

Technical Report

# **The Visual Service Design Tool**

**Version 1.4.1**

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# 1. Introduction

The goal of process modeling, as of Model Driven Engineering in general, is to provide an abstract view on systems, and to design those systems in a language and platform independent way. For that purpose the Business Process Modelling Notation (BPMN) [8] standard was created by the Object Management Group. It can be understood intuitively by all business partners, even those who have great knowledge in their domain but do not know too much about Service Oriented Architecture (SOA) or programming in general. At the same time, BPMN is formal enough to provide a basis for the later implementation and refinement of the business process. Given a respective mapping, a BPMN diagram can be used for generating readily executable code from it. A brief introduction to BPMN is given for instance in [9] and in Appendix B of this manual.

Today, the Business Process Modelling Notation and the specified mapping to the Business Process Execution Language (BPEL) are supported by a growing number of tools. However, the problem with the majority of existing tools is that while they do provide the usual transformations from BPMN to BPEL, they are focused only on this one aspect of BPMN. Often the editors and even the underlying meta-models are adapted to BPEL in many ways. While this may be desired in order to provide highest possible usability and to support the user in the creation of executable BPEL code, the consequence is that business process diagrams created with these tools can neither be transformed to other executable languages, nor can the process model be used with other tools that might provide different transformations. Thus, while process modeling and BPMN should be independent of a specific executable language, the *tools* are not.

The solution to this problem is to keep both the underlying BPMN meta-model and the diagram editor free from influences from the BPEL world and to use pure BPMN instead, so that diagrams created with such a tool will be truly independent of any concrete language – apart from what influenced the BPMN specification in the first place. Based on this, several mappings to different target languages can be implemented and integrated into the editor as plug-ins, which may also contribute to the editor in order to support the business architect with language-specific support.

Following this approach, the *Visual Service Design Tool* (VSDT) has been implemented as an Eclipse plug-in, inherently providing the necessary modularity. For the export of BPMN diagrams to executable languages a transformation framework has been designed. The actual transformations have been subdivided in distinct stages, so that significant parts of it are reusable, e.g. the challenging transformation of the control flow. Thus the actual mapping to a given language can be integrated in a very straightforward way. While the usual mapping from BPMN to BPEL has been realized as a

## 1. Introduction

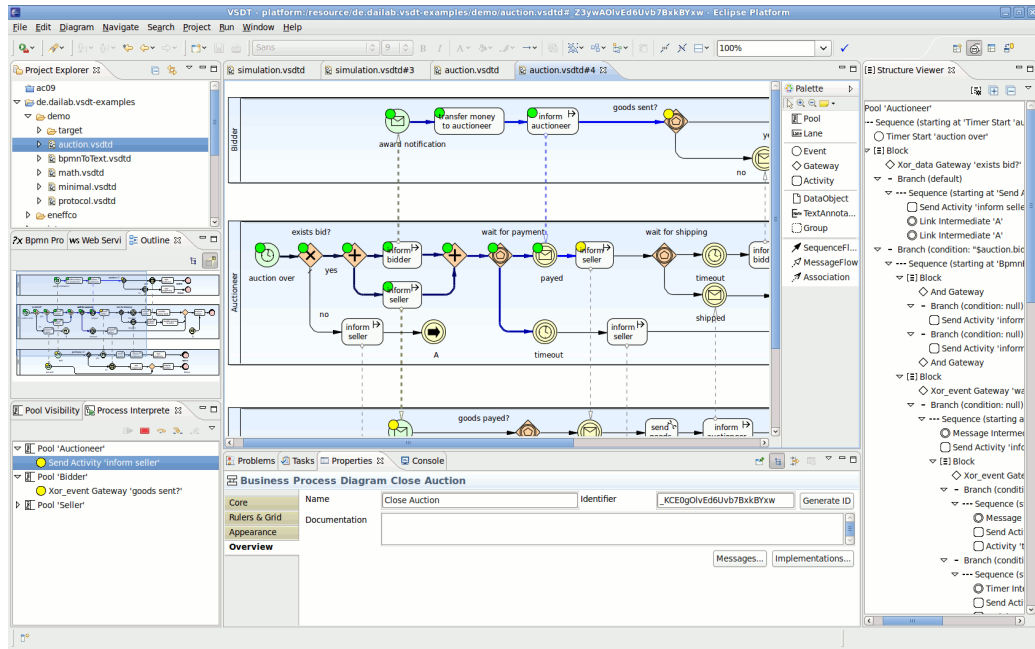


Figure 1.1.: The Visual Service Design Tool. Clockwise: Graphical Editor (with running Simulation), Structure Viewer, Property View, Process Interpreter View, Visual Outline, Navigator.

proof of concept, the main intent behind the VSDT is to provide a transformation from business processes to multi-agent systems such as the JIAC language family [3]. The respective mappings are currently under development. Our ultimate goal is to provide transformations not only in different, but also in heterogeneous systems just like they are used in the real business world.

### 1.1. The Visual Service Design Tool

The first version of the VSDT has been developed as a diploma thesis [4] in the course of the *Service Centric Home (SerCHO)* project at TU Berlin in early 2007. As the work continued, it matured to a feature-rich BPMN editor (as seen in Figure 1.1) with an extensible transformation framework and has already been used in a number of service orchestration scenarios.

#### 1.1.1. The Metamodel

The BPMN specification [8] describes in detail how the several nodes and connections constituting a BPMN diagram have to look, in which context they may be used and what attributes they have to provide. However, it does neither give a formal definition



of the syntax to be used for the meta-model, nor an interchange format, e.g. using an XML Schema Definition (XSD). Thus the editor's meta-model had to be derived from the informal descriptions in the specification. As it was our main concern to keep as close to the specification as possible, almost every attribute and each constraint given in the specification have been incorporated into the meta-model, allowing the creation of any legal business process diagram. Still, some attributes have not been adopted in the meta-model: For instance the possibility to model nested or even crossing Lanes has been dropped, as it turned out that this feature seems to be virtually never used in practical business process design.

### 1.1.2. The BPMN Editor

Like many others, the VSDT editor has been created using the *Eclipse Graphical Modelling Framework (GMF)*, automatically equipping the editor with numerous features, such as support for the Eclipse properties, outline and problem view and unlimited undo and redo, just to name a few. Being embedded in the Eclipse workbench, the editor is easy to use while at the same time providing a powerful tool for professional business architects and service developers.

While GMF provides a solid basis for the editor, several customizations have been made to the code, further improving the editor's overall usability and supporting the creation of new business processes. For example, the generated property tables have been supplemented with custom-made sheets, in which the several attributes are more clearly arranged. For managing the non-visual elements given in the BPMN specification, such as Properties, Messages and Assignments, a number of clear and uniform dialogs were created. The various constraints given in the specification were translated to several audit constraints used to validate a given business process diagram.

As already mentioned, the VSDT was designed to be a pure BPMN editor and independent of BPEL, so the business process diagrams can be transformed to other languages, too, given the respective export plug-ins. Of course, the downside of this approach is that the editor lacks built-in support for BPEL, e.g. the editor itself does not validate an expression given in the diagram to conform to the BPEL syntax. However, it is possible to supplement the editor with additional plug-ins, which can contribute e.g. to the property sheets or provide whole new views with language-specific functionality.

One example of how the VSDT can be extended with features specific to a certain target language – in this case: BPEL – is the Web Service View, which can be seen in Figure 1.1, too. Using the Web Service View, existing Web services can be inspected and imported into the diagram. In the process, an Implementation object is created for the Web service as well as a set of Message objects, matching the service's input parameters and result. Optionally, also a new Pool will be created for the service, which can be connected to the currently selected Activity via a pair of Message Flows. Further, the Implementation and the Message objects will be associated to the Activity and its type will be set to SERVICE. Thus, the orchestration of existing Web services

in a BPEL process can be simplified greatly. Similar features can be created for other target languages, too.

Once the business process diagram is completed, it can be validated and exported to an executable language, such as BPEL or the JIAC agent framework. As the VSDT is intended to provide export features to arbitrary target languages, and to support developers in the creation of these features, we have created an elaborate export framework. For each of these features, being realized as additional Eclipse plug-ins, an individual wizard can be made available in the Export menu.

For more information regarding the Visual Service Design Tool, please refer to [\[5\]](#).

## 1.2. Features

In the following, some of the features of the VSDT are listed. For more information on selected features, please refer to [Section 5](#).

- export to (and import from) executable BPEL and JIAC Code and STP-BPMN
- translation of Expressions to the language used in the target framework
- process simulation and interpretation
- BPMN-to-text generation
- combination of BPMN-diagrams with Use-case-like 'higher view'
- pattern-based modeling, insertion of patterns on existing edges
- quick assembly of process diagrams using keyboard-shortcuts
- quick assignment of service parameters
- dynamic filtering of displayed pools
- variables-view and similar tools for the management of non-visual elements
- verification of process structure at design time
- automated, structure-based layout of BPMN diagrams
- one-click deployment of JIAC agent services generated from BPMN diagrams on a JIAC runtime

## 2. Setup

In the following the VSDT's installation process will be explained. As the VSDT is an Eclipse plug-in, the installation process consists of three steps:

1. Install Eclipse
2. Install Dependencies
3. Install VSDT

*Note that for running the VSDT Java is required in Version 5 or higher.*

### 2.1. Installing Eclipse

For using the Visual Service Design Tool you need the Eclipse IDE which can be downloaded from <http://www.eclipse.org> for different operating systems.

The current version of the VSDT, 1.4.1, works with Eclipse 3.6 “Helios”; it has not yet been tested with Eclipse 3.7 “Indigo”. For Eclipse 3.5, you can use the VSDT in version 1.4.0, and for Eclipse 3.4, you can still use the VSDT up to version 1.2.2.

### 2.2. Installing Dependencies

The VSDT depends on a number of other plug-ins which again will have some dependencies on their own. It is recommended to use the Eclipse Update feature, since this way all the dependencies and the dependencies of the dependencies will automatically be installed, too. The dependencies are:

- Graphical Modeling Framework SDK (group “Modeling”)<sup>1</sup>
- XText SDK (group “Modeling”)

For installing the plug-ins, make sure you are allowed to write in the Eclipse program folder; especially when running Linux you should start that instance of Eclipse with `sudo`. In Eclipse, select *Help* from the menu, then *Install New Software....* Select the

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<sup>1</sup>The VSDT 1.4.1 was created with GMF 2.1 and has been adapted to work with later Versions of GMF

*Galileo* repository from the drop-down menu and select the Dependencies from the list below. Now click on *Next* to automatically calculate further dependencies (this can take a few moments) and continue through the installation process. After that you might have to restart Eclipse. If the installation was successful the new features should appear in the *Installed Software* tab of the same dialog.

Theoretically, Eclipse can resolve the dependencies on its own, so it should be enough to select the VSDT itself. Still, we recommend to install the dependencies manually.

### 2.3. Installing the VSDT

Once Eclipse and GMF are set up you can install the Visual Service Design Tool itself. The latest version of the VSDT can be obtained from the following site(s):

<http://www.jiac.de>

Download the VSDT as an archived update site and add the site in the *Install New software* dialog (see last section), using the *Add...* button.

The VSDT's update site consists of the following features:

- *VSDT: Visual Service Design Tool* This is the core component of the VSDT, the visual BPMN editor, along with a number of useful extensions and the basic transformation framework.
- *VSDT: BPMN - BPEL Transformation* This feature provides the export to executable BPEL code.
- *VSDT: BPMN - JIAC V Transformation* This feature provides the export to JIAC V multi-agent systems. Additional Dependency: *Agent World Editor*
- *VSDT: BPMN - STP-BPMN Transformation* This feature provides exchange with the popular Eclipse STP BPMN editor. Additional Dependency: *BPMN Project Feature*
- *Agent World Editor* An modeling tool for creating and configuring JIAC agents. Required for the transformation from BPMN to JIAC V.
- *JIAC Utils* A JIAC node running inside an Eclipse plug-in, providing some useful functionality, being described in Chapter 8.

