better retained in winter. In contrary, the SATE system is an exterior thermal insulation system that applies tiles on the outside of the facade. The panels can directly be mounted on the facade, so no supporting structure is needed. Another benefit is the low thermal conductivity of the tiles.

The panels are also tensile and resistant to compression. Some characteristics of the SATE system are the reduction of the building energy consumption, the elimination of thermal bridges or the simple installation for instance.

The next step is again not depending on the chosen surface, as it is required for all buildings. Not only the facade, but also the **window surface must be finished**. This might include the cleaning and smoothing the surface for further processing steps. Afterwards, the **final quality check** follows. In particular, the improved installations are checked with a check list. This is done before the removal of the scaffold, in case if any further actions must be taken. If everything was successful, the **deinstallation and uncovering of the equipment** follows.

The following task is only relevant, if the decision was to reorganize gas, electricity and telecommunication. If this was the case, **gas, electricity and telecommunication must be put back** again. Efficient processes normally reorganize gas, electricity of telecommunication directly in the beginning. This means that the disassembly and assembly are conducted in one step, which is beneficial as there is continuity in energy services for the residents. This task can be used to control the installations, or it is simply left out.

At this point, the facade renovation is nearly finished. For this reason, the scaffold is not needed anymore, so the **scaffold is disassembled**. Before ending the facade renovation on the outside, everything is **cleaned** and cleared up. This task includes the disposal of waste, the packing of equipment and the removal of raw material that was not needed. Finally, a **final check** is conducted. When this final check was successful, the outside facade improvement can be completed, which is indicated by an end event in the process.

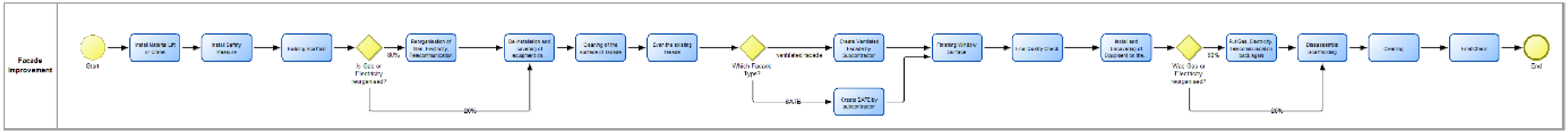


Figure 27: Facade Improvement Template – Outside (Annex: Figure 43 ff.)

5.1.4 Facade Improvement – Inside

The facade improvement inside of the wall, as visualized in Figure 28, describes the required tasks for the renovation of the facade inside of the building. The box around the process, also known as pool, indicates that the process is fully conducted by one organization. In this case, a common construction company or an enterprise specialized in inside facade renovation may take over this part of the building improvements.

The start event is the start of the improvement process. First, a preparation task follows. The reason for this task is to **check if everything is prepared**. For instance, the rooms must be accessible, anything stored in the rooms must be relocated and wall decoration like pictures must be removed for the renovation period.

Afterwards, all **covers must be unmounted**. If they are in a good condition, they might be reused after the improvements, otherwise they are disposed and replaced with new components. For example, sockets, lights or sliding doors have to be unmounted for an easier processing of the facade renovation. A decision follows after making sure that all required preparations are finished. It has to be decided whether the existing indoor layers must be removed, or if their condition is good enough so that they can be kept.

Following three tasks are conducted in case the existing layers must be removed, otherwise they are skipped. First, a **waste removal system** is installed. This waste removal system can for instance include the delivery and setup of a waste container for bulky components. Normally a lot of rubble emerges, when the indoor layers are removed, so the waste system is absolutely necessary to keep the construction site well organized and safe.

The second and the third task required after the removal decision are conducted in parallel. Second, the **existing indoor layer is removed** and the surface as well as the area around is cleansed. All broken elements are sorted out and parts in good condition might be recycled for other purposes. Third, the **waste** resulting from the removal of the existing indoor layer is separated and disposed in accordance with the regulations.

Not only on the outside, but also inside of the building, insulation is required. Therefore, the next task is to **apply insulation panels**. Lightweight mortar can be used for the insulation. Mortar is a mixture of sand, water and cement that can also be used to fix bricks or stones when building walls. The lightweight version can be fibre reinforced. The material has various benefits like breathability, compatibility with insulations systems and easy usage. It is important to notice that this task has to be checked with respect to the ventilated layer for electrical installations, as both depend on each other and have to go together.

Moreover, **screw anchors** are applied for further processing steps. The screw anchors allow the connection of structural elements and the reinforced concrete foundation. They can transfer the force based on concentrated pressure exchange between screw and concrete through pitches. To make the whole construction more stable, a **reinforcement mesh** is applied by using mortar. This mesh is not only used for stability, but also for reinforcing the heating systems of the buildings' facade and the interior plaster and/or concrete works.

The mesh can be made of fiberglass, it has a high level of mechanical strength, a strong weaving and it is mostly resistant to alkali. Afterwards, the **plastering** is finished. Mostly a mixture of lime or gypsum, sand, water and fibre is used. It is applied in a pasty form to walls and hardens after drying.

A smooth and protected surface emerges with this wall coating. In the beginning of the process, covers were unmounted. Now it is time to **mount the covers**. For instance, sockets are installed, as well as switches or light. Also, an electrician should be involved in this task, as it must be clarified what happens with the electric installations. Finally, a **final quality check** is conducted. When this final check was successfully, the inside facade improvement can be completed, which is indicated by an end event in the process.

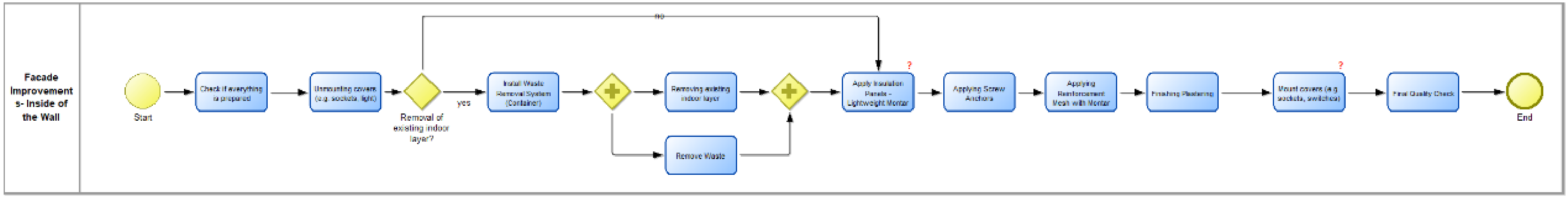


Figure 28: Facade Improvement Template – Inside (Annex: Figure 46 ff.)

5.1.5 Window Exchange

The window exchange, as represented in Figure 29, describes the required tasks for the renovation of the windows of the building. The box around the process, also known as pool, indicates that the process is fully conducted by one organization. In this case, a common construction company or an enterprise specialized in window renovation may take over this part of the building improvements.

The start event is the start of the window exchange process. First, a preparation task follows. The reason for this task is to **check if everything is prepared**. For instance, the windows must be accessible, anything stored on the windowsills must be relocated and decoration elements like curtains must be removed for the renovation period.

The next task is the **removal of the existing windows**. All broken elements are sorted out and parts in good condition might be recycled for other purposes. In most cases, the old windows are exchanged due to bad thermal characteristics.

The following tasks are then conducted in parallel. Where the first path holds a sequence of five tasks and the second path is responsible for the waste. The waste resulting from the window exchange is separated and disposed in accordance with the regulations.

The first path contains tasks for the real window exchange. First, the **windows are positioned and fixed**. This means that the new components are inserted into the facade at the correct position and temporary fixed. For sure, the temporary fix is not enough, so the second task in this path is the **sealing with foam and/or silicone**. The sealing must be resistant to external influences like air and water. For this reason, PU foam and/or silicone are used here. The polyurethane foam has a variety of possible applications, as it can be highly flexible or rigid. Also, structures ranging from solid to open cellular structures are available.

One of the most important thermal characteristics is that they do not melt when they are heated. Silicone is a synthetic material that can either be liquid or similar to rubber. Silicones are usually heat-resistant, have a low thermal conductivity, are light resistant and have properties for electrical insulation.

After the sealing, **waiting time** emerges, as the sealing material needs some time dry. This time depends on the used material, as well as on external influences like the temperature. It may take only some hours to more than a day. Fourth, **the installation of the windowsill**s follows. The shelves are formed by the bottom part to the frame of a window. They are on the outside and on the inside of the building.

They are not only used for decoration aspects, but also hold the window and the glass in place. Furthermore, on the outside of the building they keep rainwater away from the wall directly below the window. They can be made of masonry construction or in wood framing for instance. The path of exchanging the windows is finished by a **quality check and an inspection**.

For instance, it is inspected if the windows are waterproof, if they are fixed and their opening and closing mechanism works correctly. Finally, a **final quality check** is conducted. When this final check was successfully, the window exchange process can be completed, which is indicated by an end even.

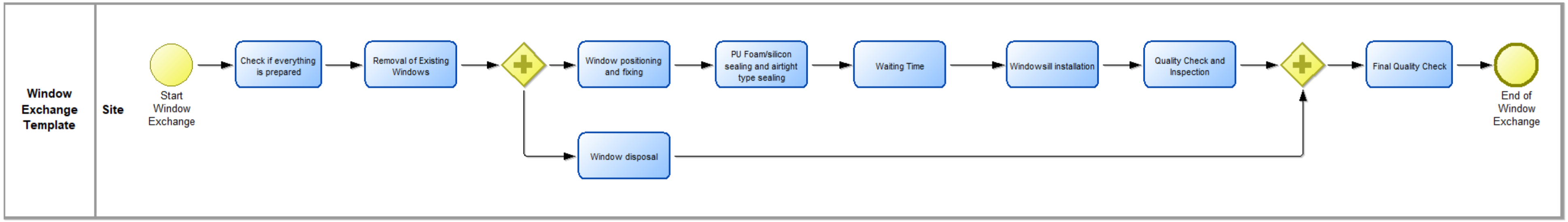


Figure 29: Window Exchange Template (Annex: Figure 48 ff.)

5.2 Process KPI Models[10]

KPIs can have various characteristics, (Amor & Ghannouchi, 2017; Florès, 2014). In order to provide a catalogue of basic KPIs and key figures, their characteristics and foundations are described below. The idea of such a catalogue is that the KPIs and their concepts can be used modularly. This means that the relevant figures are picked individually for each part of the renovation process. This kind of modular system enables easier usage and reduces the complexity for the overall renovation process. In specific, some of the use cases and process phases might require specific KPIs, whereas others do no. For instance, if a subcontractor is involved in the process, an additional KPI for the subcontractor personnel costs makes sense. Also, the aggregation of estimations and assessments are eased through the implementation of KPI catalogue.

The following main characteristic for KPIs seem to be essential for differentiation, however there is a variety of other aspect. Notice, that the purpose and the context of the KPI might influence the characteristics and their manifestation.

1. **Limitation**: There are three main options on how KPIs can be limited. Firstly, they can be limited from top, which means that there is a set time limit or a maximum budget. Secondly, bottom limited KPIs indicate that there is an "at least" relationship between the KPI and its threshold. For instance, innovation and overall quality must be ensured, which can be supported by a minimum training and education budget for each employee. Thirdly, KPIs cannot only be limited from one side, but also from both. Research would be an appropriate example here. On the one hand, it is important to foster new developments, but in contrary, a limited amount of resources is available for this topic.
2. **Tolerance**: There is a strict differentiation between KPIs with and without tolerance, as those two alternatives are mutually exclusive. If there is no tolerance, the KPI and the calculated measure can simply be compared. On the contrary, if there are KPIs with tolerance the level of tolerance must be defined in order to get a clear measure. For the definition of the tolerance level, statistical computations like standard deviation or confidence intervals might be used.
3. **Indicator**: Special thresholds are used as an indicator. Various stages are reasonable. The two most important stages are warning or critical. If an indicator points out that there is an early warning for a specific KPI, actions and plans can be adapted to meet the original goals. The critical indicator should pop up, in case of crucial risks or problems. The granularity for the indicators can be set as required. However, a threefold division with colour codes – red, yellow, green – like used for traffic lights might be reasonable. If the granularity is too deep, the system might get unnecessarily complex and the benefit of getting a fast overview might get lost.
4. **Range**: Especially key figures measuring opinions and subjective information must incorporate various possible answers. Ranges and categories might support the transformation of individual knowledge in measurable metrics. For instance, opinions and expectations can be categorized in positive, negative or indifferent. In most cases, an even number of categories is more reasonable to find out at least a direction instead of getting stuck in the middle category.

In particular, the aggregation of the different KPIs and key figures offers a huge potential for improvements, as the exact calculations and rough estimations as well as the information from domain experts can be incorporated at one time. A variety of perspectives on the problem is considered, hence additional information that creates value for the renovation process is identified.

[10] https://www.brightgauge.com/blog/quick-guide-to-11-types-of-kpis

Qualitative KPIs

Qualitative KPIs are often seen as no real measures, as they do not work with numbers, but rather with classifications. Therefore, they do not belong to the performance measure. However, they support the overall analysis, as quantitative measures are normally based on the opinion of people. The main question is "why" something is done this way instead of "how" it is done. Indicative measures include: customer satisfaction, personnel time, personnel costs, experiences, productivity, resources, sub-contractors, machine down times, etc.

Quantitative KPIs

Quantitative measures can further be divided in continuous (decimal) or discrete (integer). Continuous measures can take any value, whereas discrete ones often use scales for rating something. As quantitative KPIs are measured by a number, they are straight forward.