## 3. The Perspective

This section will briefly introduce those parts of the Eclipse GUI that are relevant for the work with the Visual Service Design Tool. These views are aggregated in the Easy Service Creation perspective, which can be selected via the Menu *Window* → *Perspective*. Figure 1.1 (page 2) is showing a screenshot of the Visual Service Design Tool featuring most of the relevant views. In the following each of the views will be introduced briefly.

### 3.1. VSDT Editor Views

The editor window is the central view, shown when a file is opened in Eclipse. Depending on the file type this can be a plain text editor, a browser, an elaborate code editor or some sort of graphical editor. For the Visual Service Design Tool there are two editors available: A visual editor showing the BPMN graph and a tree editor reflecting the internal structure.

**The Graphical Editors** These are the primary editors when working with the VSDT (see Figure 3.1):

- The *Business Process System* editor is opened when the diagram file is clicked. It is used for organizing the several interdependent Business Processes which make up the system as a whole, as well as the Participants involved in these Processes.
- The *Business Process Diagram* editor is opened when double-clicking one of the Business Process Diagram nodes in the Business Process System editor. This editor is the actual BPMN editor used for modeling the individual Business Processes.

Both editors feature a palette with the nodes and connections. For placing a node on the canvas or inside a compartment of another node (e.g. a Pool or a Sub Process) click the icon in the palette and then click again on the canvas. For drawing connections, click on the first node, draw the connection to the second node and release the mouse button. Note that nodes and connections can not be drawn arbitrarily, but have to follow the BPMN syntax, e.g. a Task can only be drawn inside a Pool and a Sequence Flow can only connect Flow Object within the same Pool, etc.

### 3. The Perspective

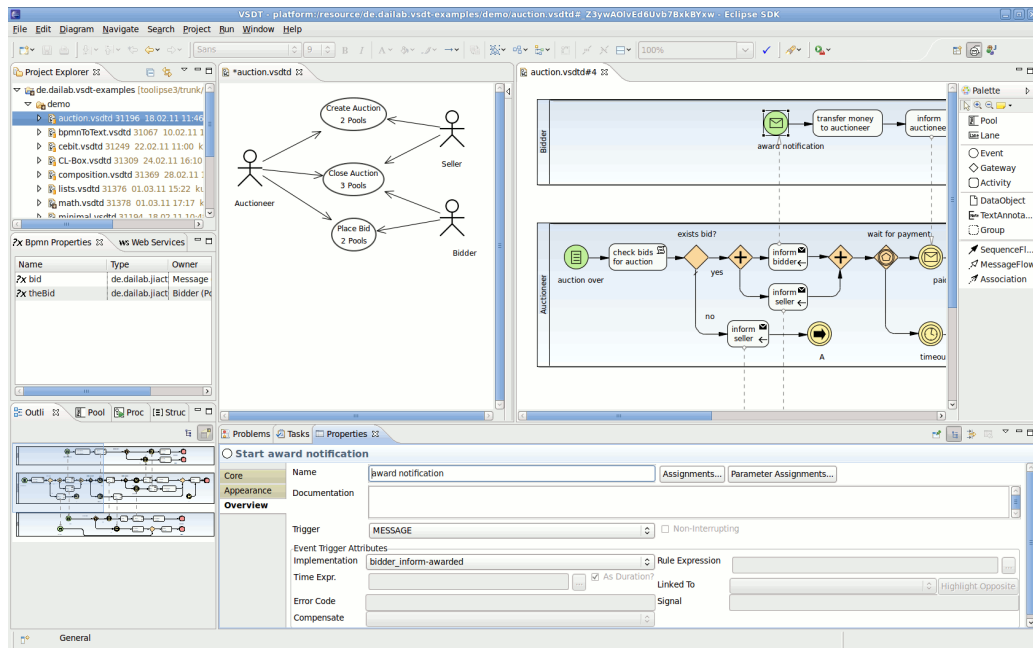


Figure 3.1.: Business Process System and BPMN editor shown side-by-side.

**The Tree Editor** The tree editor can be useful for managing and editing those parts of the Business Process Diagram that do not have a graphical representation.<sup>1</sup> Note that the tree editor has fewer restrictions than the graphical editor, and the diagram might be invalidated when doing certain operations in the tree editor. Especially, the tree editor should *not* be used for creating any elements that *do* have a graphical representation in the diagram, as this representation will not be created along with the element.

**The Text Editor** Of course, VSDT's files can also be opened with any text editor and edited as XML. While this can be helpful for adapting existing models to changes in the meta-model of a newer version of the VSDT, you should in general avoid editing the files' XML sources, as this can render them unreadable for the other editors.

These are the three possibilities to edit a VSDT file. However, unless needed (e.g. because the file is broken and can not be opened in the graphical editor), and unless you *really* know what you are doing, you should use only the graphical editor and avoid the others.

<sup>1</sup>Although in general it is not necessary to use the tree editor, as the graphical editor provides means for editing non-graphical elements, too.

## 3.2. General-purpose Eclipse Views

In the following some standard views of the Eclipse IDE will be introduced, that are relevant or otherwise useful for the work with the VSDT.

**The Project Explorer** Here the user can manage his projects and create and delete files. Note that Eclipse provides different similar views for managing files, e.g. the Project Explorer, Navigator, or the Package Explorer, each providing slightly different features.

**The Properties View** Although some attributes, like an element's name, can be edited in the graphical editor view as well, for most other attributes the properties view will be needed, where all the attributes relevant to the user can be inspected and edited. Of course, each change done in the properties view can be undone and redone and the editor will be immediately updated. There are two tabs available in the properties view: The *Core* tab provides a table showing the attributes in categories and in alphabetic order, while the *Overview* tab provides a clearer look, grouping the attributes and arranging them by relevance in two columns. Further, the *Overview* tab features a number of buttons, providing access to additional dialogs for managing e.g. an Activity's Properties and Assignments.

**The Outline** This view provides a short outline of the current editor's content. In case of a graphical editor, like the VSDT, this can be a miniature view of the entire diagram, and in case of a tree editor an additional tree view for easier navigation.

**The Problem View** This view lists all the problems that have been found in the model, subdivided in errors and warnings. By double-clicking one of the items the editor will focus on the element the problem occurred on (for refreshing the errors shown in the Problem View, select *Diagram — Validate* from the menu).

**The Error Log** Other than the Problem View, the Error Log will log problems with the editor itself. So if you encounter strange behavior or in case the editor should crash you can check here for the reason and send in an error report.

## 3.3. Additional Views for the VSDT

The following are views that have been crafted especially for the VSDT.

### 3. The Perspective

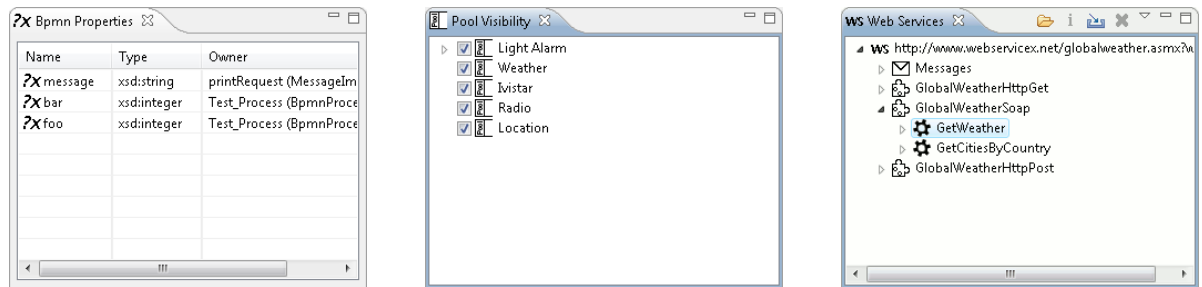


Figure 3.2.: The BPMN Properties View, Pool Visibility View, and Web Service View.

**The BPMN-Properties View** The BPMN-Properties View (see Figure 3.2, to the left) provides an easy way to inspect the Properties in the scope of the currently selected element in the active editor, i.e. the Properties that can be used in an Assignment owned by that element. The property scope of a BPMN element comprises the Properties of (a) that element itself, e.g. an Activity, (b) Messages going in and out of that element, e.g. the in- and output parameters of a Web service call, and (c) the (transitive) parents of that element, e.g. (Sub-) Processes.

The Properties are displayed in three columns, showing the name and the type of the Property and the name and the element type of the Property's parent element. The properties can be sorted by clicking on the column heads. By double-clicking on a Property, an Organize Properties Dialog will be opened for the Property's parent element.

**The Pool Visibility View** In the Pool Visibility View, which is seen in the center of Figure 3.2, all the Pools in the diagram are displayed. If the check box in front of an entry is unchecked, the corresponding Pool and all incoming and outgoing connections, e.g. Message Flows, will be hidden. This feature can be of some use in diagrams holding many Pools: When modeling three or more interconnected Pools, Message Flows going from the first to the third Pool might cross the second Pool, which can be confusing when editing that Pool. In this case, the first or the third Pool may be hidden, so the Message Flows (which are then hidden, too) do not longer obstruct the view on the second Pool. In the same way the Pools and Message Flows can be shown again by checking the corresponding check box. Note that these settings are not persisted, so when closing and re-opening a diagram all Pools will be visible again.

**The Web Service View** The Web Service View (see Figure 3.2, to the right) provides access to Web Services, which can be inspected and imported into the current diagram. Web Services can be added to the list by clicking the Open button and entering the exact URL of the WSDL definitions file. The Web Service is displayed as a tree, including the various Messages and their types, and the Port Types, their Operations, and their



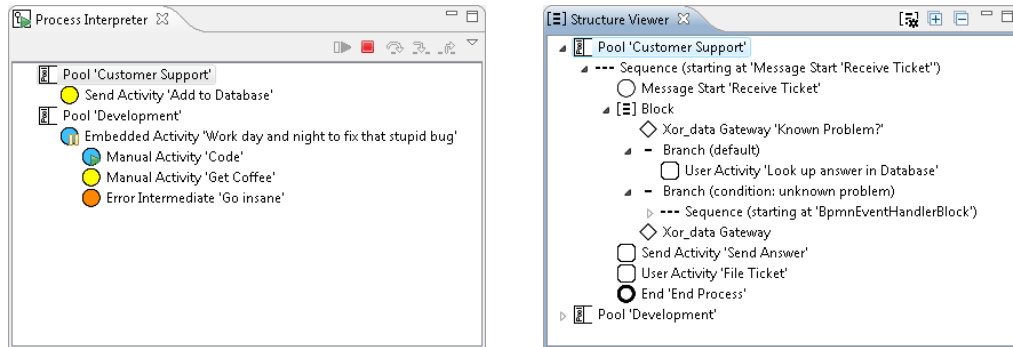


Figure 3.3.: The Interpreter View and Structure View.

In- and Output Messages. By clicking the Info button, the complete WSDL definition is shown in plain XML. Most importantly, Messages and Operations can be imported from the Web service description into the Business Process Diagrams, so they can be reused in a Web service invocation.

**The Interpreter View** BPMN diagrams created with the VSDT can be simulated and interpreted using the built-in process interpreter (see Figure 3.3 and Section 5.3.3). For starting a simulation, first switch to the BPMN diagram you want to simulate. Open the Process Interpreter View and click the *Start* button. For each Pool in the diagram, the view will show those Activities that are currently ACTIVE or READY. For advancing a step in the simulation, expand a Pool and double-click one of the listed elements, that is the Flow Objects currently being ready, e.g. Start Events. For more control, you can also select one of *Step Over*, *Step Into* or *Step Out*. Hit the Stop button for ending the simulation and removing the markers from the diagram editor view.

**The Structure View** This view allows to apply the Structure Mapping (Section 7.1) at modeling time, displaying the results in a tree. By clicking on an element, the corresponding node in the diagram is highlighted. Further, the user is notified if there seem to be structural conflicts in the process, which is determined from the number of left-over Sequence Flows. This view should prove highly useful for validating the structure of processes prior to transformation to executable code (see Figure 3.3).



## 4. Basic Tutorial

In this chapter the user will be guided through the creation of a simple Business Process Diagram, from creating the diagram file to validation and code generation.

### 4.1. Creating a new Business Process Diagram

These are the basic steps for creating your first Business Process Diagram:

1. Start Eclipse and select a location for the workspace. This is where all the projects – BPMN and others – will be stored. When starting Eclipse for the first time, a welcome screen will be shown. Read something about the features of Eclipse, if you want, then exit the screen.
2. Open the *VSDT* Perspective using the *Window* menu.
3. Select *New* → *Project* → *General* → *Project* in the menu bar. Open the Navigator View to see the newly created Project.
4. On the project, select *New* → *VSDT Meta Diagram* and enter a name for the file. On the last page of the wizard some of the global settings for the Business Process Diagram, such as the Title, Description and Author name, can be set. A file with the extension **vsdtd** is created, holding both the semantic model and the notational model (i.e. the layout information).
5. By now, the diagram should have opened automatically; otherwise open it manually by double-clicking it. It will be opened with the graphical editor.

### 4.2. Setting up Participants and Business Processes

With the VSDT, not only individual Business Process Diagrams, but sets of Business Process Diagrams belonging to the same scenario – here referred to as Business Process Systems – can be modeled. For this, the modeling starts with defining the several Participants and the Business Processes they participate in.

1. Select a **Participant** from the palette and click on the canvas. A stick-figure will appear. Repeat for each Participant relevant for the Business Process System. These can be companies, roles, computer systems or individual persons.

2. Now select **Business Process Diagram** from the palette and draw it on the canvas. These represent the individual processes (quite similar to 'Use cases').
3. Now select the connection form the palette and connect the Participants with the Business Processes.
4. Finally, perform a double-click on one of the Business Process Diagram nodes, which will open it in a new diagram editor.

### 4.3. Modeling a basic Business Process

Next, we will formulate a simple business process. Here, we will focus on the visual elements of BPMN.

1. To get started, perform a right-click on the canvas and select *Initialize ...* → *Initialize Pools* and hit *OK* to confirm the dialog. For each Participant associated with the Business Process a Pool will be created.
2. Alternatively, select **Pool** from the top of the palette and move the mouse to the canvas. Press the mouse button and drag it to the lower right to create a large Pool. Enter a name for the Pool and select one of the Participants associated with the Business Process using the Properties view.
3. Along with the Pool also a Lane will be created. To create more Lanes, select the **Lane** element from the palette and click on the Pool's label (as existing Lanes will fill the Pool's compartment completely). Note that the Lanes can not be moved manually. According to the BPMN specification the first Lane will be invisible (faded out in the editor).
4. Let's create some **Flow Objects** inside of the Lane. Select one of the Flow Object from the palette, i.e. Events, Activities and Gateways, and click inside of the Lane. In case you selected the Event, a small menu will appear, asking whether to create a Start, End, or Intermediate Event; otherwise the element will be created right away.
5. Select the **Sequence Flow** icon from the palette and connect the several Flow Objects by pressing the mouse button on the source and dragging it to the target. When connecting the Activity be sure to aim for the label. If you hit the Activity's compartment you can not create a connection. You can change the routing style from the tool-bar or add more bend-points to a connection by dragging it.
6. Use the Property Sheets to alter the Elements' name, description, type, and type-specific attributes. Select the element, e.g. an event, and open Eclipse's Property View. Select the Overview sheet from the tabs to the left to find a clearly arranged

form holding the various attributes. If you want to set only the type of a Flow Object, e.g. for making an Event a *Message* Event, you can also use the element's context menu and select *Edit... → Set Type*, or use the keyboard shortcut **Ctrl+T**.

7. Now select the **Message Flow** icon from the palette. Select an Activity or an End Event as source and draw the Message Flow to an element in a different Pool, or to some point beneath the Pool and select to create a new Pool element there.

## 4.4. In-depth Modeling

Now that we created the diagram visuals, this section deals with the equally important underlying, non-visual parts of BPMN, such as properties, assignments, conditions, and service invocations.

1. To define Services and/or Messages, select the *Services...* and *Message Channels...* buttons from the Business Process Diagram's property sheet. Alternatively, Services can also be imported using the Web Service View, or similar views for other executable languages, like JIAC, which is much more comfortable and will be explained in depth later. Note that depending on the target language, Services and Messages can map to different concepts.
2. Next, we will define the process data, i.e. Properties associated to the Pool. Open the Pool's overview property sheet and click *Process Properties...* or select the respective item from the Pool's context menu. Create some properties using the buttons in the dialog and edit the values of the selected Property using the text fields in the lower part of the dialog. Besides the top-level process, Tasks and Subprocesses can hold Properties, too, which are available only for that activity or its child activities.
3. Besides "basic" data types, such as numbers and strings, you can also declare specific complex data types, for example Java classes or ontologies, using the *Organize Data Types Dialog*, which is accessible through the Business Process Diagram's properties sheet. These data types can then be used as types for Properties.
4. To assign a value to a Property, you have to create an Assignment. Open the property sheet of some element in the process and click the *Assignments...* button. Create a new Assignment, select the Property and enter an Expression. Click the button with the dots (...) on it to open another dialog helping you to enter and validate an expression using the VSDT Expression Language VXL (see Appendix C).
5. Now that the Properties are declared and have values assigned to them, they can be used e.g. in condition expressions. Select a Sequence Flow coming from a

Gateway (a point where the flow of control branches), set the Condition Type to *Expression* and enter the Condition Expression. Again, use the button with the three dots(...) to validate the Expression.

6. The payload of a Message and the input and output parameters of a Service call are represented as properties, too. To set those, use the dialogs for managing messages and services introduced above.
7. To pass the parameter values to the Message (or some Service parameters), create one or more Assignments on the Flow Object the Message (or Service) is going in or out of. There are two ways for doing this:
  - The easiest way is to use the *Parameter Assignment Dialog*. Select the Activity or Event sending or receiving the Message(s) and hit the *Parameter Assignments...* button in its property sheet. The dialog will show all of the messages' input and output Properties and offer drop-down menus for selecting another Property or entering an individual Expression to be assigned to these parameters.
  - For more control over the parameter assignments, you can also open the *Organize Assignment Dialog* via the Flow Object's property sheet or context menu and manually create the individual Assignments. Select a Property to assign the value to, e.g. one of the input parameters of the Web service's input message, and enter a from expression.

To refer to a Property in the expression, just use the Property's name in an expression, e.g. `foo + 1`. Note the assign time value: if this is set to BEFORE, the assignment will be made before the Activity is executed, i.e. the Web service is invoked, otherwise the assignment will be made afterwards. Thus this value should be set to BEFORE, when passing values from the process to a Service's input parameter, and to AFTER, when passing values from a Service's output parameter back to the process.

## 4.5. Validation and Simulation

When your process is done – or seems to be done – you should validate it. There are several means for validation in the VSDT: First, you can validate the process diagram against the constraints given in the BPMN specification; second, you can check the structure of the process, which is important for most transformations to executable code; and third, you can run a simulation, testing the several Expressions, Conditions, and Assignments.

1. To validate the diagram against the constraints from the BPMN specification, select *Diagram → Validate* from the menu, or by clicking the checkmark symbol

in the tool bar. You might notice some error or warning marks in your diagram or entries in the problem view. You should fix these problems before exporting the diagram to executable code.

2. For checking the structure of the process, open the Structure View (see Section 3.3) and click the *Structurize* button. This will trigger the same Structure Mapping used in the actual transformations and display the result, i.e. a structured form of the process, featuring elements such as sequences and blocks. While the structured model might be a bit cumbersome to read, it gives evidence of the structure that will be recognized from the process, and if this is not the structure you intended you should consider restructuring the process. Unfortunately, most executable languages are much more restrictive than process notations such as BPMN, so this check is necessary.
3. For a more in-depth validation of the process – especially the expressions used in assignments and conditions – you may consider running a simulation. Currently there are two types of simulations implemented: a manual simulation and an interpreting simulation (see Section 5.3.3).
  - Use the manual simulation to get a feel of how the process behaves when taking a certain path, and to identify possible deadlock situations
  - When using the VSDT Expression Language (VXL, see Section 5.2.3), the interpreting simulation will help you validating the several condition and assignment expressions used throughout the process.

## 4.6. Code Generation

Once all three validations are successful, the diagram can be translated to executable code. Of course, there might still be semantic errors in the process the validation can not uncover, so you should think about thoroughly testing the resulting program code before deploying it to productive use.

1. Once the diagram shows no more errors, it can be exported to executable code. Select *Export...* from the file menu or from the model file's context menu. Select the desired target language from the *BPMN Export* group and proceed through the dialog. Select the model file(s) to be exported, adjust the target directory or the other options, if necessary, and hit the *Finish* button.
2. Note that the Business Process System has an attribute which marks whether the system is intended to be executable (used for code generation) or not (used for documentation only). This flag is used to determine e.g. which type of simulation is used by default, or how strict to validate the diagram. Before generating code,

be sure to set this flat to executable, otherwise the transformation might abort with an error!

3. The export might take some seconds. If the model is sound, the output files will be created in a new directory in the specified target directory, named after the Business Process Diagram. By default, also a log file will be created along with the model files in the specified target directory.
4. If the process has been modeled accurately, the resulting program can be readily executable. Still it is recommended to check the result with a native editor for the respective language, to be sure the files are free from defects.



## 5. Selected Features

This chapter will give further insight on how to use some of the features of the Visual Service Design Tool. We subdivide those features into two groups: Features for assisting in the modeling of Business Processes at a rather low level, and features for managing a process model at a higher level, e.g. related to validating and simulating processes.

### 5.1. Low-level Modeling Assistance

The VSDT provides a number of features that help the user to quickly assemble a business process diagram, such as both mouse-based and keyboard-based modeling shortcuts.

#### 5.1.1. GMF Modeling Assistance

The *Eclipse Graphical Modeling (GMF)* framework the VSDT is based upon comes with a number of valuable modeling assistance features (if not desired, modeling assistance can be turned off in the preferences). In the following some of these will be briefly introduced. Figure 5.1 is showing the modeling assistance in use.

- When resting the mouse on top of a compartment, a small palette will show up, showing the elements that can be placed in this compartment. Thus one does not have to go all the way back to the palette for creating a new node.
- When resting the mouse on top of a node, small arrows going in and out of the node will appear. By dragging these arrows new connections can be drawn.<sup>1</sup>
- When a connection is drawn and the mouse button is released over the canvas or another compartment, a node can be created in that place along with the connection.
- In case multiple node- or connection-types can be created using a given tool in a given context, the user will be prompted to select one.

In case you do not like this feature, it can be disabled in the Preferences.

---

<sup>1</sup>Depending on the location, different connections will be offered: In the top and bottom region of a node incoming and outgoing Message Flows, in the left half incoming Sequence Flows and Associations, and in the right half outgoing Sequence Flows and Associations respectively.