- Quantitative continuous variables: kilograms, hours, minutes, seconds, euros, cents, meters, square meters, transport time, lead time, weight, …
- Quantitative continuous measures: average delivery time, average throughput time, average construction costs, average net profit, average personnel costs, average personnel time, …
- Quantitative discrete variables: satisfaction level, complaints, accidents, attitude, experience, productivity, …
- Quantitative discrete measures: average customer satisfaction, number of down times of the digger, percentage of projects completed on time, average number of ill employees, percentage of men in the renovation sector, percentage of full-time positions, …

Threshold/Tolerance – with or without

Thresholds for KPIs are set to enable the functionality of warning systems. They can either be set statically before the process execution or they can be set dynamically during the process execution. The selection of an appropriate threshold mostly depends on the seriousness of the influence of the related KPI. A balance between a realistic and a motivating threshold must be found. The KPI get reasonable through thresholds, since they have to be compared to any reference value. As sometimes a strict threshold does not make sense, a tolerance level is introduced. For this tolerance level often statistical evaluations like variance or standard deviation are used. If there is a significant difference between the KPI and the threshold considering the tolerance, a problem might be indicated.

Indictors and Early Warning Systems

Indicators try to find out trends, which is very helpful for the identification of problems and risks. One main difference between indicators and KPIs is that indicators focus on identifying problems beforehand, whereas KPIs are often applied afterwards.

There are various types of indicators. For predicting an outcome, trends are analysed by using leading indicators. Most of the times using only leading indicators is not enough. Success or failure of the results are measured after a certain period of time by lagging indicators. Resources and their availability can be measured by input indicators. Efficient courses of the process can be measured by so called process indicators. Output indicators show success or failure of business process activities. Practical indicators are tailored to a specific business, company or domain. Directional indicators are used to show trends like improvement, decline, maintaining or crash. A lot of indicators are of financial nature to ensure economic stability and growth.

5.2.1 *Simple Cost Driver: Cover Sheeting Material Costs Sample*

Cover sheeting material is used for various purposes in a renovation process. Basic applications would be the covering of the equipment or the covering of the construction site. The amount of needed cover sheet material is highly influenced by the environment, like the weather or the season. If there is a rainy season, much more cover sheeting material is required. However, the cover sheeting material is normally bought in reels. So, there is fixed price for each reel. For this reason, the number of reels matter. If there are two reels used half, both have to be paid, although there is something left. For the cover sheeting material this might not be critical, as the left cover sheeting can be reused on other construction sites.

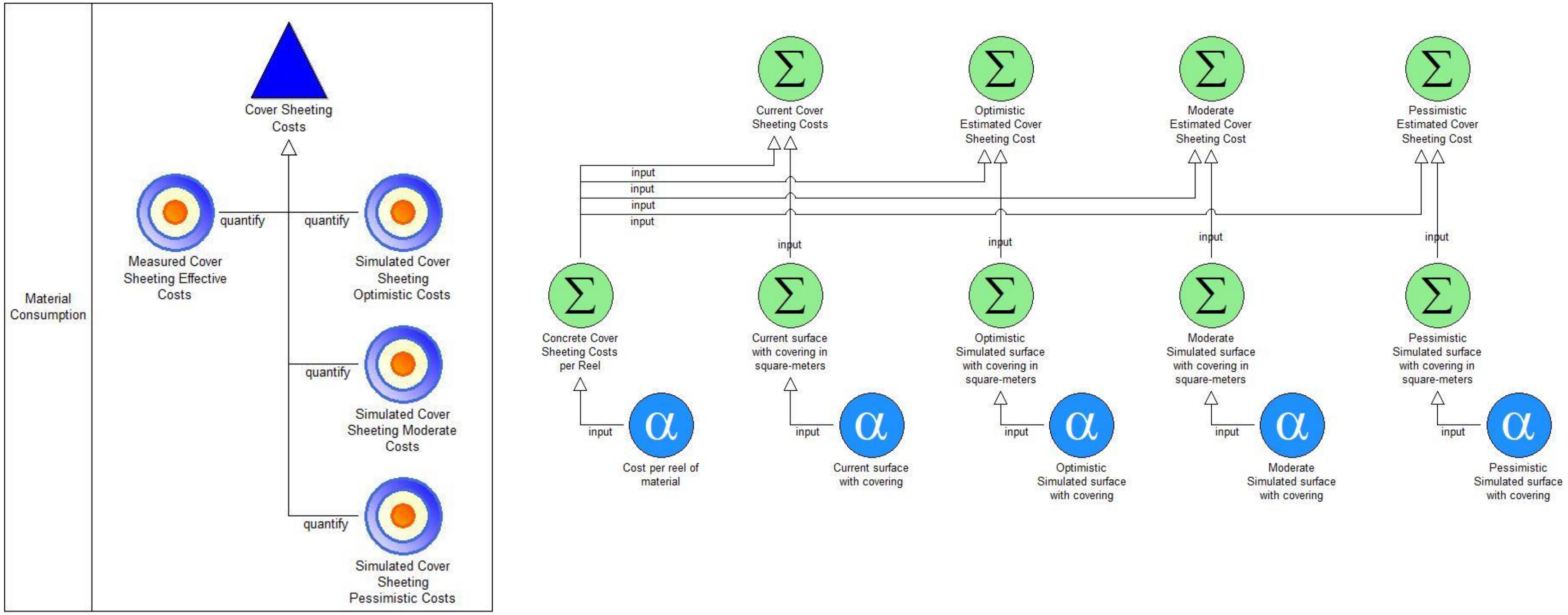


Figure 30: KPI and Data Calculation Model - Cover Sheeting Material Costs Sample

5.2.2 *Calculated Cost Driver: Subcontractor Personnel Costs Sample*

Personnel costs are commonly calculated on an hourly basis according categories. Subcontractors or own staff costs are therefore multiplied per category and per hourly rate. The different cost categories need to be defined, either per sub-contractor or by own staff and a continues reporting using time sheets are used to calculate the consumed budget.

There are different ways to monitor the personnel costs, one way is to delegate the cost control to the sub-contractor, which is simple but on the other hand, the project manager is not aware of any issues – possible over- or underspending. Therefore, it is advisable to at least estimate the working time with an average hourly rate. This sample is in the model below.

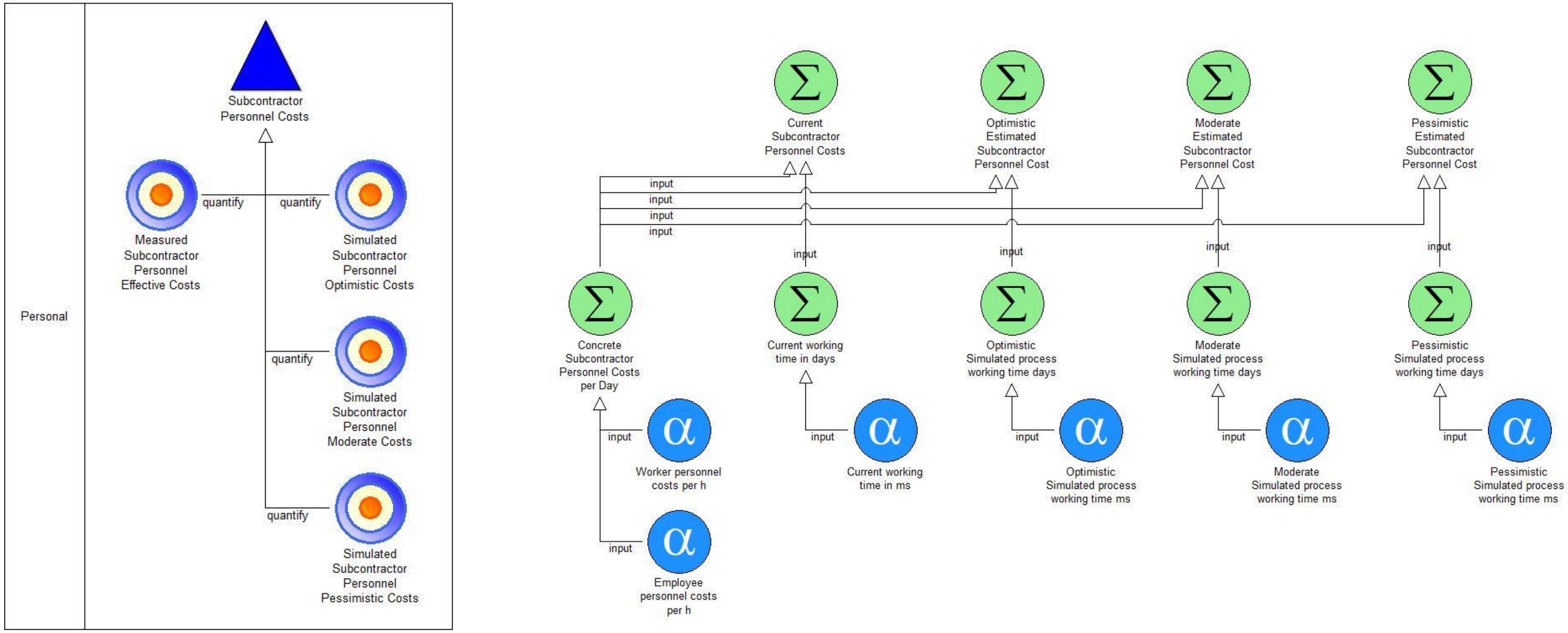


Figure 31: KPI and Data Calculation Model – Subcontractor Personnel Costs Sample

5.2.3 *Context-Dependent Cost Driver: Material Costs Sample*

During a renovation process, a lot of material is required. Two types of material can be differentiated (a) basic material and (b) customized material. Basic material is used on a lot of constructions sites. For instance, bags of cement or expanding foam do belong to this category. More interesting is the customized material, as this is made upon order and is therefore, custom-built. This indicates that the parts can only be used for a specific renovation process. Windows and windowsills are an example of this category. They are built specifically for a concrete use case, where the customer can customize characteristics like glass thickness, shading, insolation, frame colour or insect protection. Unfortunately, once produced, it is very hard to find any other usage, except the planned one. Therefore, the risk of being left with the costs is much higher for customized material than for basic material. Tailored material may also be more error prone, as it deviates from the standard procedures.

Furthermore, it is mostly the case that this kind of material is more expensive, already in acquisition. However, the material costs are comprised of costs for basic material, which are rather low, and costs for customized material, which might be higher and increase the risks (reusability, sensitivity, …). The concept of the simulation works in the same way for all following sample models. Therefore, for explaining the overall principle and in order to focus on the relevant parts, the threefold simulation (optimistic, moderate and pessimistic) was accumulated to one simulation metric (see red ellipse on the picture).

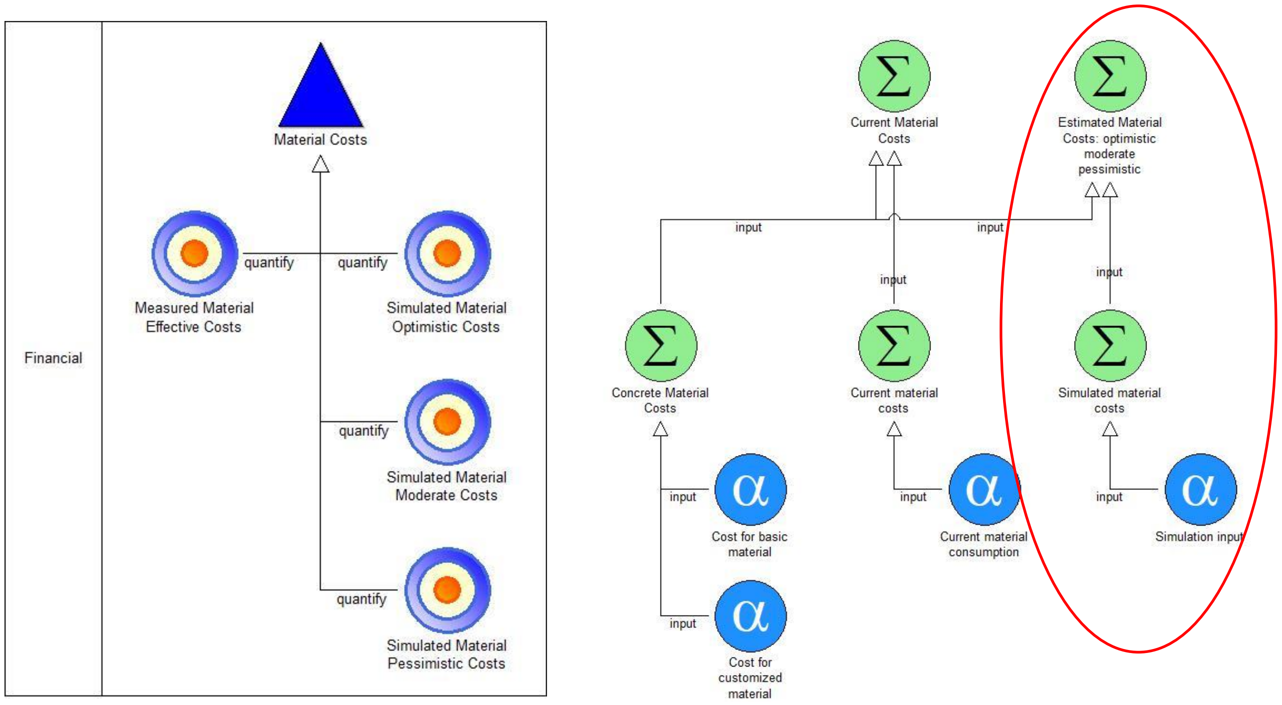


Figure 32: KPI and Data Calculation Model - Material Costs Sample

5.2.4 Context-Dependent Cost Driver: Waste Costs Sample

There are quite specific regulations for waste disposal. Following three main waste categories might be differentiated: (a) normal waste, (b) waste that can be recycled and (c) special waste. Normal waste can be disposed for free or at least at a very low price. On the contrary, it is not trivial to dispose special waste and to stick to the recycling rules. Special waste like asbestos can increase the costs of waste disposal. The material was used in the 1960s and 1970s. Today it is forbidden, as it came out that the dust is highly harmful. For this reason, it should not be broken during the disposal. Some parts of the waste might be recycled. For instance, wooden parts or brash can be rehashed and reused afterwards. However, it is important to consider the effort of waste separation for each type of waste. For instance, windows do consist of a frame and the window glass. Both parts might be separated as old window frames were made out of wood, which can be recycled, whereas the glass might have a crack and cannot be reused anymore.