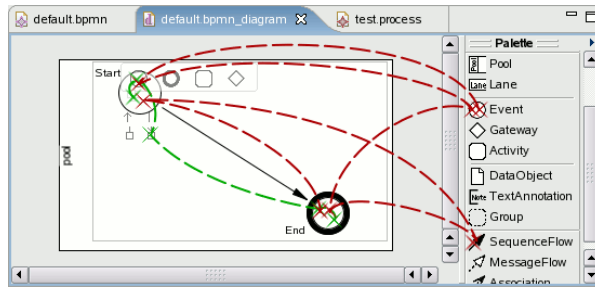


Figure 5.1.: Mouse movement with and without the use of the Modeling Assistant.

### 5.1.2. Appending Flow Objects

Even faster than using the GMF modeling assistance, the *Append* Actions can be used for quickly appending new Flow Objects after existing ones. It can be reached through a Flow Object's context menu, or – more conveniently – by using the keyboard shortcuts **Ctrl+Shift+(A|G|I|E)** for appending Activities, Gateways, Intermediate and End Events. Thus, after the first Start Event has been placed, the basic workflow can quickly be assembled using only the Append action and the TAB key to navigate between the existing nodes.

### 5.1.3. Connecting Flow Objects to a Sequence

A group of Flow Objects can be selected and connected with Sequence Flows using *Connect to Sequence* Action or the keyboard shortcut **Ctrl+Shift+C**. The Flow Objects will be connected in the order they have been selected. Therefore they should be selected one by one (holding down the Shift or Ctrl key), and not using a selection margin. This feature can be very useful when modeling a process by first drawing a set of activities on the diagram and deciding later how to arrange those activities to a working process.

### 5.1.4. Inserting Elements and Patterns

By right-clicking on a Sequence Flow the *Insert...* menu can be reached. Here it is possible to insert a new element in between the source and the target of that Sequence Flow, which is very useful for extending existing diagrams. The existing sequence Flow will be reoriented to the new element, preserving existing attributes such as the condition, and a second Sequence Flow is drawn from the new element to the existing Sequence Flow's former target.

Apart from basic elements such as Activities, Intermediate Events and Gateways, it is also possible to insert complex workflow patterns, such as a split/merge block or a loop. This does not only greatly reduce the time needed for the diagram creation<sup>2</sup>,

---

<sup>2</sup>Reducing the pure editing time by up to 70% according to [1].

but also ensures that the workflow's structure is sound (Referred to as "correctness by construction").

*Note* that by now the layout of the diagram will not be adapted to the newly inserted elements, thus the user will have to rearrange the surrounding elements to make room for the new nodes.

## 5.2. Handling non-visual Elements

As noted earlier, the nodes, edges and labels visible in a Business Process Diagram are just one half of the actual process model. There are also a large number of non-visual attributes to the visible elements and even entirely non-visible elements, which are equally as important for the process. The VSDT provides a number of dialogs for managing those elements.

### 5.2.1. Dialogs for Handling Non-Visual Elements

For each of the non-visual elements – Properties, Assignments, Messages, and Services – there is a dedicated a management dialog. The dialogs follow a clear and recognizable layout, showing the elements as-is in a list along with a number of buttons for inserting, removing and sorting of the elements and text fields for editing the attributes of the currently selected item (see Figure 5.2).

The various dialogs can be accessed in the following ways:

- The *Organize Properties Dialog* can be accessed via the context menu and property sheet of Pools, Activities and Message Flows, and by double-clicking an element in the BPMN-Properties View or a Message Flow.<sup>3</sup>
- The *Organize Assignments Dialog* can be accessed via the context menu and property sheet of Pools and Flow Objects, and by double-clicking Flow Objects.
- The *Organize Message Channels Dialog* can be accessed via the property sheet of the Business Process Diagram.
- The *Organize Services Dialog* can be accessed via the property sheet of the Business Process Diagram.
- The *Organize Data Types Dialog* can be accessed via the property sheet of the Business Process Diagram.

---

<sup>3</sup>In the case of Message Flows, the Properties of the underlying Message, if any, will be edited, and in the case of Pools, the Properties of the Pool's Process.

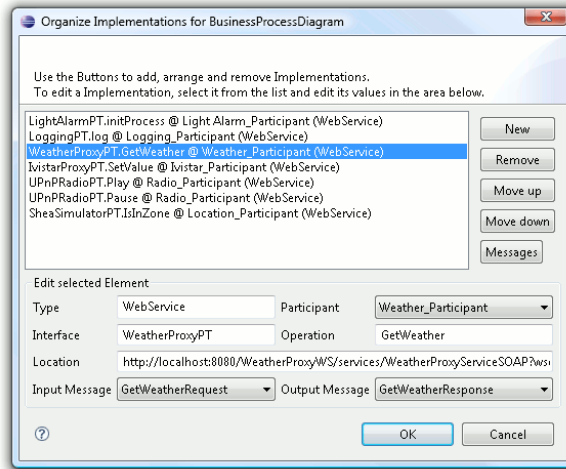


Figure 5.2.: A Supporting Type Organization Dialog.

### 5.2.2. Service Parameter Assignments

While the *Organize Assignments Dialog* provides means for organizing all types of Assignments, it can be quite weary to make the assignments to a service call, passing a number of values to the service's input parameters and storing its results in other local variables. Moreover, this is a common source for mistakes, like selecting the wrong assign time, or missing an important input parameter. Using the *Parameter Assignments Dialog* this task can be facilitated in many ways.

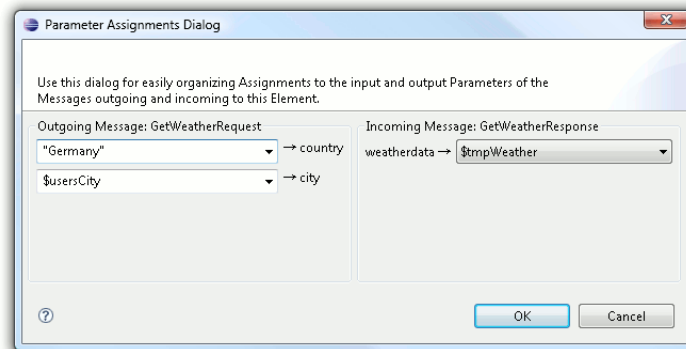


Figure 5.3.: Parameter Assignments Dialog

This dialog is available for all Activities and Events sending or receiving messages, such as the Message Event and Send, Receive, Service and User Activity. Provided that the Implementation and the input and output Messages for that service are specified, the dialog displays a drop-down menu for each of the incoming and/or outgoing Messages' Properties. The values set in these lists will then be used for the Assignments to the input

and output parameters. For the outgoing message, arbitrary expressions can be inserted, while the parameters of the incoming message can only be assigned to a local Property. If more specific Assignments are needed, the dialog can still be used for generating stubs for those Assignments, which then can be refined in the *Organize Assignments Dialog*. Further, the dialog will notify the user if there are input parameters that have no value assigned to them.

### 5.2.3. Expressions

The BPMN standard does not specify an expression language to be used. Instead, it is assumed that the language of the target framework is used, e.g. XPath. However, in a tool that provides transformations to various target frameworks this is not an option. While the diagram structure could be translated to the syntax of the target system, the expression, given that they are written in an unknown language, could not – although all those languages might be very similar. To address this flaw, the VSDT comes with its own, very simple expression language, the *VSDT Expression Language (VXL)*. The advantage of using VXL is that it provides a greatest common divisor of the expression languages used in the target frameworks. Thus, most expressions can be given using VXL, in which case they can be validated and – more importantly – parsed and translated to the respective expression languages used in the target frameworks.

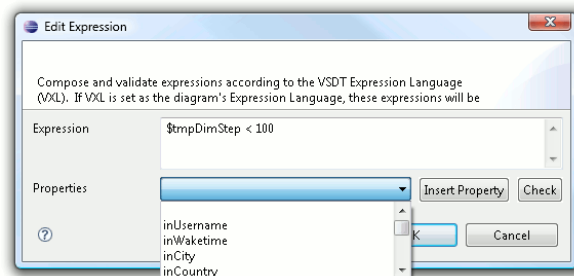


Figure 5.4.: The Edit Expression Dialog.

Each text field referring to an Expression in the dialogs and property sheets of the VSDT provides a small button for opening the Edit Expression Dialog, which can be seen in Figure 5.4. This dialog not only provides a larger text field for editing the Expression, but also a list of all the Properties visible in the scope of the element owning the Expression, which can be selected from the list and inserted into the expression. Further, the *Check* button can be used to validate the Expression, which will check both the syntax and the availability of the variables used in the expression.

*Note* that there is no type checking yet. However, this feature is on the agenda, and will be implemented as soon as possible.

## 5.3. Higher-level Process Management

Finally, the VSDT provides a few features situated at a somewhat higher level, such as validation and simulation, layout, process documentation or team-work.

### 5.3.1. Model Validation

The VSDT provides two kinds of validation: Validation of BPMN constraints, and structural validation.

**Validation of Constraints** BPMN diagrams can be checked to conform to the constraints given in the BPMN specification by selecting *Diagram* → *Validate* from the menu or by clicking the checkmark icon in the tool bar. Afterwards errors will be listed in the problem view. Additionally, faulty or otherwise problematic elements will be marked with a respective icon in the process graph.

**Structural Validation** Besides the individual elements, also the structures in which these elements are connected are important. For checking the structure of the process, open the Structure View (see Section 3.3) and click the *Structurize* button. This will trigger the same Structure Mapping used in the actual transformations (see Section 7) and display the result, i.e. a structured form of the process, featuring elements such as sequences and blocks. While the structured model might be a bit cumbersome to read, it gives evidence of the structure that will be recognized from the process, and if this is not the structure you intended you should consider restructuring the process.

### 5.3.2. Structure-Based Layout

The Structure Mapping can also be used for calculating the layout of the BPMN diagrams. Compared to the layout algorithm provided by GMF, this proves especially useful for diagrams containing upstream loops. Still, since the structure-based layout is still in an early stage, the default layout algorithm still is the one provided by GMF. The structure-based layout can be reached via the Structure View (see Section 3.3).

The recursive layout algorithm is sketched in algorithms 1 and 2. First, the process diagram is transformed to a block structure. Then, the algorithm will step down into the structure and calculate the layout of the “blocks” in a bottom-up way, taking the positions of the nested elements into account. The result of the algorithm is a map holding the bounding box for each element, which can then be used for laying out the elements in the diagram editor.

While the structure-based layout yields good results for well-structured diagrams, i.e. diagrams that can be transformed to a block-structured form, the algorithms is not applicable for non-structured diagram.

---

**Algorithm 1** CREATELAYOUTMAP(*diagram*)

---

```
structuredDiagram  $\leftarrow$  STRUCTURIZE(diagram)  
layoutMap  $\leftarrow$  create empty map  
hint  $\leftarrow$  (0, 0)  
for pool in structuredDiagram do  
    box  $\leftarrow$  CALCULATEBOX(pool, hint, layoutMap)  
    hint  $\leftarrow$  (0, box.bottom)  
end for  
return layoutMap
```

---

---

**Algorithm 2** CALCULATEBOX(*element*, *topLeft*, *layoutMap*)

---

```
hint  $\leftarrow$  topLeft  
if element is atomic then  
    box  $\leftarrow$  (topLeft.x, topLeft.y, WIDTH(element), HEIGHT(element))  
else  
    if element is sequence then  
        height  $\leftarrow$  0  
        for child in element do  
            box  $\leftarrow$  CALCULATEBOX(child, hint, layoutMap)  
            hint  $\leftarrow$  (box.left, box.top)  
            height  $\leftarrow$  MAX(height, box.height)  
        end for  
        box  $\leftarrow$  (topLeft.x, topLeft.y, hint.x - topLeft.x, height)  
    end if  
    // similar for block, loop, subprocess, event handler, etc.  
end if  
insert (element, box) into layoutMap  
return box
```

---

### 5.3.3. Visual Simulation and Interpretation

BPMN diagrams created with the VSDT can be simulated and interpreted using the built-in process interpreter (see Section 3.3). For starting a simulation, first switch to the BPMN diagram you want to simulate. Open the *Process Interpreter* view and click the *Start* button. For each Pool in the diagram, the view will show those Activities that are currently ACTIVE or READY. For advancing a step in the simulation, expand a Pool and double-click one of the listed elements, that is the Flow Objects currently being ready, e.g. its Start Events. For more control, you can also select one of *Step Over*, *Step Into* or *Step Out*. Hit the Stop button for ending the simulation and removing the markers from the diagram editor view. In the diagram itself, the Flow Objects are annotated with a marker symbol representing their state (see Table 5.1).

Table 5.1.: Mapping of Marker Colors to Flow Object States

Marker	State of Flow Object
Yellow	Ready for execution
Blue	Currently active / executing
Green	Executed successfully
Red	Execution failed or interrupted
None	Not yet executed or ready; idle

Once the simulation is running, the user can *Step Over*, *Step Into* and *Step Out* of Flow Objects. Stepping into a Flow Object is particularly interesting for Activities with attached Event Handlers or Embedded Subprocesses, for which it is the default behavior. Different kinds of interpretations are available (or planned for the future):

- *Manual Simulation*: Here, the user is asked which way to proceed when coming to a branching point. This mode is intended for presentation of documentary processes, but also for detecting e.g. deadlocks or other kinds of structural conflicts.
- *Interpretation*: In this mode, Expressions used for instance in Assignments and Conditions are evaluated<sup>4</sup> and stored, so that the process will automatically decide how to proceed at a branching point. Still, the user has to provide initial parameters and return values for service calls. This mode is especially useful for testing the various Conditions and Assignments.
- *Execution*: This mode integrates with a Service Directory, meaning that in addition to the *Interpretation* mode, services used in the diagram will actually be invoked and their return values will be bound to the respective process properties. Thus the user just has to provide the initial parameters of the process itself. Apart from

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<sup>4</sup>Note that only Expressions given in the VSDT Expression Language (VXL) can be automatically evaluated, and that by now only simple data types are supported.



testing the interworking of the several services in the process, this mode can also be used for actually executing and monitoring the process. (*work in progress*)

#### 5.3.4. Text Generation

The VSDT features a powerful transformation of the Business Process Diagram to natural language text. Currently only English text is supported, but other languages may be included in the future, as well. The output text can have different formats, e.g. plain text, HTML or Latex, which to use can be selected in the Export Wizard. While this feature is yet at an early stage, it can already be used for quickly generating documentation for those who can not read the process diagrams or for media where they are difficult to present, e.g. in a talk. Emphasis has been laid on preserving the process structure as much as possible in the text, e.g. using indentation. Further a number of randomly selected redundant terms is used to increase the linguistic diversity of the resulting text.

The Text Generation has been implemented using the same transformation framework also used for code generation (see Section 7). It can be accessed via the *Export* menu.

#### 5.3.5. Import and Merging of Process Diagrams

VSDT diagrams can be imported into and merged with each other. While basically this feature can be used for merging any two or more diagrams, it is most useful for merging diverging versions of the same process diagram, having a common ancestor.

After selecting *Import other VSDT diagrams* from the Import menu, select one or more diagrams to import *from* and one diagram to import *into*. You can also check whether to create a backup of the original target file (recommended), and whether the layout should be imported, too, or only the model data, and whether the algorithm should try to merge identical elements. The latter, of course, only makes sense if the source and target files are different revisions of the same process diagram.

The merging algorithm works by recursively comparing the *IDs* of the objects to be merged, so these should not be changed in different revisions. Also there are still some issues with conflicting changes, so one should always be sure to create a backup and possibly use a `diff` tool to check whether the changes to the file's XML source look plausible.



## 6. Preferences

This chapter will explain the several preferences that can be set for configuring the VSDT for your personal needs.

The preference pages can be accessed by navigating to *Window* → *Preferences...* in the menu and selecting the item *VSDT* from the list.

The GMF framework provides a number of settings on its own, e.g. for improving performance by deactivating certain features of the GMF runtime, or for setting the default colors and fonts for certain diagram elements. As these settings are self-explaining we will not go further into detail on those. In the following we will explain the VSDT-specific settings only.

### General

- **Author** sets the default author for all new Business Process Diagrams created.
- **Enable Modeling Assistance** turns GMF's modeling assistance on or off.

### Appearance

- **Enable Activity Icons** activates additional markers placed in the corners of Activities. These markers use intuitive symbols to indicate the Activity's type and whether the Activity has any Assignments and/or Properties.
- **Use Additional Colors** helps to distinguish the several diagram elements by the use of colors.
- **Show XOR-Marker for Gateways** sets whether to display the cross-marker for XOR gateways.
- **Meta Diagram Style** lets you choose between a notation similar to UML use cases or BPMN 2.0 communication diagrams for the VSDT's entry diagrams.

**Connections** Here you can select the drawing style for Sequence Flows, Message Flows and Associations.

*Note* that both the Enable Activity Icons and the Use Additional Colors settings take effect only after closing and reopening a given Business Process Diagram file.



## 7. Model Transformation

The core of the Visual Service Design Tool clearly is the transformation to executable code. Currently, both the transformations to BPEL and to JIAC agent services can conveniently be used in practice.

For directions on how to invoke the transformation please refer to Section [4.6](#).

### 7.1. Understanding the Transformation Framework

This section will provide a brief introduction in the basics of the transformation framework. The transformation framework has been designed from the very beginning to be as *extensible* and *reusable* as possible. For that purpose the process of transformation has been subdivided into several stages, which are sequentially applied to the input model:

1. In the *Validation* stage, all identifiers are validated to contain only characters that are legal with respect to the given target language. Further, the validation will check if each element needed is in place and provide clear error messages in case something is missing.
2. The intent of the *Normalization* stage is to put the process diagram in a uniform form, and to transform it to a semantically equivalent representation of the diagram following more strict constraints than those given in the BPMN specification.
3. In the *Structure Mapping* stage, the model is searched for graph patterns which are semantically equivalent to block structures. When such patterns are found, they are replaced with a special structured element, until the entire process within each Pool has been reduced to a single complex element, e.g. a sequence, or until it can not be reduced any further due to structural flaws.
4. In the *Element Mapping* stage, the several BPMN elements are mapped to their counterparts in the target language, e.g. BPEL or JIAC. How this stage is realized for the individual target languages will be explained in the next sections.
5. In the *Clean Up* stage, a set of rules is applied on the newly created target model, improving the readability of the generated code.

A simple example of the consecutive execution of normalization and structure mapping can be seen in Figure [7.1](#).

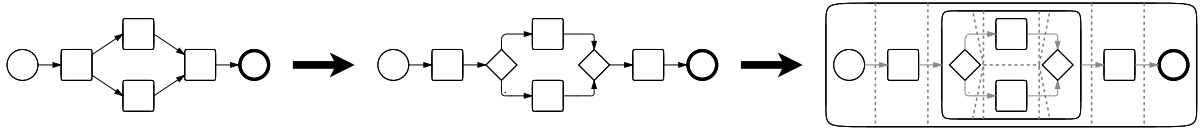


Figure 7.1.: Simple example of normalization and structure mapping.

### 7.1.1. Transformation of Expressions

Besides the actual workflow, Expressions that are used in assignments and conditions have to be translated, too. This can be done only if the Expression Language is set to “VSDT Expression Language” or “VXL”. If then the *Translate Expressions* option is checked in the Export Wizard (see Figure 7.2) these expressions will be parsed and, if possible, translated to the respective target language.

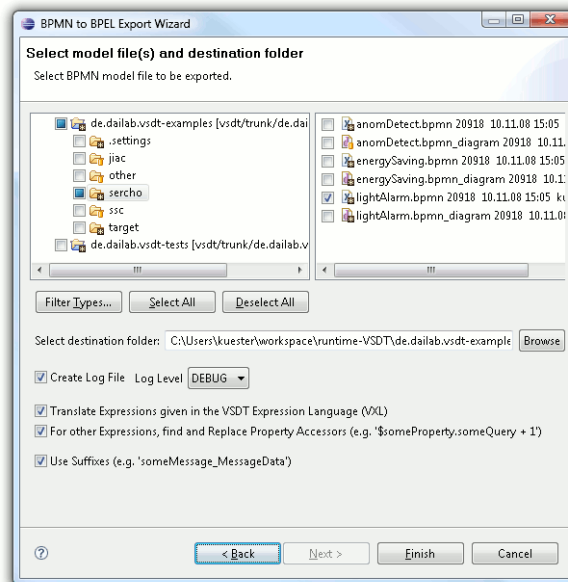


Figure 7.2.: BPEL Export Wizard with Expression Translation checked.

Still there may be cases when VXL does not have enough expressive power. In this case the option can be disabled (or the Expression Language can be changed) and the *Replace Property Accessors* option can be checked. Now the Expressions will only be scanned for Property Accessors in the Form `$foo.bar`, which will then be translated to the syntax of the target language. Thus, these simple variable accessors can be embedded in expressions of another language. For instance, in the case of BPEL, an expression like `$foo.bar + 1`, might be changed to `bpws:getVariableData('Proc.ProcessData', 'foo', 'bar') + 1`. Thus the user does not have to care about the

way Properties are converted to variables and how these variables are to be accessed in the transformation to that language but can simply use a Property's name.

Finally, when Properties are given one of VXL's predefined basic data types (e.g. `string`, `boolean`, etc.), these will be translated to the respective basic types of the target language, e.g. `xsd:string` and `xsd:boolean`.

## 7.2. Transformation Implementations

The following sections describe in short the various transformations that have already been implemented.

### 7.2.1. Transformation to Text

See Section [5.3.4](#).

### 7.2.2. Transformation to BPEL

The transformation to BPEL covers nearly the entire mapping as given in the BPMN specification [8, Appendix A], including event handlers, inclusive OR and event-based XOR Gateways, just to name a few.

**Export** Nevertheless there are some elements for which the mapping is not given very clearly, such as TIMER Start Events, independent Sub Processes or multi-instance parallel loops. While these elements will be transformed as described in the specification, the resulting BPEL processes will require some amount of manual refinement. Besides the BPEL process files a WSDL definitions file is created, holding the message types derived from the process properties and the input and output messages and interfaces (port types) for the several Web services being orchestrated by the process. Still, the WSDL's binding and service blocks and necessary schema types, if any, can not be generated automatically yet, due to insufficient information in the source model.

In the validation, all identifiers are tested to contain only characters that are legal with respect to BPEL, and all expressions used e.g. in assignments and loop conditions are translated to XPath, if possible. Properties are aggregated to one variable per Process or Message; for instance, if a Process `Proc` has a Property `foo`, `foo` will be a Part of Variable `Proc_ProcessData`.

**Import** The Import from BPEL to BPMN is still at an early stage. While basic control flow can be imported, there are still problems e.g. with event- and fault handlers. Further one should be aware that the export to BPEL does not preserve all information in the BPMN diagram, thus diagrams re-imported after being exported to BPEL will most likely be less readable than before, although they may be semantically equivalent.

### 7.2.3. Transformation to JIAC

One of the mayor goals behind the development of the VSDT is the generation of JIAC multi-agent systems, and specifically JADL services [6]. Note that this work is not yet finished, and thus the mapping of the several concepts of BPMN and JIAC is still transitional and subject to change.

**Export** A prototypic transformation targeting the agent framework JIAC V has already been implemented. In this transformation, the Participants diagram is translated to an Agent World Diagram [7], and the individual Business Processes are translated to several JADL services [2].

What's special about the transformation to JIAC is that apart from the JADL services and the agent configuration, also a set of *service starter rules* is generated, which can be deployed to a Drools rule engine integrated into the JIAC agent and which will trigger the different services accordingly to the start events given in the business process diagrams.