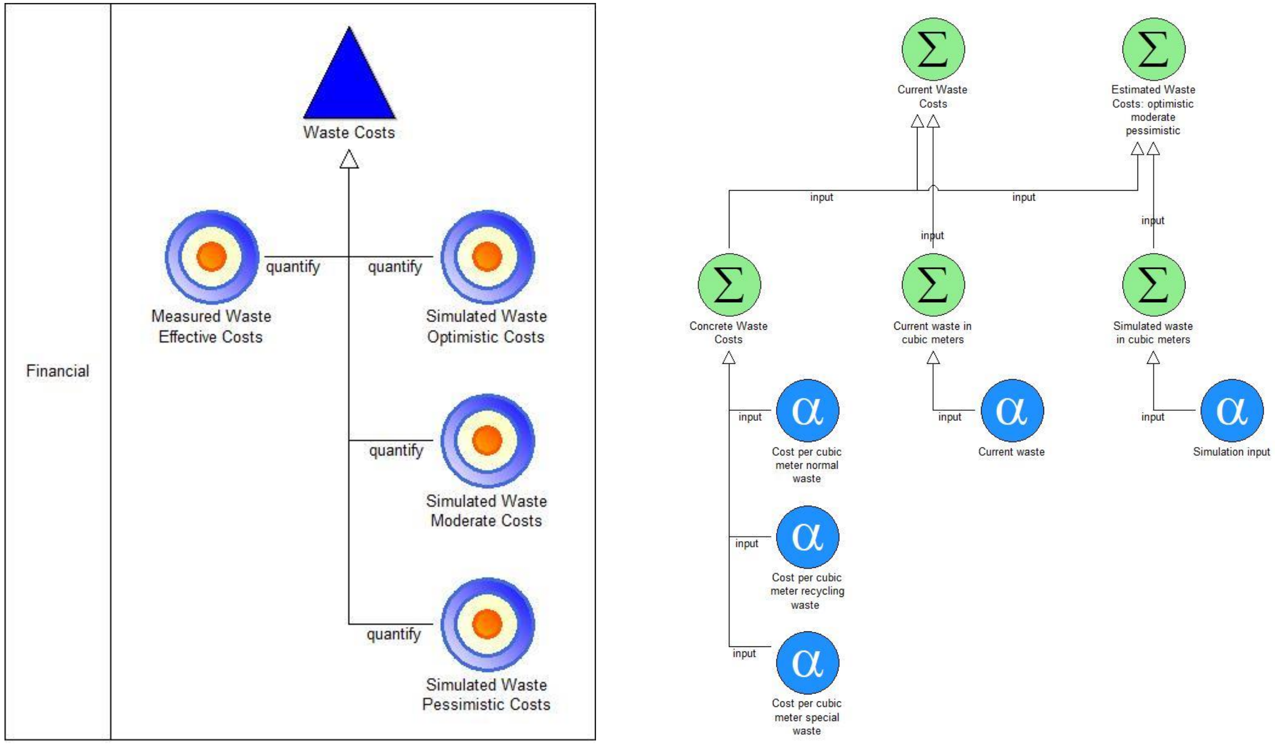
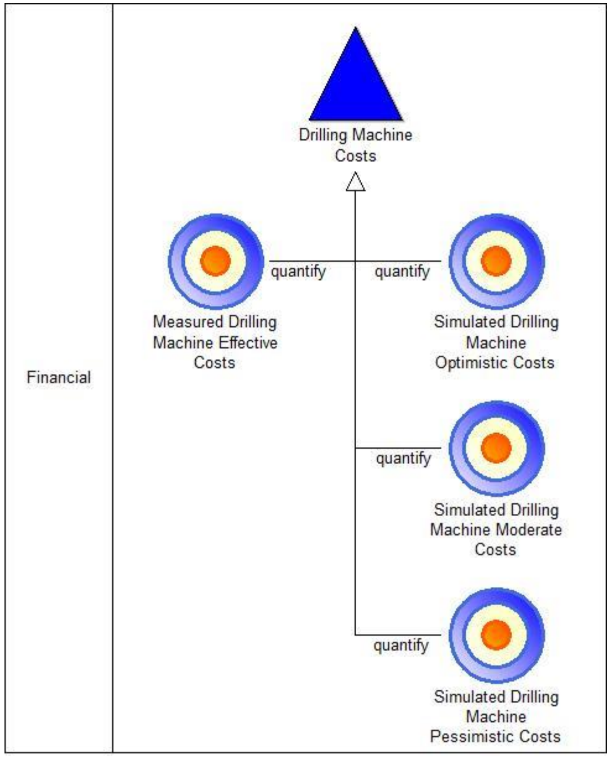


Figure 33: KPI and Data Calculation Model – Waste Costs Sample

5.2.5 Combined Cost Driver: Drilling Machine Costs Sample

The rental fee for renovation equipment like a drilling machine mostly consists of two costs. There are the basic costs, which are for instance calculated in days. In particular, the delivery, the setup, the maintenance and the pick-up are included here. Additionally, there is a cost for each hour of usage, as the value of the drilling machine decreases during the usage time, due to attrition. It is important to keep the downtime low in order to reduce the overall rental costs. However, if the surface is very soaked or dry, the drilling machine might not be used. Also, if the subcontractor cannot deliver as planned, some waiting time might increase the basic costs for the drilling machine.



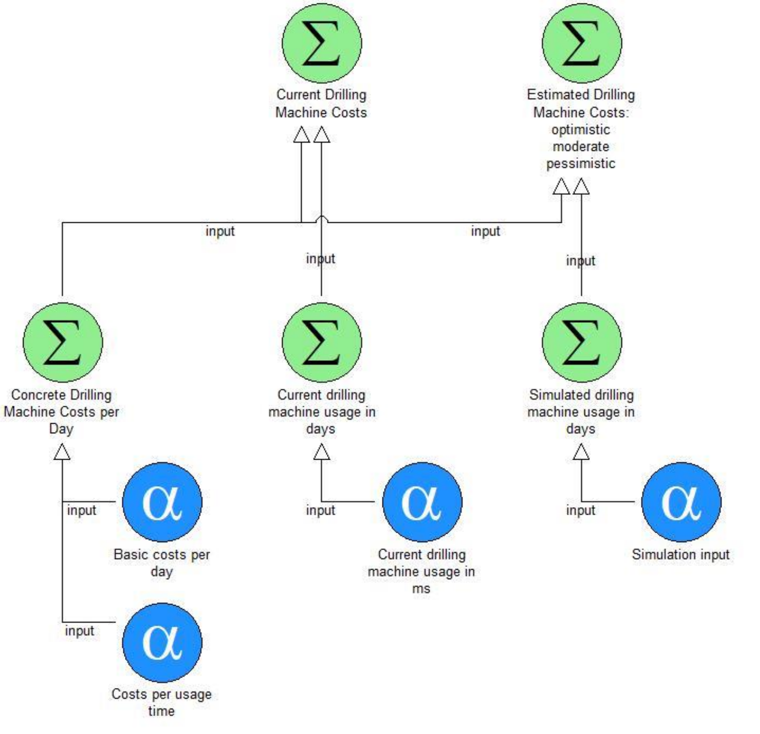


Figure 34: KPI and Data Calculation Model – Drilling Machine Costs Sample

6. FACADE IMPROVEMENT OUTSIDE SAMPLE AS USE CASE OUTLOOK

In the following sections, we focus on the facade improvement outside process to describe the transformation of the template process into a concrete use case. In a first transformation step, all variations from the template process are excluded, as one of the options is defined for a concrete use case based on a specific construction site.

Characteristics of the concrete use case sample building (assumptions):

- built in the 1940s
- seven stories high
- a sidewalk is close-by
- the last renovation was 30 years ago

6.1 PROCESS DESIGN

The facade improvement outside of the wall, as visualized in Figure 35, describes the required tasks for the renovation of the facade in a concrete use case. The box around the process, also known as pool, indicates that the process is fully conducted by one organization.

In this case, a specific construction company takes over this part of the building improvements. The construction company knows the building and its conditions. The start event indicates the start of the improvement process. The first task that must be conducted is the **installation of a material lift or crane**.

In our concrete use case, the building has seven stories. Therefore, the required material must be lifted during the renovation. As both the material and the tools can be quite heavy, large and impractical, a lift eases the job of the construction workers. The facade of the use case building is in a bad condition, as the last renovation was a long time ago, therefore a grinder for removing the old exterior rendering is necessary as well as a facade milling machine, for instance.

The next task is the **installation of safety measures**, which are essential for the construction workers as well as passers-by. As there is a sidewalk close-by the use case building, the construction area must be closed and a temporary redirection for the passers-by is installed as safety measure. They are redirected to the sidewalk of the other side of the street. As already mentioned, most buildings are higher than one story – seven stories in the concrete use case. Therefore, a supportive structure is needed. For this reason, a **scaffold** is built up.

The scaffold allows the construction workers to easily reach each story of the building from outside. The scaffold is standing till the end of the renovation process. As the building is quite old and some installations are not fully conforming to current standards, it was already decided before starting the facade renovation, that a reorganization of gas, electricity and telecommunication is required. The reorganization is not only required to adapt to the regulations, but also to find the best-looking solution regarding the design of the new facade.

The **deinstallation and equipment covering on the facade** outside follows. This includes removing loose parts of the facade with a grinding tool. Furthermore, critical parts of the facade and the equipment is protected and covered with tarpaulins, as the weather forecast predicts rain and wind.

It is usually the case that the pre-processing steps resulted in some dirt and waste. In our use case, the loose material from the facade was deinstalled. For this reason, the next task is about **cleaning the facade**. The main dirt and dust are removed in this task. This is necessary that new layers and installations can be attached on the existing facade. As our sample building is quite old and the condition could be better, the facade is not a hundred percent smooth and even. Therefore, the **facade is evened**.

Before starting the facade renovation on the outside, it was decided to choose the **SATE system**, as it offers various advantages at the concrete use case construction site. The SATE system tiles for ensuring exterior thermal insulation are applied on the outside of the facade. No additional supporting structure is needed, as the panels can be mounted directly on the existing facade. The attachment on the facade is beneficial due to low thermal conductivity of the SATE system tiles. Also, tensile capacity and resistance to compression are ensured, as well as a reduction of the building energy consumption, the elimination of thermal bridges. One reason for choosing the SATE system at the concrete use case building was the simple installation and therefore lower personnel costs in this context. Not only the facade, but also the **window surface must be finished**. This task includes the cleaning and smoothing of the surface for further processing steps. The whole facade surface, especially sharp edges, are grinded.

Afterwards, the **final quality check** follows. In particular, the new installations for improved thermal capabilities are checked with a check list before the removal of the scaffold. If everything was successful, the **deinstallation and uncovering of the equipment** follows. As a reorganization of some installations (gas, …) was conducted at this specific building, a final control of the disassembled and reassembled **gas, electricity and telecommunication** is reasonable. At this point, the facade renovation is nearly finished. For this reason, the scaffold is not needed anymore, so the **scaffold is disassembled**.

As the scaffold is rented for this concrete use case, the rental costs comprise the whole period between the scaffold assembly and the disassembly. In addition, the delivery and some waiting time before the built up must be considered. Before ending the facade renovation on the outside, everything is **cleaned** and cleared up. This task includes the disposal of waste, the packing of equipment and the removal of raw material that was not needed. Finally, a **final check** is conducted. When this final check was successful, the outside facade improvement the sample building for our concrete use case can be completed, which is indicated by an end event in the process.

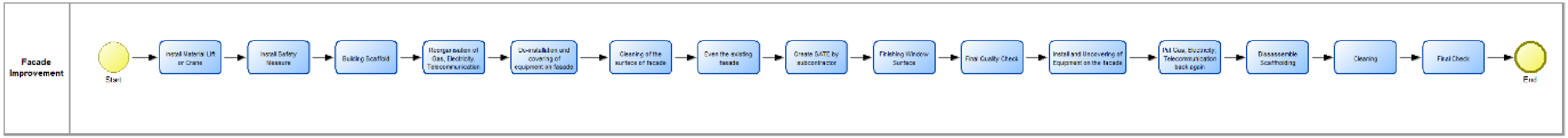


Figure 35: Facade Improvement Instance – Outside

6.2 EXTRACTION OF RULES AND FORMULAS

For discussing the required costs, times and resources of the facade improvement process (outside), an Excel table was set up. An overview of this table is shown in Table 2. As the facade improvement process has fifteen tasks, there is a row for each of those tasks. Additionally, the start element has its own row. The first column assigns a number to each task. The second column comprises the names equally to the BPMN facade improvement process tasks. In column three, the specific source of information for the correct monitoring of this activity is provided.

The following questions are used suitable to the process tasks:

1. Are there dependencies with respect to start like Season, Weekday and Organization that influence the project?
2. How to calculate / estimate time and cost. Cost of rental or use, Cost of personnel resources, duration, execution time etc.?
3. Are additional influence factors possible - like in-house equipment, local regulations etc.?
4. Are additional influence factors possible - like who is performing the task?

Those questions helped to work through the process and identify that there are generic risks like (a) delay because of bad weather, (b) delay because of inadequate sub-contractors, (c) delay because of a problem with the customer, and (d) delay because of difficulties with the infrastructure like electricity or water. Some additional risks have been identified for some activities, like the delivery of insufficient or wrong material, quality issues, safety issues or wrong planning.

The times and costs have been split for monitoring.

Times are relevant with respect to:

(a) duration to indicate when to start with the next activity and
(b) execution time to calculate how much unit costs – e.g. rental or staff costs – arose.

Costs are split in:

(a) personnel costs that are either staff of sub-contractor costs which are paid per time,

(b) equipment costs that is also paid by time – either depending on the duration like a rent, depending on the usage like productive hours or a combination of a fixed rent an additional cost for usage,

(c) material costs that occur when material is used. Sometimes the material is covered by a sub-contractor and hence does not need to be assessed by the project manager.

The trustworthiness and origin of the measures indicate, where the data to manage this particular activity comes from. This corresponds with the goal of assessment that is indicated in the last column.