The *BPMN to JIAC Transformation* feature requires the *JIAC Agent World Editor* feature.

### 7.2.4. Transformation to STP-BPMN

Since BPMN does not provide a standardized interchange format, transferring a diagram from one editor to another is difficult. For that reason the VSDT provides a Transformation to the popular Eclipse STP-BPMN Editor. Thus one can export a Diagram to STP-BPMN and carry it to a colleague using that editor, or someone formerly using the STP editor can import his existing files when changing to the VSDT.

**Export** The export to STP is nearly complete. The only elements that are not mapped are Lanes, which is because the STP editor is encountering problems when initializing the diagram files containing Lanes. Alas, the same also applies to Embedded Subprocesses, as there are problems opening those diagrams. However, this is a problem with the STP editor that will hopefully get fixed soon.

**Import** The import from STP works very well, with the exception that, again, Lanes will not be mapped. *Note* that the transformation to STP will only create the BPMN model files, but not the diagram files; those files, holding the graphical information, have to be generated anew from the model file. Consequently, the transformation does not preserve the layout of the diagrams.

The *BPMN to STP-BPMN Transformation* feature requires the *Eclipse SOA Tools Project BPMN Editor* feature.



## 7.3. Limitations

Although the transformation framework is quite powerful, it is important to understand that there are still some limitations, both in the mapping of structures and of elements.

- Given a well-structured workflow, the transformation yields very good results. However, as BPMN is more expressive than block-oriented languages, such as BPEL and JIAC, there will always be graph structures that can not be transformed to an equivalent program of the target language. In that case the diagram should be manually restructured *before* being exported.
- The mapping to BPEL is as complete as possible, according to the specification. Still, there are some points in the specification that are missing, unclear or ambiguous. The transformation to BPEL is implementing the specification in almost every detail, but regarding these elements a small amount of manual refinement may be necessary.
- The mapping to JIAC is still at an early stage. For a subset of both BPMN and JADL, the transformation yields good results and can be used for creating meaningful, executable scripts, but there are still some open issues.

We are constantly investigating ways of extending both the quality of the element mappings and the performance of the structure mapping.



## 8. JIAC Node Plugin

Not actually a part of the VSDT, but closely related, is the so-called *JIAC Node Plugin*, which will be the topic of this chapter.

The central part of the JIAC Node Plugin is – as the name suggests – a JIAC agent node [3] running *inside* of an Eclipse plug-in, which can be used as a platform for several applications, integrating features provided by JIAC agents (both running on the node itself *and* on other nodes in the network) with into the Eclipse environment.

In the following, we will introduce two especially graphic applications for the JIAC Node Plugin: The *Multicast-Chat* and the *Service-Deployment View*. Both of those views can be found in the *DAI-Labor* group in the views menu.

### 8.1. JIAC Multicast-Chat View

The *JIAC Multicast-Chat* was the first application developed for the JIAC Node Plugin. It is, in essence, a simple Chat application running inside of Eclipse, making use of JIAC communication infrastructure. While not being overly useful, given the abundance of existing chat programs, the ease of integrating a chat view into Eclipse using the JIAC Node Plugin is compelling. Therefore, the Multicast-Chat can also be seen as an elaborate tutorial for developing other JIAC-based Eclipse plug-ins.

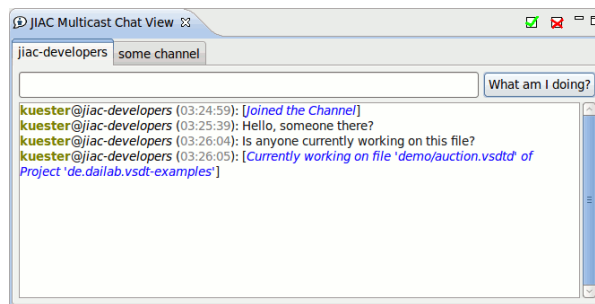


Figure 8.1.: The JIAC Multicast-Chat View.

The Multicast-Chat View, as seen in Figure 8.1, allows the user to subscribe to one or more chat channels, each one corresponding to a multicast group channel in JIAC. The user can then send messages to fellow developers being subscribed to the same channel. Since the multicast-chat is aimed especially at developers working in their Eclipse IDEs at the same time, a special feature of the Multicast-Chat is to broadcast which file of

code one is currently working on, possibly alleviating problems due to conflicting changes on that file.

### 8.2. JIAC Service Deployment View

Another, much more useful view is the *JIAC Service Deployment View*, shown in Figure 8.2. This view uses JIAC's service-discovery and -invocation mechanisms to provide a number of features to the user:

- *Look up* services currently being provided by other JIAC agents in the network, displaying them in a tree view, grouped by agent and agent node,
- *import* those services (both actions provided by JIAC agent beans and JADL services) as Service descriptions into the current VSDT diagram, so they can be reused and orchestrated to new services,
- *deploy* new services composed in the VSDT<sup>1</sup> or in the JADL editor to some JADL interpreter agent currently running on some node,
- *invoke* services and actions being provided by some JIAC agent on the network, including the ones just deployed, and
- *undeploy* services.

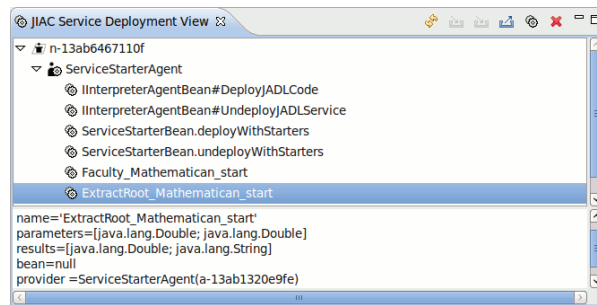


Figure 8.2.: The JIAC Service Deployment View.

While there are still some restrictions, e.g. service invocation from the Deployment View currently works only for services with basic input and output types (numbers, strings, etc.), these features are extremely helpful for developing or composing new JIAC services – both using the VSDT or the basic JADL source code editor.

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<sup>1</sup>VSDT Process Diagrams will be exported to JADL services prior to being deployed on the JADL interpreter.

## 9. FAQ

This chapter will give valuable advice on how to solve several tasks, solve problems, and answer other questions related to the Visual Service Design Tool.

### 9.1. How to...

**...draw Flow Objects on the Canvas?** Although sometimes such diagrams can be seen, Flow Objects *can not* be drawn on the canvas. Instead, each Flow Object has to be contained in a Lane, and the Lane has to be inside of a Pool. However, according to the specification one Pool per diagram may have an invisible border, which can be set using the property sheets.

**...create an Embedded Sub Process?** First, create a basic Activity. Then, in the Activity's property sheet, set the activity type to EMBEDDED SUB PROCESS. Now you can resize the Activity/Sub Process to an appropriate size and create further Flow Objects inside of it.

**...create an Intermediate Event on an Activity's boundary?** For creating an Intermediate Event on an Activity's boundary, i.e. an event- or error handler, you should select the Event type from the palette and click the Activity's label or boundary, but *not* its compartment (in case it is a subprocess). Alternatively, you can use the miniature palette that appears when hovering the mouse over the Activity's label or boundary. Once created, the Intermediate Event can be moved freely around the Activity's border.

**...draw Artifacts inside of a Pool?** Contrary to Flow Objects, Artifacts can not be created inside of a Pool, but only directly on the canvas. However, you can create the Artifact on the canvas and drag it over the Pool. But remember that the Artifact is *over*, and not *in*, the Pool, so it will not be moved together with the Pool.

**...make Assignments to Service Parameters?** The arguments and results of service invocations are being stored in the Service's input and output Properties. So if a service is to be called with the argument "Hello World", that value has to be assigned to the service's respective input Property using the *Organize Assignments Dialog* of the Activity calling the service. Note, that Assignments to the input parameters have to be

made *before*, and Assignments storing the output parameters in local variables have to be made *after* the Activities execution. The Assign Time can be specified in the Dialog, too.

A more convenient way, and sufficient in most situations, is to use the *Parameter Assignments Dialog*, which will take care of most of these details. Of course, the same applies to Message Events and Send and Receive Activities, as well.

## 9.2. Troubleshooting

**My diagram file is broken. How can I fix it?** In case the diagram is broken, it can be recreated from the model. In case you are using separate files for semantic model and notational model, delete the diagram file `vsdt_diagram` and create a new one by right-clicking the model file `vsdt` and selecting the respective menu item. In case you are using one file for both semantic and notational model, `vsdtd`, open the file in a text editor and remove the `notation:Diagram` elements (one for each diagram contained in the file). Now rename the file to `vsdt` and initialize the diagram file (in this case, the newly generated file will contain both the diagram and the model, so you should delete the old model file afterwards). In both cases, you will have to recreate the diagram's layout.

**I've drawn a legal Business Process Diagram, but when I try to export it the resulting code is broken.** The diagram has to be in a certain form so it can successfully be transformed. The diagram has to be *structured*. Primarily, there must not be blocks or loops with multiple entry or exit points. Although the VSDT can handle some forms of slight unstructuredness, for best results you should design your diagram in a way it can be mapped to a block-oriented language in a straight-forward manner.

If you are not sure whether the VSDT can handle all the structures used in the diagram, use the *Structure View* to check how the structure will look like after the transformation.

**I've created a Business Process Diagram using element XYZ, but in the resulting code this element is missing.** Not each single feature of BPMN can be taken into account in all of the transformations yet. For those elements that can not be mapped, a no-operation element will be created in the target model, such as a **empty** Activity in BPEL or a **logwarn** in JIAC. Be sure to substitute these elements with a proper implementation after the transformation.

## 10. Using the VSDT in ILIAs

In order to create processes for managing the smart grid environment, a corresponding development environment is adopted for better process creation and -improvement. One part of this environment is the process oriented development of services for the SmaGriM system. The main elements for this are services that are provided as well defined functionalities by a service provider, in order to allow service consumers to use those functionalities. Such services can be combined into processes that define concrete combinations of service calls, thus realizing more complex functionalities. Such processes are also called service compositions and provide an easy to read yet powerful modeling approach for the required grid management functionalities.

The ILIAs system allows for extensive testing of services and processes developed for the SmaGriM platform. Simulations that are used to predict the behavior of the grid to specific actions can also be used to test the effects of new or changed implementations in what-if simulation scenarios. Such scenarios are realized as extended test cases by defining a test grid with known behavior, simulating new services and processes in this scenario and comparing the simulation results to the expected behavior of the grid. This allows assessing the effects of changes in a very concise procedure reducing overall testing efforts.

Using the Visual Service Design Tool (VSDT), those processes can be modeled, simulated (tested) using the SmaGriM simulation and finally be deployed to the system. In the following Sections, we will describe the general process of using the VSDT in the ILIAs project and then provide details about how to simulate the process models prior to deploying them to the live system.

### 10.1. The ILIAs Development Process

Two main roles can be identified in the ILIAs development process: First, there is the *process engineer*, whose role is (a) developing and providing different basic services to be orchestrated to complex processes in the process diagram, and (b) creating such orchestrations for handling individual emergency situations, such as power outages, and deploying them on a repository for later use. In both cases, the process engineer's creations have to be certified before being put to productive use. And second, there is the *SmaGriM Operator*, monitoring the system, whose job in case of an emergency is to select a suitable process from the repository, adapt it to the needs of the situation, test it in the simulation, and finally deploy it to the actual system. Finally, there are

a number of agents and other computer systems involved in the process, such as the process repository, or the simulation (Figure 10.1).