	Task	Source and Trustworthiness of Measures	Duration Time	Execution Time	Cost on Person Resources	Cost on Equipment	Cost on Material	Risks	What needs to be assessed?
	Start		none	none	none	none	none	Delay based on weather Delay based on subcontractor Delay based on customer Availability of infrastructure (water, electricity, waste)	Pre-Conditions
1	Install Material Lift or Crane	Estimated	X	none	none	X	none	Delay based on weather Delay on supplier Wrong machine	Quality and safety of the equipment
2	Install Safety Measure	Expert Knowledge	X	X inspection time	X security agent	none	none	Delay based on weather Delay based on subcontractor Delay based on customer Non-Compliant Safety Measure	Quality and approval
3	Building Scaffold	Expert Knowledge	X	none	none	X usage of scaffold	none	Delay based on weather Delay based on subcontractor Delay based on customer Non-Compliant Safety Measure	Duration of using the scaffold
4	Provisionally reorganisation of Gas, Electricity, Tele-communication	Expert Knowledge	X	X time	X special agents	none	none	Delay based on weather Delay based on subcontractor Delay based on customer Non-Compliant Safety Measure	Duration and availability of special staff
5	De-installation and covering of equipment on facade	Expert Knowledge	X	X time	subcontractor or staff	none	none	Delay based on weather Delay based on subcontractor Delay based on customer Non-Compliant Safety Measure	Time and stock availability

6	Cleaning of the surface of facade	Calculated using standardised procedures	X	X	subcontractor or staff	none	higher costs on material	More material needed than expected Real material is different than expected Delay based on weather condition Delay based on subcontractor Delay based on customer Non-Compliant Safety Measure	Time, cost and quality
7	Even the existing facade	Calculated using standardised procedures	X	X	subcontractor or staff	none	higher costs on material	Delay based on weather Delay based on subcontractor Delay based on customer More material needed than expected Real material is different than expected Non-Compliant Safety Measure	Time, cost and quality
8	Create Ventilated Facade or SATE by Subcontractor	Calculated using standardised procedures	X	X	subcontractor	none	none	Delay based on weather Delay based on subcontractor Delay based on customer More material needed than expected Real material is different than expected Non-Compliant Safety Measure	Time, cost and quality
9	Finishing Window Surface	Calculated using standardised procedures	X	X	subcontractor	none	none	Delay based on weather Delay based on subcontractor Delay based on customer More material needed than expected Real material is different than expected Non-Compliant Safety Measure	Time, cost and quality
10	Final Quality Check	Expert Knowledge	X	X	special staff (third party, subcontractor, staff)	none	none	Delay based on weather Delay based on subcontractor Delay based on customer Non-Compliant Safety Measure	Quality
11	Install and Uncovering of Equipment on the facade	Estimated	X	X time	subcontractor or staff	none	none	Delay based on weather Delay based on subcontractor Delay based on customer Non-Compliant Safety Measure	Time, cost and quality
12	Disassemble Scaffolding	Estimated	X	none	none	X	none	Delay based on weather Delay based on subcontractor Delay based on customer	Time

13	Cleaning	Estimated	X	X	subcontractor or staff	none	X	Delay based on weather Delay based on subcontractor Delay based on customer Non-Compliant Safety Measure	Time
14	Final Check	Expert Knowledge	X	X	special staff (third party, subcontractor, staff)	none	none	Delay based on weather Delay based on subcontractor Delay based on customer	Quality

Table 2: Facade Improvement Template - Outside[11]

[11] http://www.generadordeprecios.info/

With Table 2, each project manager can now work out a particular monitoring that fits the specific purpose. Once a KPI-model is generated, it serves as a KPI pool or as a template also for other processes.

We started to fill this KPI model pool with the “building scaffold” task.

In collaboration with a domain expert, we found out that there are three stages of planning involved:

1. Initial Plan: cost and time estimations
2. Concrete Plan: signing of contracts
3. Monitoring Plan: check if real world site is according to plan

The initial plan is a rough estimation of the costs and the times, based on historical data as well as assumptions and in-house knowledge. Due to in-house knowledge it might be suggested to estimate 15 EUR per m^2 for the scaffold budget. For example, if we have 1.000 m^2 we need 15.000 Euro for the scaffold then. Furthermore, it is assumed that it takes 3 months to renovate a 1.000 m^2 facade. With these calculations, the way should be paved for understanding the importance of the simulation by learning from all project partners as well as the domain expert.

After the initial plan, the concrete plan is established. This includes the consideration of KPIs. The main questions in this context are what should be measured, why should it be measured, what is the tolerance and how can we get the data for the measure. The different building blocks of the contract can be parted in times and costs for instance. Another differentiation in measured costs and simulation can take place. In collaboration with the expert, we worked out a possible scenario for the building of the scaffold, considering the following parameters:

- Start time: t0
- End Time: t1
- Execution: not relevant
- Duration: 90 days (from start to end)
- Target cost estimation: 15 EUR per m^2
    - Measure:
        - Price per day = m^2 of facade * EUR per m^2 = 1.000 m^2 * 15 EUR = 15.000 EUR
        - Costs per period = Price per day * days = unknown as we do not know how many days the scaffold is actually needed.
    - Simulation:
        - likelihood of no payment of client (linear risk) – scaffold keeps staying
        - likelihood of weather delays in next months (depends on demand forecast)
        - likelihood of subcontractor failure (depreciated risk)
        - likelihood of unforeseen problem (depreciated risk)

First, the planned KPI value is estimated and stored. Second, the data source is identified that calculates the days the scaffold is in use. In addition to the costs calculation, the likelihood of weather-, sub-contractor -, customer- or other issue based delay is estimated with normal distribution.

The result was the first configuration of the monitoring, where data services provided (a) the estimated planned figures using a manual entering of the data, (b) a data service that accesses a data source providing the number of days the scaffold is in use and (c) three excel sheets with an optimistic, a moderate and a pessimistic simulation scenario that is continuously triggered by the monitoring cockpit.

In order to get further insights on the importance and the principle of Table 2, another row is explained in more detail. Above we described the scaffold task. As there are quite varying requirements regarding times, costs, trustworthiness and assessments, we also want to go into further detail for the "create ventilated facade or SATE by subcontractor" task.

For the initial plan, rough estimations of costs and times are taken. As a subcontractor is involved in the creation of the facade, it might be the case that there is no direct in-house knowledge available, except subcontractor contracts and details about past collaborations. This makes it even harder to set up the concrete plan, as the calculations and KPIs depend on external input. Again, the main questions in this context are what should be measured, why should it be measured, what is the tolerance and how can we get the data for the measure. For sure, the duration is of interest, as well as the execution time. In contrary to the scaffold task, the creation of the facade is taken over by a subcontractor. Hence, the personnel resource costs are important, whereas costs for material and equipment are not directly considered. In collaboration with the expert, following parameters are of peculiar interest:

- Start time: t0
- End Time: t1
- Execution Time: How long does the facade creation take in person hours? This measure is used to plan the further tasks.
- Duration: overall time from start to end
- Target cost estimation: 25 EUR per hour for one construction worker with one labourer
  - Measure:
    - Price per day = price per hour * hours per workday
    - Costs per period = Price per day * days
  - Simulation:
    - likelihood of no payment of client (linear risk) – interim solution for facade might be required to protect it against external influences like rain
    - likelihood of weather delays in next months (depends on weather forecast)
    - likelihood of subcontractor failure (depreciated risk)
    - likelihood of unforeseen problem (depreciated risk)
      - more material is needed than expected
      - real material is different than expected
      - non-compliant safety measure

After the planned KPI value is estimated and stored, the likelihoods of the risks are simulated. Since this task depends on a subcontractor, getting the figures might be more complex compared to a task conducted internally. Instead of relying on expert knowledge, standardised procedures for the calculations must be taken. Therefore, the combination and comparison of different figures and KPIs might be reasonable. For instance, it is reasonable to measure the progress on the construction site, have a look at the personnel time sheets in the reporting system and compare them to the subcontractor contract/invoice.

The creation of the facade has additional risks and different assessments compared to the scaffold task. Especially, the material can include some critical issues. For instance, the material delivery could go wrong and more material is delivered. This requires a sophisticated decision about the further processing – store the remaining material, send it back or change the agreement with the supplier. It can also be the case that the delivered material is different than expected. This case might involve adapting the standard procedures or in worst case losing time by ordering new material.

In contrary to the scaffold task, the facade creation does not focus on the duration. Not only times, but also costs and especially quality must be considered. In case of regular quality issues, it might be necessary to change the subcontractor, for instance.

Concluding, Table 2 should show the interconnections of data measures, data sources, times, costs, risks and assessments. By giving explanations for two samples – “building scaffold” and “create ventilated facade or SATE by subcontractor” – the importance of the mentioned issues should be obvious.

7. Conclusion and Outlook

7.1 Conclusion

The first iteration of process management: (a) introduced the principles of process management in the domain of renovation initiatives, (b) generated the first set of templates with the domain experts, (c) exemplarily extracted knowledge for predictive simulation from domain experts and (d) technically set up the possibilities to create a digital twin for the renovation process as well as (e) tested the transformation of a renovation process template towards an executable renovation process as proof of concept.

The introduction of process management into the domain of renovation initiatives resulted in (i) the adaptation of the approach, as well as (ii) the introduction of the approach to the domain experts.

For (i) the adaptation of the approach the principles of "Industrial Business Process Management" have been considered, since this approach also deals with physical business processes. As our approach currently only considers time and costs, the available BPMN standard and the corresponding tool family for Industrial Business Process Management was applicable. However, in specific cases, we proceed also to more complex aspects like the management or sub-contractors, their contracting, material flow and similar aspects, the process notation BPMN may be re-visited to sufficiently cover also those aspects.

The tool family that was used, needed some configurations in order to better enable the reflection of expert knowledge and address the individual characteristic of renovation initiatives. The Industrial Business Process Management is often applied in semi-automatic or automatic production environments, hence a highly automatized and repetitive sequence of actions, whereas the renovation process is unique for each site and mainly performed manually. This phenomenon was addressed by introducing transformation layers between the different renovation process models – from template to instance and workflow – which is a domain specific characteristic.

Furthermore, the absence of massive data and the need to rely on domain-expert knowledge required changes in the way the KPIs are calculated and simulated. The heterogeneous influence factors and the different expert opinions have been reflected in the knowledge-based simulation environment that needs more domain-expert user-friendly possibilities to contribute with knowledge.

The (ii) introduction of the process management approach to the domain experts was a very fruitful and positive experience. There are significant similarities between already existing project management and the here introduced process management. Hence, the identification of where existing project management leaves the room for complementary support as well as the fact that a thorough planning phase is needed before the process models can be used, was accepted and positively received by the domain experts in the project.

The renovation process models quickly gained awareness between other partners, as the concrete sequence of actions, tool interactions and required data were mapped form existing approaches with the top-down process management that was driven by the domain experts. In that case, the process model acts as a moderation platform to bring high level domain experts on board of the project.

7.2 Outlook

This document describes the first set of renovation processes, which will be complemented by the second set of renovation processes. In addition, there are related descriptions (D6.4 and D6.5) that describe the corresponding tools to apply the introduced process management of renovation processes. In the following we provide an outlook on:

(a) Lifting renovation process design to full-fletched Renovation Process Modelling

The current simple design of renovation processes will be lifted with modelling functionality, such as analysis, that query critical parts of the process or provide a formal verification of the process. Questionnaires to approve and release a certain process can also be an applicable form for a collaborative model release workflow. Such a functional enrichment is necessary when considering the complexity and combining several processes together.

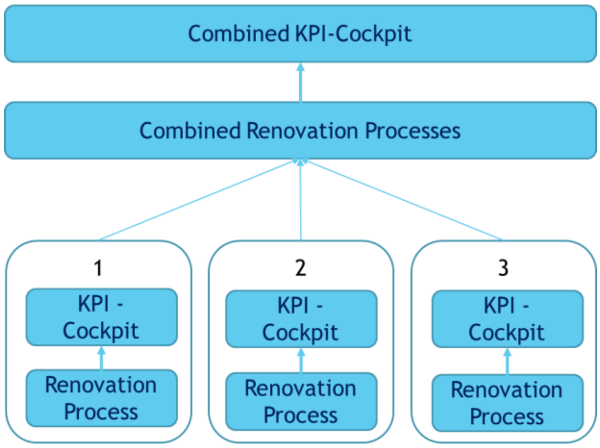


Figure 36: Nested Process-Management

Figure 36 shows a sample of nested processes, where each renovation process has its corresponding KPI cockpit for monitoring. In most cases a renovation process consists of several initiatives – and not just one – hence is a combination of several processes that run in combination at one concrete site. Cross-process dependencies can be modelled by an overview process that combines the different renovation initiatives to a combined renovation project. The corresponding KPI-cockpit will then guide the whole site and not just one initiative.

Furthermore, an organization typically runs several sites in parallel, so applying the same principles of nested process management to whole projects will result in a combined project across several sites. The corresponding process simulation and KPI-cockpit may have the potential to monitor several sites for a whole season. In such scenarios, the process management needs more sophisticated process modelling capabilities compared to the current initial process design.

(b) Introducing Artificial Intelligence for efficient Renovation Process Management

The challenge for renovation processes is the transformation of process templates into instances.

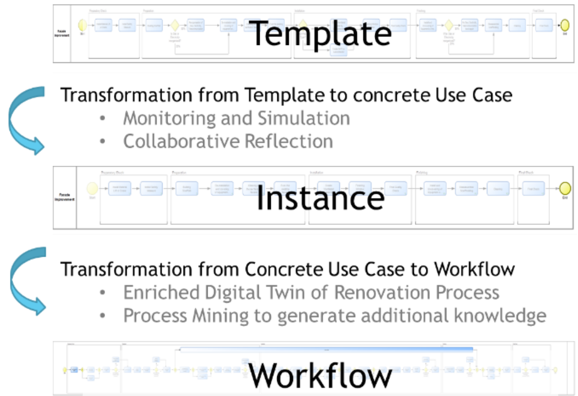


Figure 37: AI Techniques to support Model Transformation

Figure 37 indicates the three different levels of renovation processes, starting from the process template, the process instance for a concrete site and the workflow that creates a digital twin of the renovation process.

The transformation is currently exclusively performed in a manual and intellectual way from a process modeler. The goal is to introduce knowledge-based algorithms that support the transformation of process models to make process modelling more applicable.

(c) Enriching the digital twin of a Renovation Process and raise the interconnection with BIM tools

Renovation Process Management strongly relies on manual execution of the processes on the construction site, hence the role of a traditional workflow engine that orchestrates a sequence of software components can only be applied in a limited version for renovation processes.

We identified two challenges for the workflow engine. First, it is used to create a digital twin of the renovation process by not only timestamping each activity of the renovation process, but also by storing the necessary information for each step.

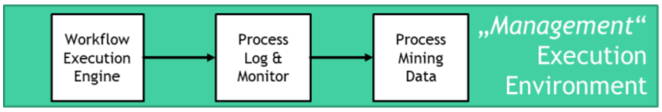


Figure 38: Prominent Role of Workflow Engine

Figure 38 indicates how such a digital twin of the renovation process can be used for process mining. First the workflow execution engine populates a process log, which can be mined afterwards.

Depending on the expected learning that should be derived from the process mining, the corresponding data needs to be collected and stored in the process log. In the first step, we consider times and probabilities as interesting, hence we timestamp each activity but also store the simulation assets. This enables a comparison, how close the different simulation models at the time of the decision were to the reality that is only known afterwards. Such findings of process mining enable a learning cycle, where those simulation models that were closer to the real process get a higher weight and those simulation models that have a large declination get a lower weight for the next run.

The second challenge of the workflow is not only to store the different data sets with a timestamp in order to generate a digital twin, but also to actually invoke the different software tools in order to assist the project manager in the various steps along a renovation project. This is approached by following a bottom up approach, starting from current renovation processes and stepwise also include offering or planning processes.

7.3 RELATED CONTENT

This document (D6.2) explains the first set of renovation processes and introduces how process management can be applied in the renovation domain. The successor of this document (D6.3) will complement the current renovation process models according to the aforementioned outlook.

The corresponding process modelling tool will be explained and provided as a report and in form of a downloadable tool package (D6.4), whereas the first version of the tool supports the processes of this document and the second version of the tool (D6.5) supports the processes of the succeeding document (D6.3).

Workflow relevant descriptions are provided in the documents D6.6 and D6.7.

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ANNEX

In the annex, the process templates including the process phases and other relevant figures can be found in a higher resolution. Furthermore, for reasons of better documentation, they are divided in parts, so that the content is readable.