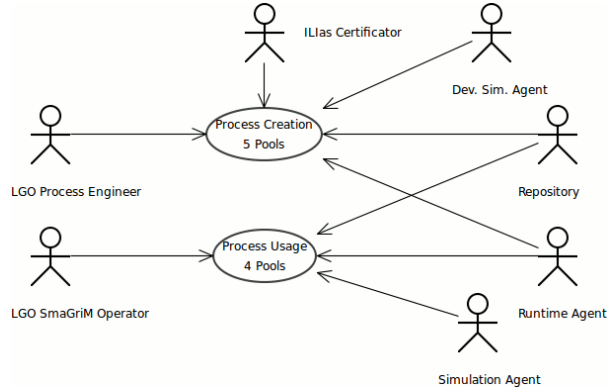


Figure 10.1.: ILIAs Use Cases

In the following we will give a short description of the two main use cases (regarding the VSDT) in the scope of the ILIAs project: *Process Creation* and *Process Usage*.

### 10.1.1. Process Engineer: Process Creation

The use case of *Process Creation* is laid out in Figure 10.2.

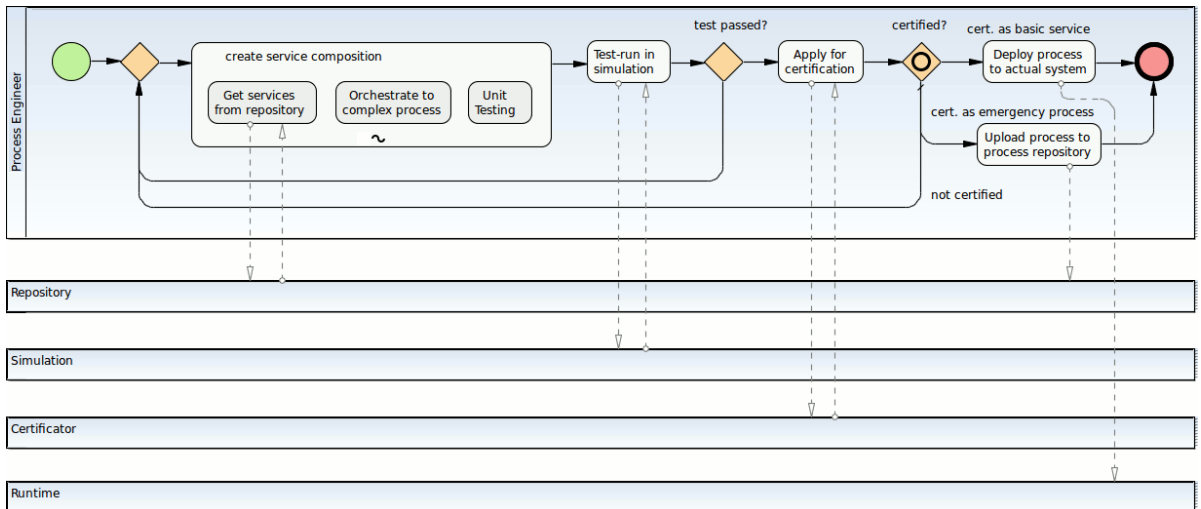


Figure 10.2.: ILIAs Use Case *Process Creation*

The actual process engineering consists of three activities: retrieving basic services from the repository, orchestrating those service to a meaningful, complex process, and



testing the process or individual parts of this. These tasks can be carried out using the generic process modeling assistants provided by the VSDT.

Once the functionality of the process itself has been tested, the process is deployed on the simulation environment for testing how the process integrates into the ILIas environment.<sup>1</sup> Next, the process has to be certified, to ensure that only thoroughly tested and simulated processes, which do not do harm to the system, are deployed. If either the simulation or the certification fail, the process engineer has to go back to the drawing board and rework the process.

Finally, certified processes can be deployed. There are two possibilities: Either, the process is deployed as a basic service, which means that it can be reused as part of another process; in this case the process is deployed to the runtime, so it can be invoked on demand. Or the process is deployed as an emergency process, for use only in special emergency situations; in this case the process is deployed to the process repository, from where it can be retrieved when needed.

### 10.1.2. SmaGriM Operator: Process Usage

The use case of *Process Usage* is depicted in Figure 10.3.

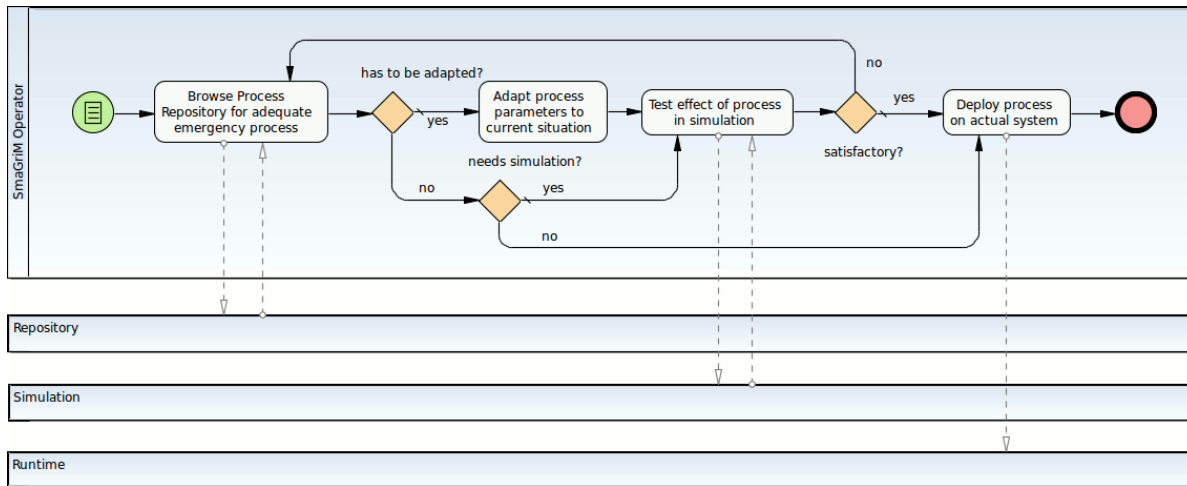


Figure 10.3.: ILIas Use Case *Process Usage*

This process is executed in case of an unexpected power outage or a similar emergency event. After assessing the situation, the SmaGriM Operator looks for an adequate compensatory process for handling this kind of event in the process repository. In case

<sup>1</sup>For this purpose, the developer uses a separate simulation, and not the one used by the SmaGriM Operator for testing compensatory processes in case of an emergency.

the process has parameters, those are adapted to the current situation (e.g. some sort of threshold, or IDs).

Afterwards, the process (with the selected parameter configuration) is tested in a simulation precisely mirroring the current state of the grid.<sup>2</sup> If the process does not show the desired results in the simulation, the operator has to select a different process or adapt the parameters; otherwise, the process can be deployed to the runtime for countering the emergency situation.

## 10.2. Testing Processes in the ILIAs Simulation

In the following we will provide a detailed description of those components of the VSDT which have been created especially for the ILIAs project, foremost the *Simulation View*, providing the connection to the agents running the simulation.

### 10.2.1. The ILIAs Simulation View

The ILIAs Simulation View provides an interface to the ILIAs Simulation, where newly created or adapted process models can be tested for suitability (see Figure 10.4). The view provides a number of controls for deploying the process model from the active editor window to the simulation, for starting and stopping the simulation and for viewing the status of the simulation.

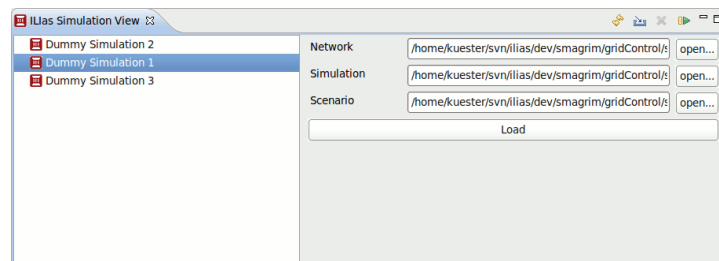


Figure 10.4.: ILIAs Simulation View

The Simulation View is based on the *JIAC Node Plugin* (see Section 8), and the deployment mechanism is similar to that of the *Deployment View*, the only difference being that the processes can not be deployed to arbitrary JIAC agents, but only to an ILIAs Simulation Agent.

Like for the regular deployment view, the processes are transformed to executable JADL services and then deployed to an agent equipped with a JADL interpreter running

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<sup>2</sup>It is also possible that the process does not require to be simulated, which may be necessary for emergencies demanding for very short response times. Determining this property will be part of the certification.

on the simulation node. Additionally, besides the services also a number of service starter rules are deployed to that agent, so that the individual JADL services are started just in the way stated by the processes' start events.

### **10.2.2. Simulating Processes**

### **10.2.3. Deploying and Executing Processes**



# A. Changelog and Version History

## Version 1.4.1

- switched to Eclipse 3.6

## Version 1.4.0

- **simplified meta model**, extended concept of *services* and *messages*
- transformation to JADL now generated **service started rules** (in Drools)
- **JIAC Node Plugin**:
- extended expression languages with *List* concept

## Version 1.3.1

- Interpreter: fixed evaluation priority in expressions, e.g. multiplication vs. addition
- **merging of different versions of a VSDT diagram**
- started Data Type Management

## Version 1.3.0

- switched to Eclipse 3.5
- support for Conversation Diagrams (BPMN 2.0)
- **using one file for both semantic model and notational model**
- creation of diagram files (not only model files) on export and import
- export of BPMN diagrams with multiple start events to JIAC is now possible
- **added Connect to Sequence Action** for quick assembling of core process
- preferences can be used to deactivate the GMF modeling assistant

### **Version 1.2.2**

- **Structure-based layout of BPMN diagrams**

### **Version 1.2.1**

- **Export to JIAC V / JADL, integration with JIAC Agent World Editor**
- improved Pool / Lane visuals
- **added Append Node actions** for quick keyboard-based assembly of process diagrams
- added translation of basic data types, such as integer, string, etc.
- *suspended support for JIAC IV and RSD*

### **Version 1.2.0**

- **new diagram type: VSDT Meta Diagram (similar to UML use cases)**
- some more changes to the meta model

### **Version 1.1.3**

- **Simulation and Interpretation of BPMN diagrams**
- **Structure View**
- added transformation rule for Event Handler Loops
- improved support for Link Events

### **Version 1.1.2**

- switched to BPMN 1.1
- automatically setting input and output Messages according to selected Implementation
- **Parameter Assignment Dialog** for quickly assigning values to message parameters
- validation of Expression syntax
- **BPMN-to-Text transformation**

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### **Version 1.1.1**

- **Pool visibility view**
- simplified meta model
- **translation of Expressions**

### **Version 1.1.0**

- switched to GMF 2.1
- improved Web service and RSD views
- **Patterns can be inserted on existing edges**, e.g. loops, blocks
- **import and export for STP-BPMN**

### **Version 1.0.1**

- further improved graphics, added symbols for Activity Types and colors
- improved clean-up (export)
- **BPEL import**

### **Version 1.0.0**

- re-organized plugin structure
- first release

### **Version beta 2.4.1 and earlier versions**

- some changes to the meta model
- connections with rounded corners, improved node figures
- improved management of non-visual elements
- **single nodes can be inserted on existing edges**
- **BPMN Properties (variables) view**
- improved normalization of identifiers (export)
- ...





## B. The Business Process Modelling Notation

The *Business Process Modelling Notation* (BPMN) was first published by the BPMI and has then been adopted by the OMG (Object Management Group) [8]. The goal of the development of BPMN was to create a standardized modeling notation for business processes, thus reducing the confusion created by dozens of proprietary business process notations. A brief introduction to BPMN is given for instance in [9].

There are four basic categories of element types in the notation: Flow Objects (Events, Activities and Gateways), Connecting Objects (Sequence Flows, Message Flows and Associations), Swimlanes (Pools and Lanes) and Artifacts (Data Objects, Groups and Annotations).