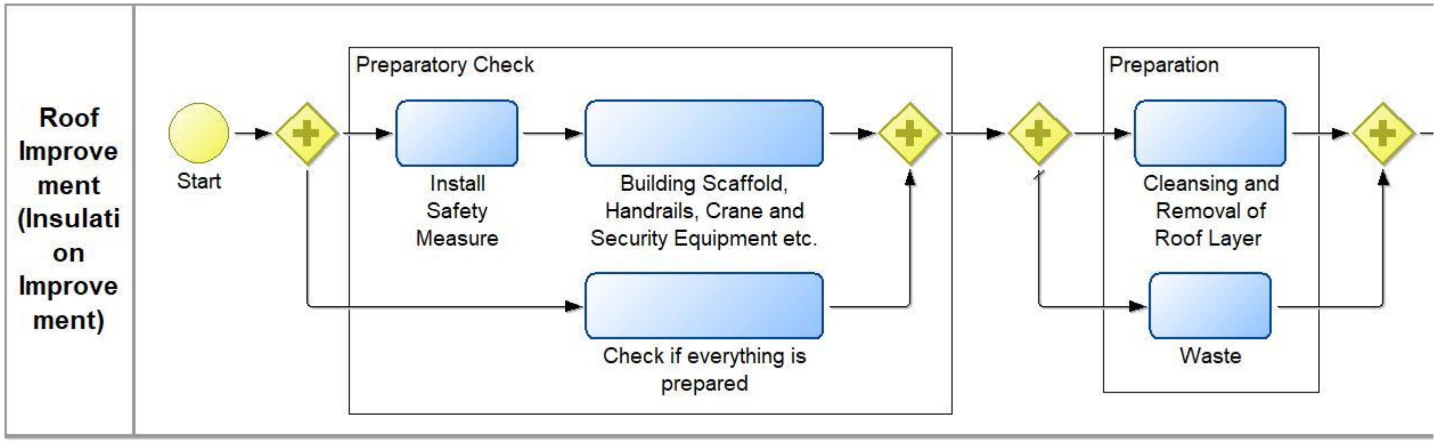

Figure 39: Roof Improvement Template - Outside - Part 1

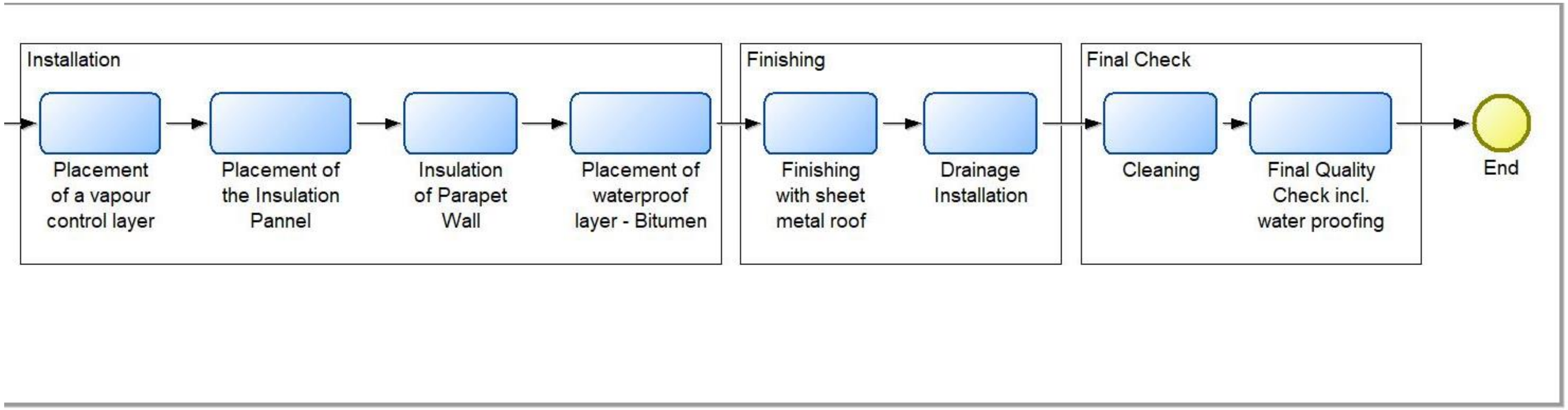

Figure 40: Roof Improvement Template - Outside - Part 2

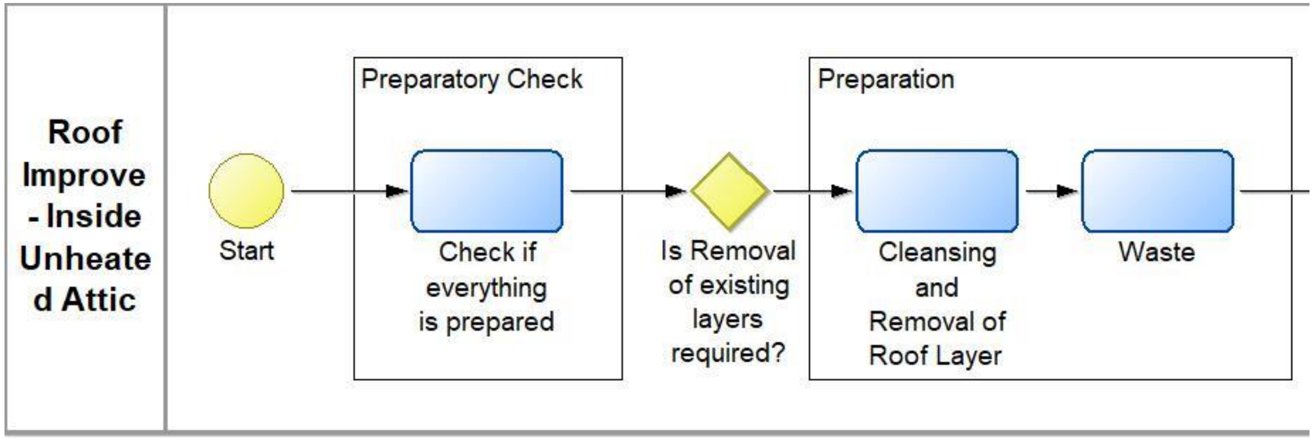

Figure 41: Roof Improvement Template - Inside Part 1

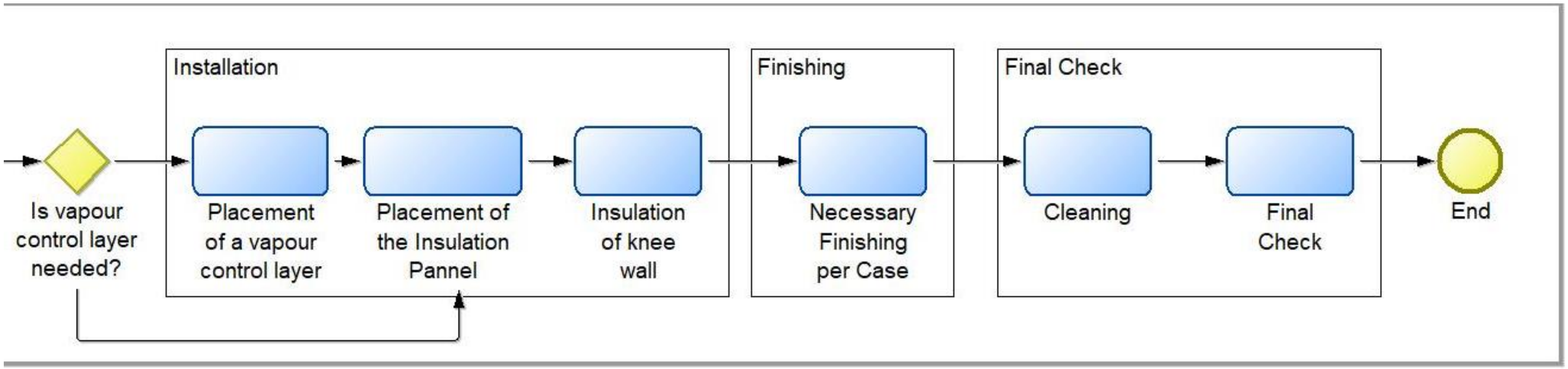

Figure 42: Roof Improvement Template - Inside Part 2

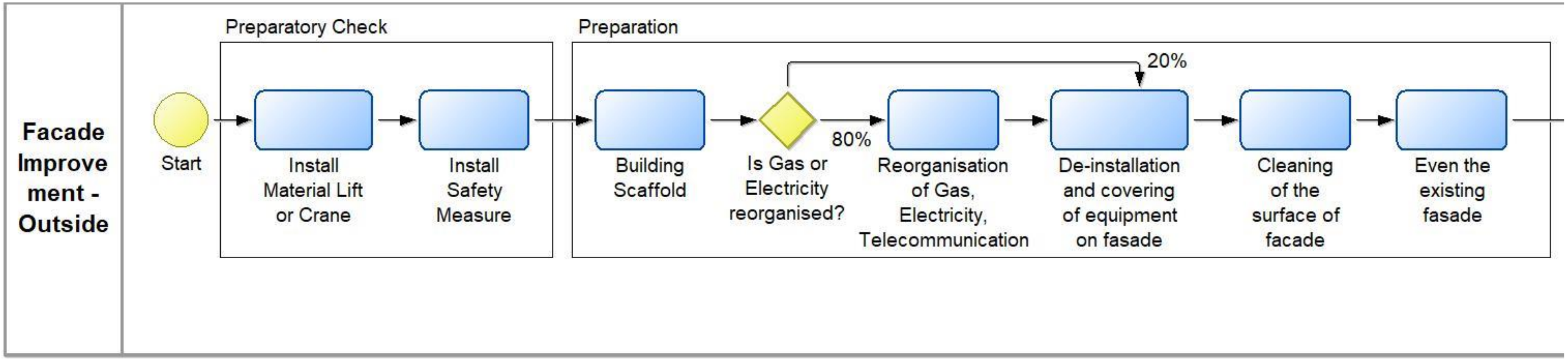

Figure 43: Facade Improvement Template - Outside Part 1

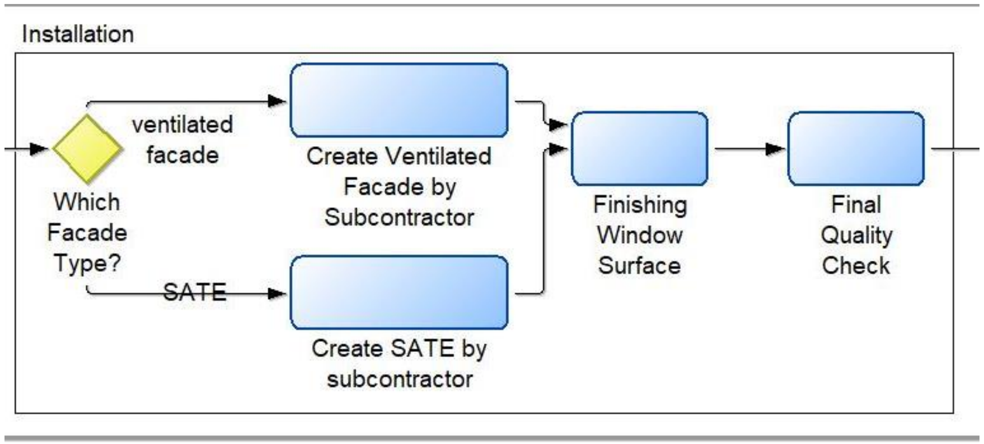

Figure 44: Facade Improvement Template - Outside Part 2

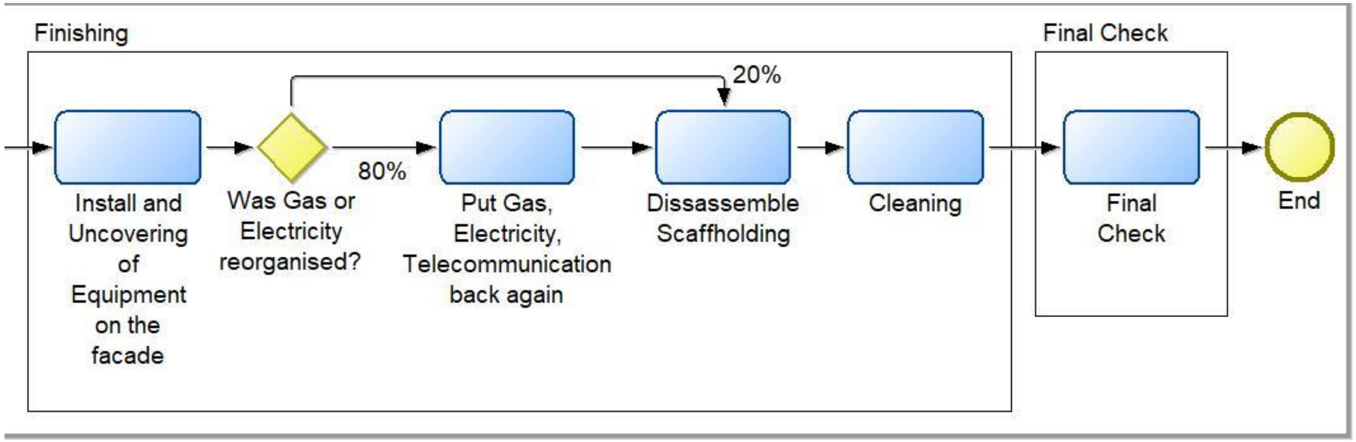

Figure 45: Facade Improvement Template - Outside Part 3

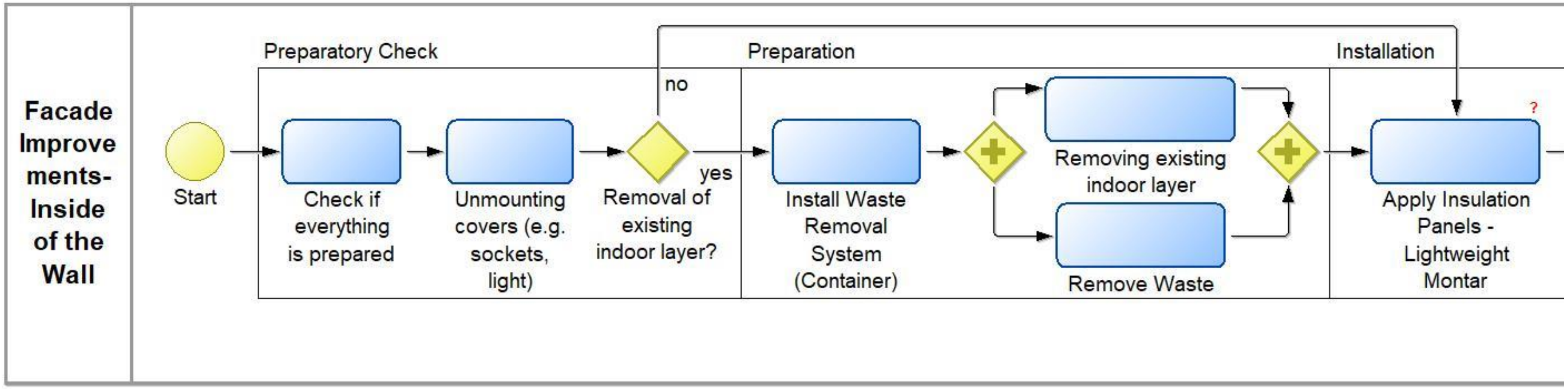

Figure 46: Facade Improvement Template - Inside Part 1

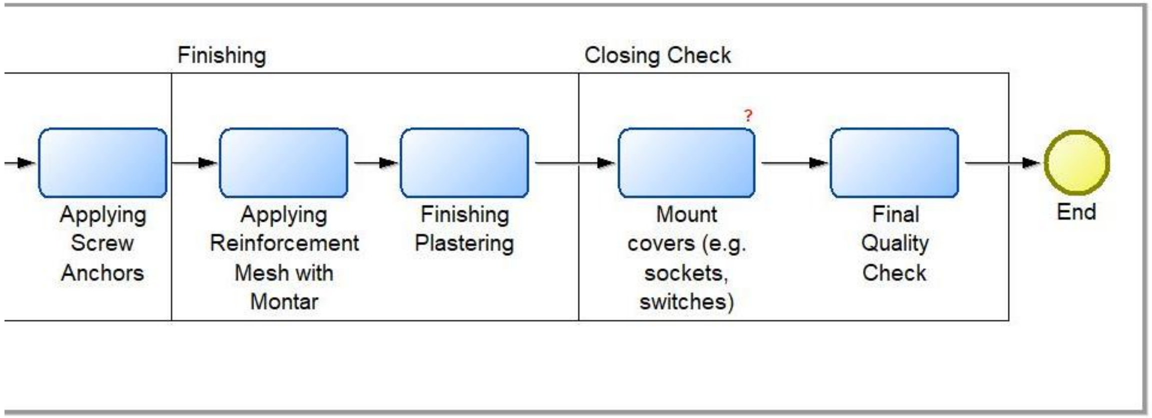

Figure 47: Facade Improvement Template - Inside Part 2

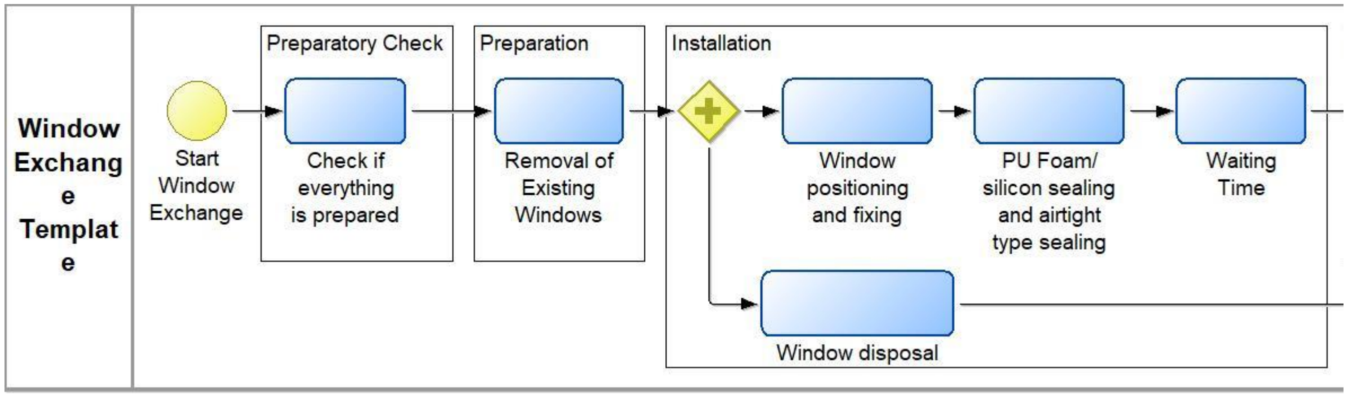

Figure 48: Window Exchange Template - Part 1

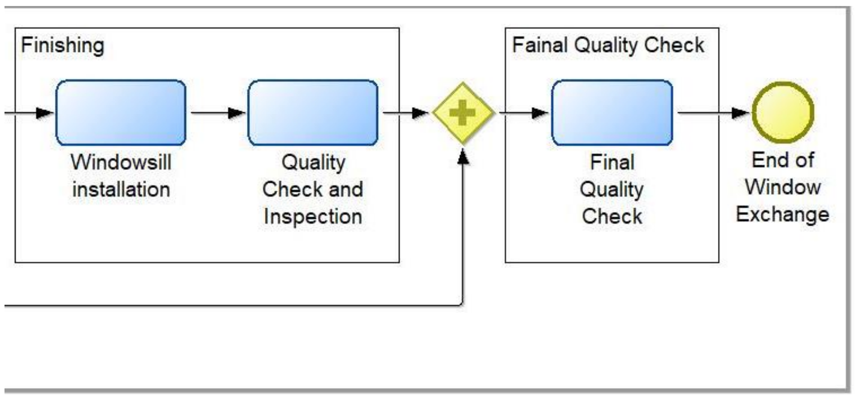

Figure 49: Window Exchange Template - Part 2

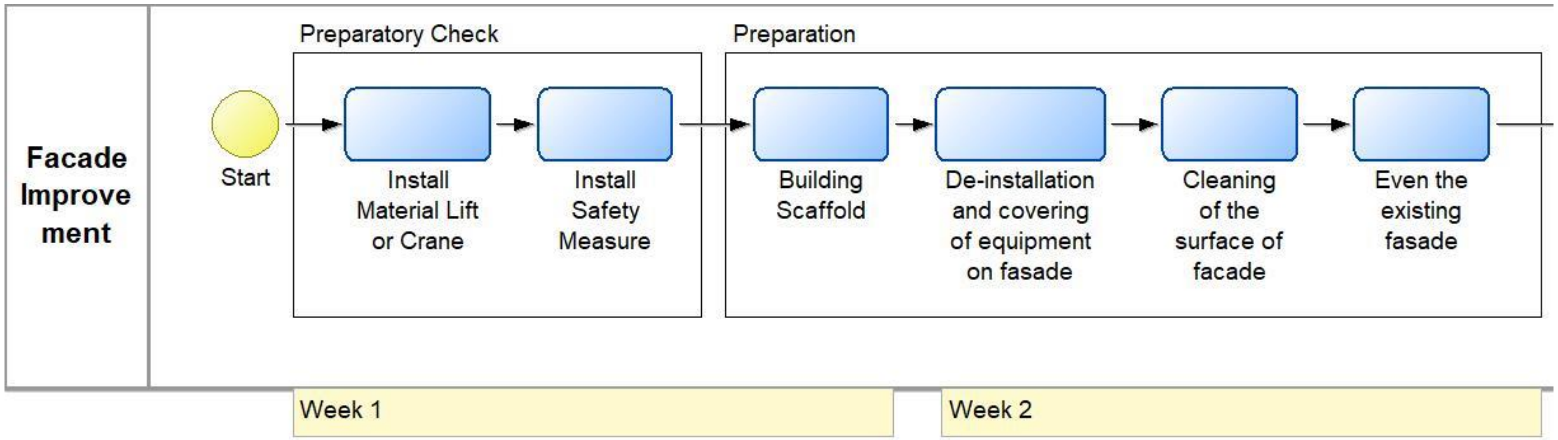

Figure 50: Facade Improvement Sample - Outside Part 1

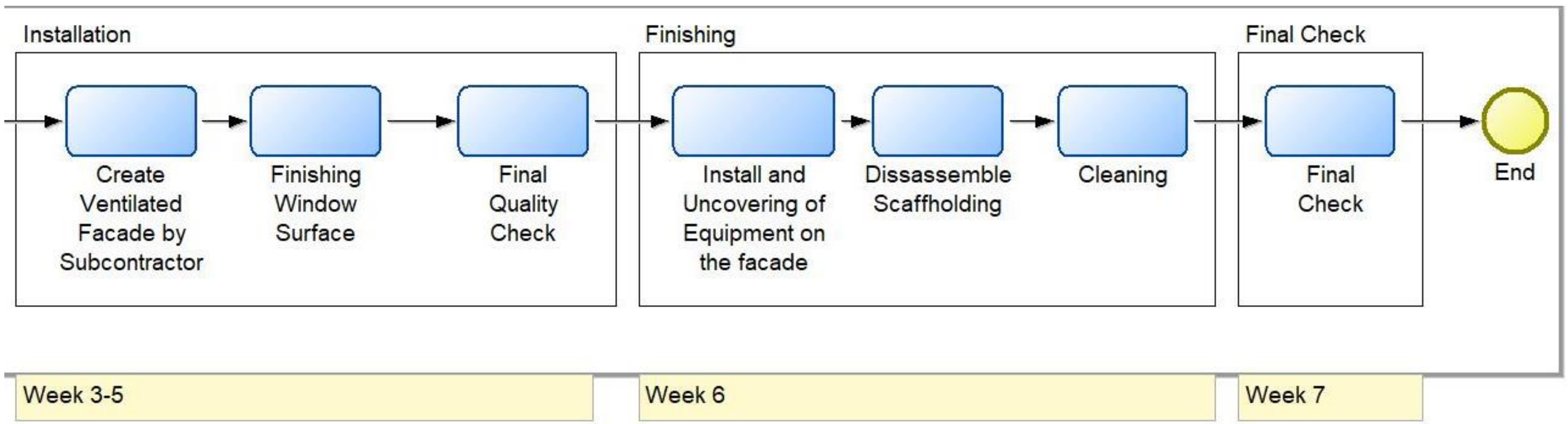

Figure 51: Facade Improvement Sample - Outside Part 2

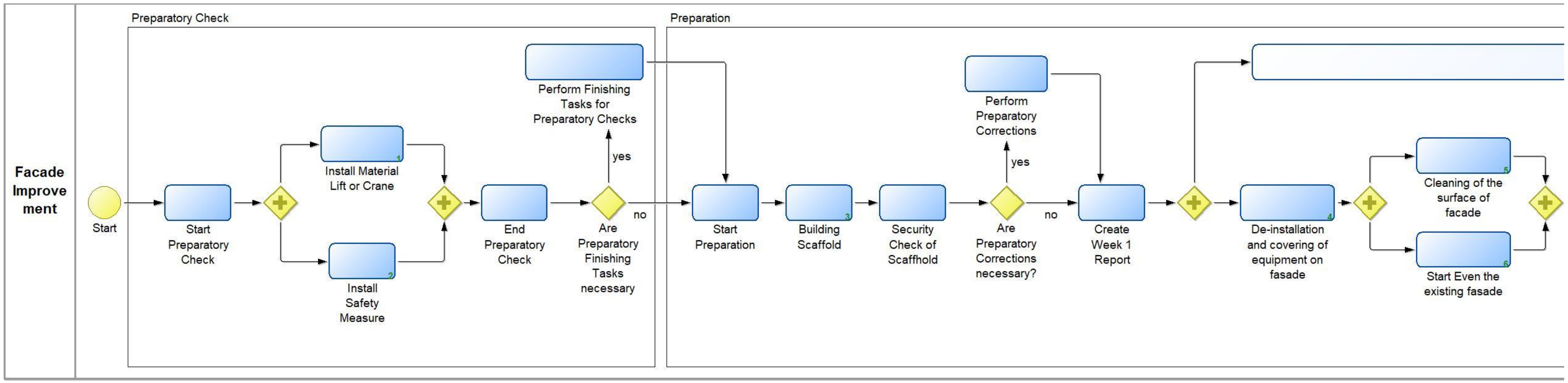

Figure 52: Executable Renovation Process of "Facade Renovation Outside" - Part 1

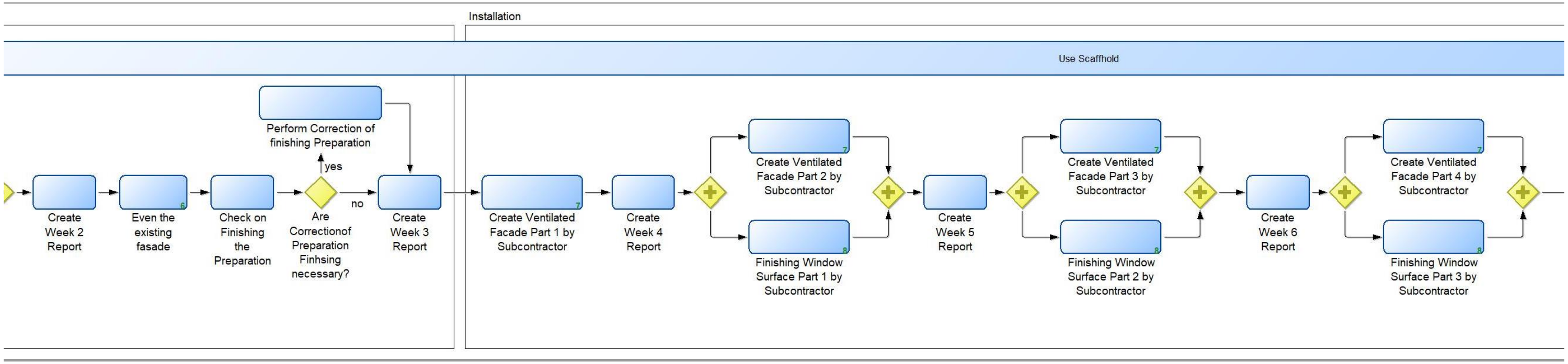

Figure 53: Executable Renovation Process of "Facade Renovation Outside" - Part 2

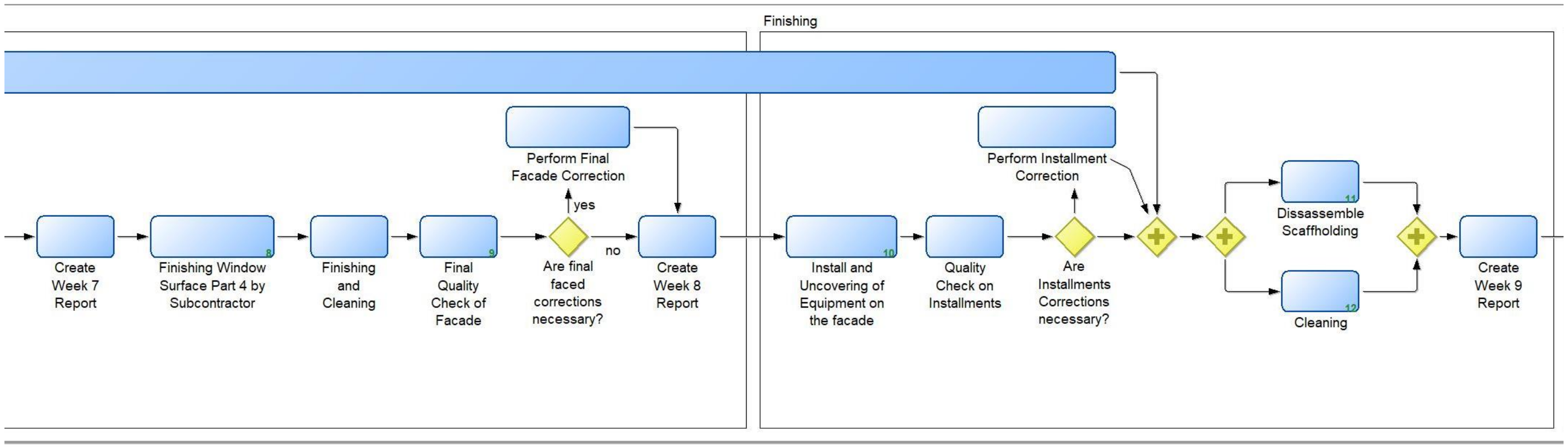

Figure 54: Executable Renovation Process of "Facade Renovation Outside" - Part 3

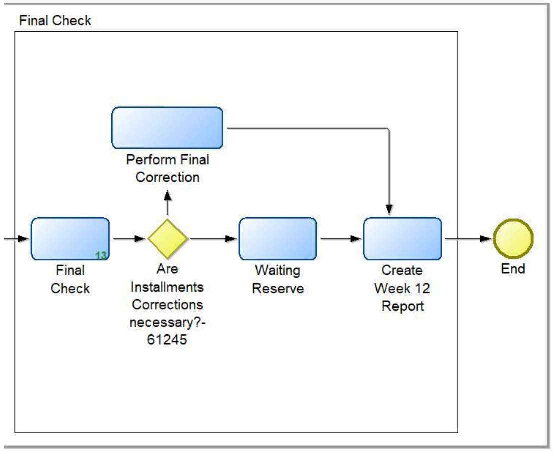

Figure 55: Executable Renovation Process of "Facade Renovation Outside" - Part 4

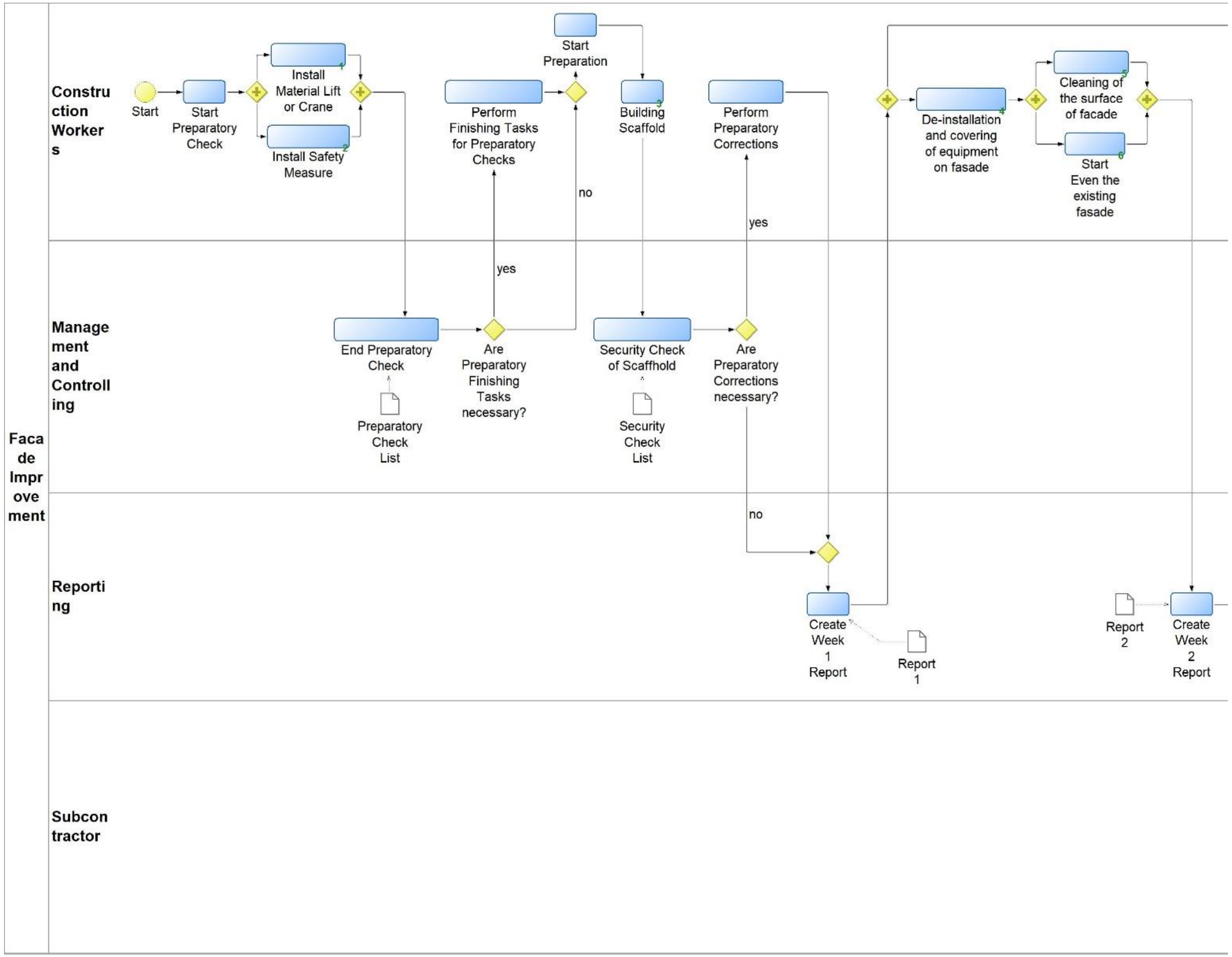

Figure 56: Business Workflow for the Facade Renovation - Part 1

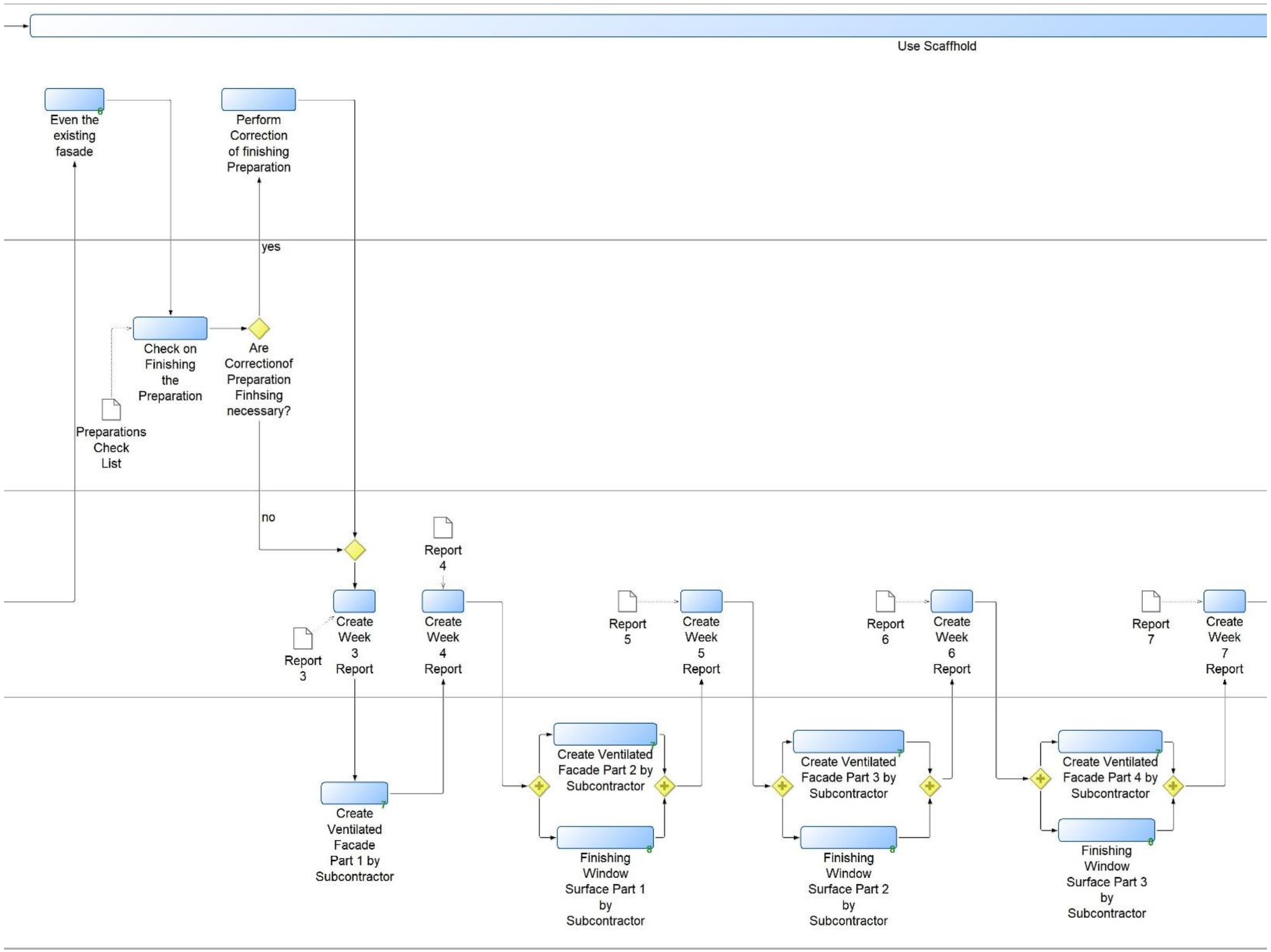

Figure 57: Business Workflow for the Facade Renovation - Part 2

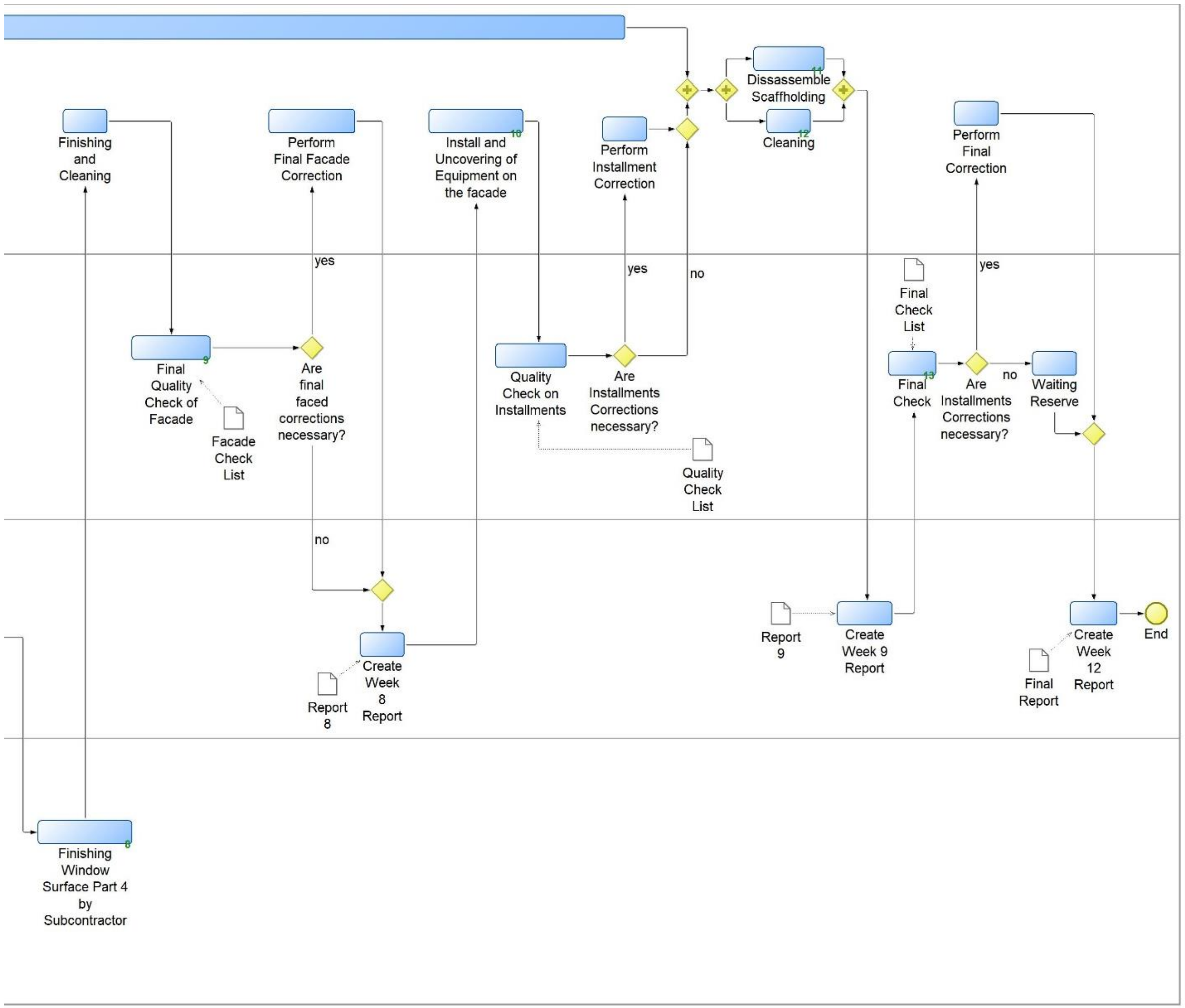

Figure 58: Business Workflow for the Facade Renovation - Part 3

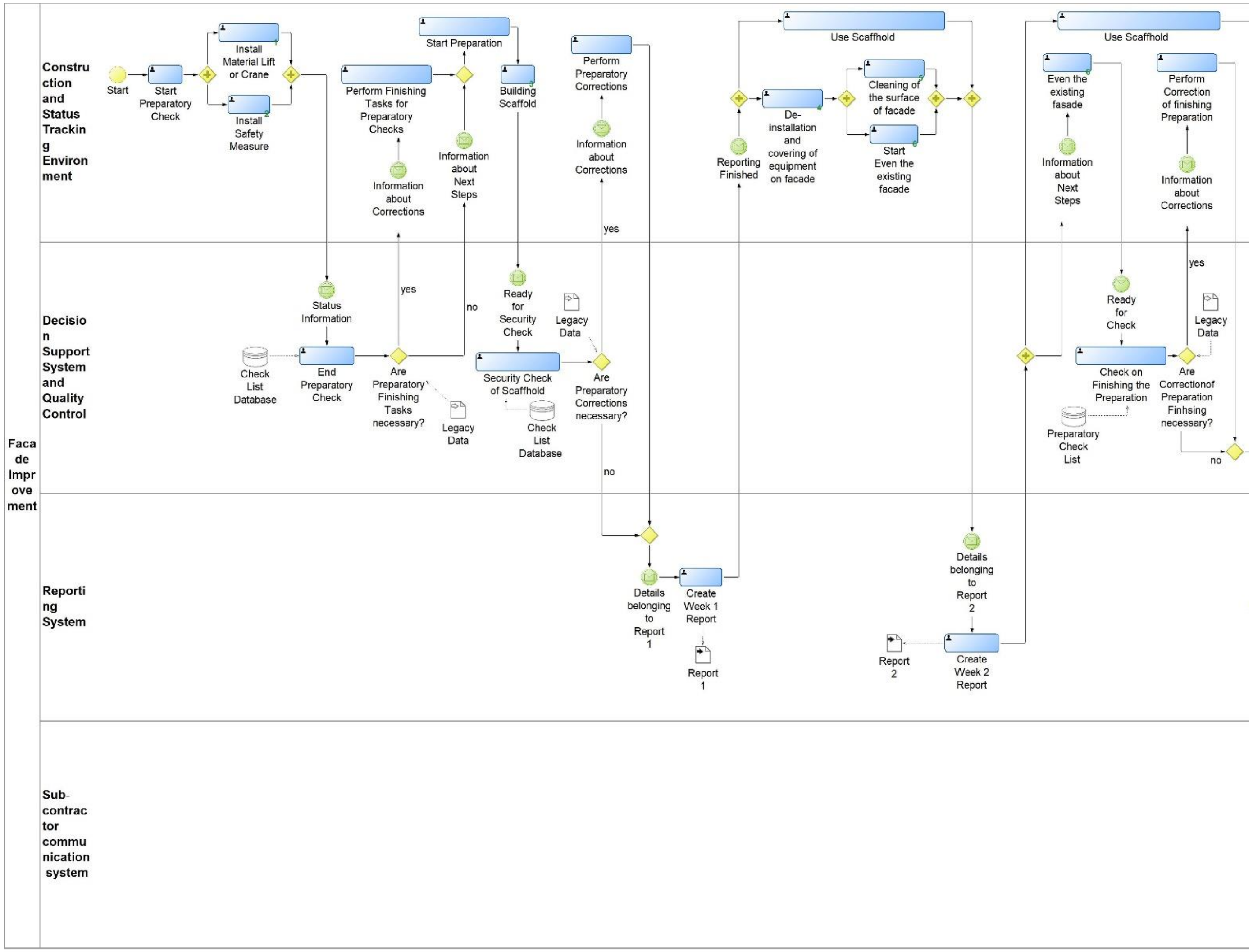

Figure 59: Abstract Workflow for the Facade Renovation - Part 1

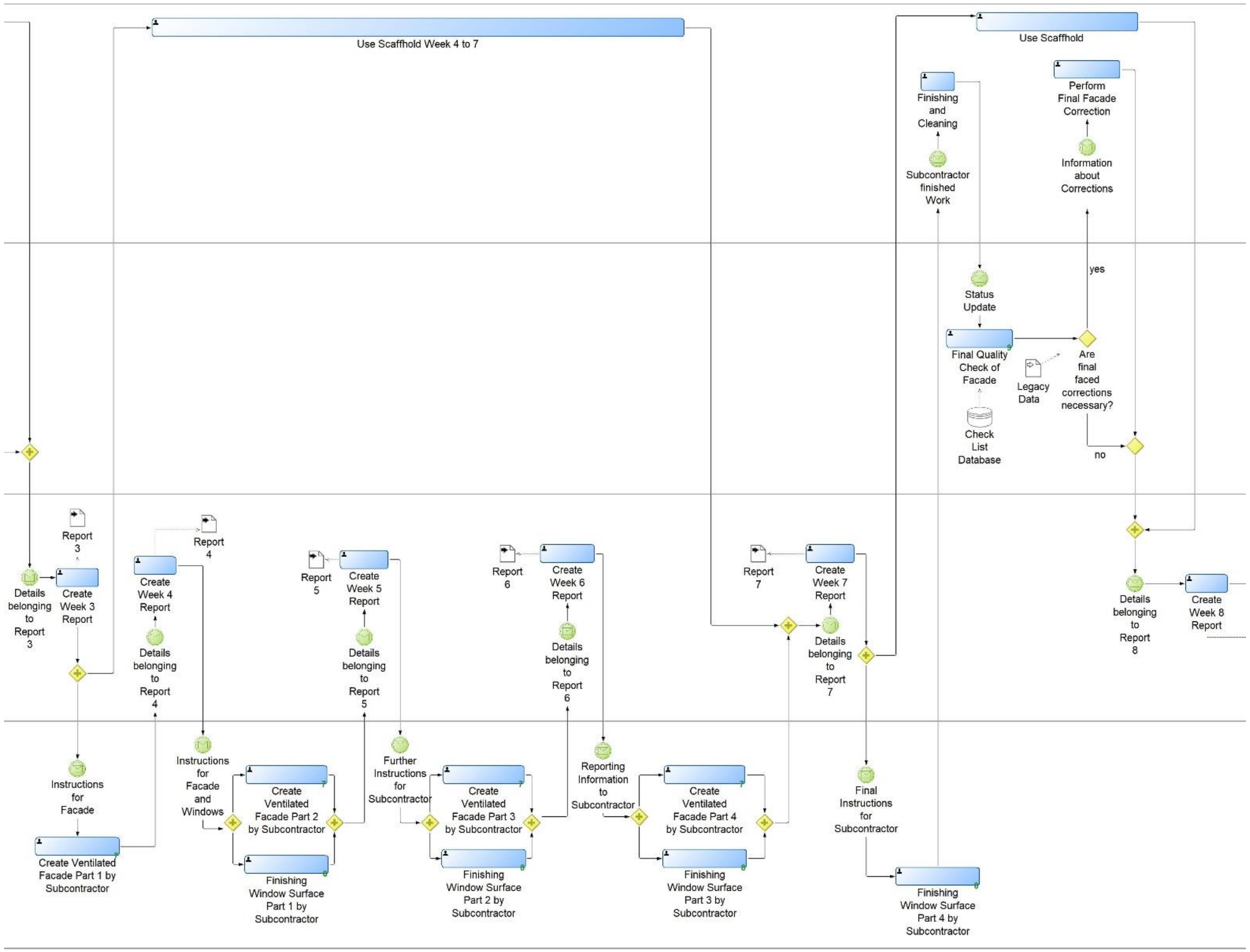

Figure 60: Abstract Workflow for the Facade Renovation - Part 2

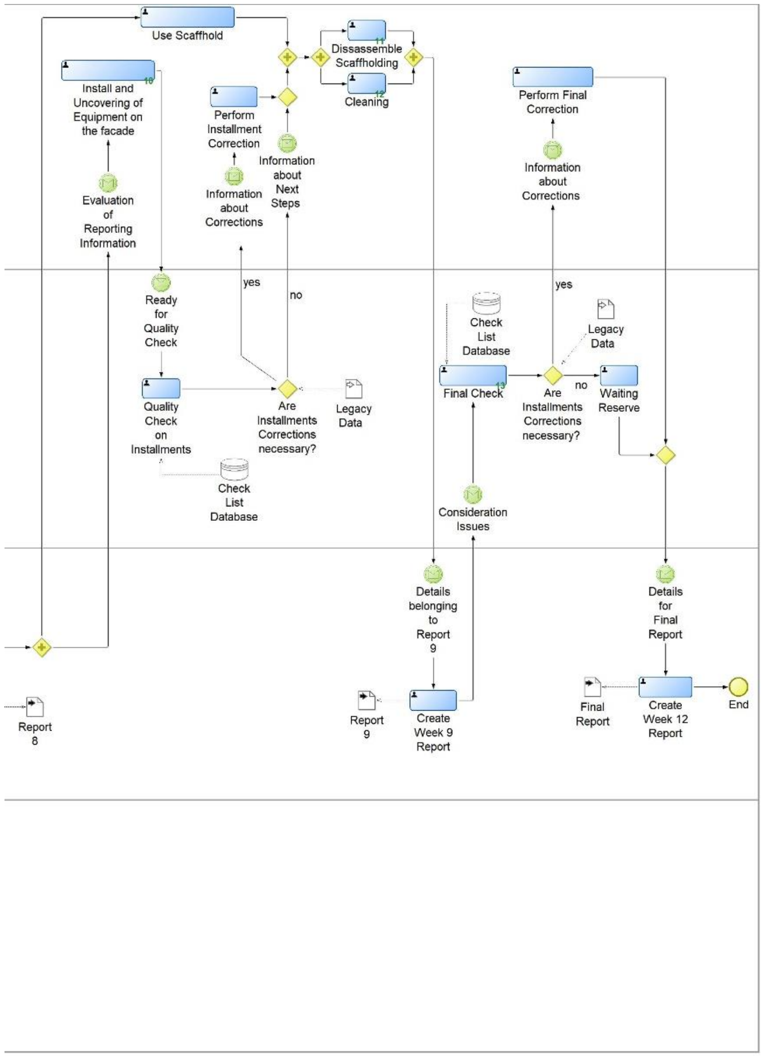

Figure 61: Abstract Workflow for the Facade Renovation - Part 3