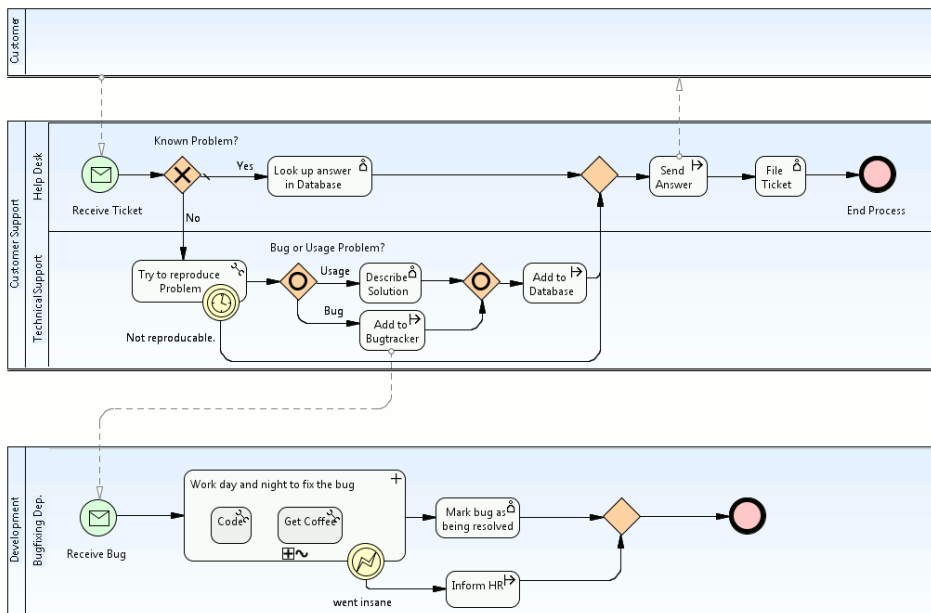


Figure B.1.: Business Process Modelling Notation Example Diagram

Figure B.1 shows a simple example diagram. The elements are quite self-descriptive and most of them are already known from other notations, so the basics of the BPMN are readily understandable for all business analysts, architects and developers and even

for non-experts. At the same time BPMN provides a large variety of subtypes for each of the Flow Objects and every element type is enriched with many non-graphical attributes, making the models sufficiently detailed for being exported to executable languages while keeping the visual notation concise and understandable.

A problem with BPMN is that it is mainly a *notation*. Although the specification describes many non-graphical attributes and a mapping to a formal language, it neither states an exchange format, like an XSD, nor clear semantics for all of the elements. Still the Business Process Modeling Notation can be used throughout the entire software engineering life-cycle, from a simplified model at the requirements analysis up to a highly detailed model that can be used for generating code for an executable language.

## B.1. BPMN Elements

This section is intended to give a brief introduction of each of the basic element groups:

- **Flow Objects:** Events, Activities, and Gateways
- **Connecting Objects:** Sequence Flows, Message Flows and Associations
- **Swimlanes:** Pools and Lanes
- **Artifacts:** Data Objects, Groups and Annotations

### B.1.1. Flow Objects

The category of *Flow Objects*, the most important elements in BPMN, is made up of *Events*, *Activities* and *Gateways*. All Flow Objects are held in Lanes (see below).

**Events** are things that *happen*, like a message arriving, an alarm, or an error, and often they mark the beginning and the end of the process. The graphical notation is a circle. They are subdivided into *Start Events*, *Intermediate Events* and *End Events*, which determines the circle's border (see figure B.2).



Figure B.2.: BPMN Event types. From left to right: Start Event, Intermediate Event, End Event

Further all three Event types have a variety of subtypes which will determine e.g. a Start Event's *trigger* and an end Event's *result*. Each of these subtypes can be distinguished by a different icon in the center of the Event figure (see figure B.3) and results in a number of attributes to be set for the Event.

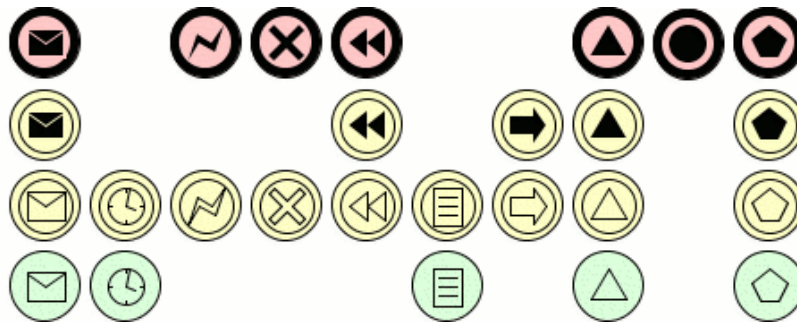


Figure B.3.: BPMN Event sub types. From left to right: Message, Timer, Error Cancel, Compensation, Rule, Link, Signal, Termination, Multiple

Basically, an **Activity** is something that is *done*. Activities subdivide in *Tasks*, which are atomic Activities, and *Sub Processes*, which are composite Activities. The graphical notation for an Activity is a rounded rectangle with the Activity's name inside of it. Sub Processes are marked with a small  $\boxplus$  sign on the bottom line (see figure B.4).



Figure B.4.: BPMN Activity types. From left to right: Task, Subprocess

Like Events, Activities also have some specializations, each one with special attributes: They can be for instance a *Send* or a *Receive* Task, stand for some *Manual* work to be done, execute a *Script* or represent the call to a whole other business process, just to name a few. All of these subtypes have the same graphical representation, but modelers and modeling tools are free to extend the diagrams with additional markers for the subtypes.

What makes Activities stand out from the other Flow Objects is that they can *loop*. Although in BPMN loops also can be defined by simply connecting a Sequence Flow to an upstream Flow Object, which might be easier to understand by non-experts, it's seen as better style to use looping Activities, where applicable. A looping Activity is marked with a small counter-clockwise arrow on its bottom line.

**Gateways** provide wide capabilities in modeling all kinds of splitting and merging behavior. Figure B.5 shows the different kinds of Gateways. Depending on whether the Gateway has multiple incoming or outgoing Sequence Flows – or even both – it has different semantics, like forking and/or joining the flows. However, Gateways are not the only way for modeling forking and joining of flows: In some cases the same semantics can be reached by omitting the Gateway and connecting multiple Sequence Flows directly to an Activity (but not Events). However, this should also be considered bad style.

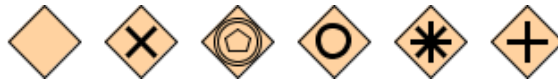


Figure B.5.: BPMN Gateway types. From left to right: Data-based XOR (with and without marker), Event-based XOR, Inclusive OR, Complex, AND

### B.1.2. Connecting Objects

The most important connections are *Sequence Flows* and *Message Flows*. Sequence Flows represent the flow of control and connect Flow Objects within a Pool in the order of execution. Message Flow represents messages – not necessarily data – being exchanged exclusively between Pools. See figure B.6 for the connections' graphical notation.



Figure B.6.: BPMN Connection types. From left to right: Sequence Flow, Message Flow, Association

The third connection, the *Association*, is mainly used for documentation purposes, for instance to connect a Text Annotation to a Flow Object that needs further explanation. Still there is an exception to this rule: For connecting a compensating Activity to a compensation Event an Association is used instead of a Sequence Flow. An Association's arrow heads are optional.

### B.1.3. Swimlanes

Swimlanes can be *Pools* and *Lanes*. Each Pool represents one Participant in the business process, while Lanes are used to partition a Pool. Doing so each of a company's departments could be represented by a Lane while the Pool stands for the company itself. However, the semantics of both Pools and Lanes is not entirely fixed. Typically Swimlanes are oriented horizontally, but may be oriented vertically, too. Further, Lanes may cross or contain other Lanes, but those techniques are poorly documented and seldom used. Figure B.7 shows a small horizontally oriented Pool containing two empty Lanes.

### B.1.4. Artifacts

The main purpose of *Artifacts* is documentation. However, like Associations, in some situations they can have semantics, e.g. when a *Data Object* is referenced by an Activity as input. Data Objects represent everything that can be input or output of some Activity.



Figure B.7.: BPMN Swimlanes. A Pool with two Lanes

In most cases this will be a file, or some piece of data, but since Activities can be *Manual Tasks*, too, a Data Object could also stand for something physical.

The other two Artifacts, *Group* and *Text Annotation*, are solely used for documentation. See figure B.8 for their graphical notation.



Figure B.8.: BPMN Artifacts. From left to right: Data Object, Group, Text Annotation

The specification states that this category may be extended by proprietary Artifacts which could have more semantics, too. This way BPMN can be extended with new elements to represent concepts that were not considered in the original specification.

## B.2. Levels of Complexity

BPMN can be seen as having at least three levels of complexity.

1. Basic Types: All diagrams are made up of the basic elements of the four categories: Events, Activities, Gateways, Connections, Pools and Artifacts. These can be understood easily even by non-experts.
2. Subtypes: The Flow Objects each have several subtypes, e.g. Timer Events, Receive Tasks and Inclusive Gateways. Using the same shapes as the basic elements enriched with some additional graphical information, like an icon, the symbol's basic type can be clearly identified by non-experts while providing additional visual information for the professionals.
3. Attributes: Each of the BPMN element types provides a large number of both primitive and complex attributes. While some of these attributes are visible in the diagram, like a flow object's name or subtype, most are non-graphical. These attributes enrich the diagram with the formal semantics necessary for the export to an executable language while not polluting the visual notation with too many details.

If the process shall be mapped to an executable language the third level is very important: Not only does it give values for many attributes that otherwise would have to be set manually. Some of the visual elements of the BPMN do not have semantics “on their own”. Message Flows for example do *not* have a mapping to WS-BPEL. Instead the source Activity has to be of type **Send** and the target Activity of type **Receive**, and both have to reference the same non-graphical **Message** element. This is necessary in cases when the communications partner is not in the same diagram and thus a Message Flow can not be drawn.

Of course it is free to the designers of new mappings to map the Message Flow, if it is available, without insisting on the existence of the non-graphical Message element.

### B.3. Export and Code Generation

One of the main purposes of the Business Process Modelling Notation is to provide a graphical process notation that can be used to generate executable code from it.

A mapping to WS-BPEL is given in the BPMN Specification. As a matter of fact, BPMN has been tailored for the mapping to WS-BPEL, which can be seen in many attributes which are needed only for the mapping. Most of these attributes can be reused for mappings to other languages, too, e.g. such common concepts as properties and assignments.

On the other hand BPMN has more expressive power than BPEL. A diagram in BPMN is a directed graph, while BPEL, and in fact most other executive languages as well, are block oriented, making the export to a semantically equivalent program complicated and in some cases impossible. Numerous papers have been written on how to identify block structures within a BPMN diagram or how to alter an existing diagram to conform to block structure. However, not every diagram can be refactored like that.

While the basic elements such as Flow Objects should neither be altered nor extended by new elements, the BPMN Specification encourages the introduction of new, domain-specific Artifacts to be used in mappings to executable languages other than BPEL. These elements can be associated with the original BPMN elements and represent concepts that were not considered in the original BPMN specification.

## C. The VSDT Expression Language (VXL)

The BPMN standard does not specify an expression language to be used. Instead, it is assumed that the language of the target framework is used, e.g. XPath. However, in a tool that provides transformations to various target frameworks this is not an option. While the diagram structure could be translated to the syntax of the target system, the expression, given that they are written in an unknown language, could not – although all those languages might be very similar. To address this flaw, the VSDT comes with its own, very simple expression language, the *VSDT Expression Language (VXL)*.

### C.1. Language Features and Syntax

The VSDT Expression language has been designed to be the greatest common divisor of the expression languages used in the target frameworks. Thus, most expressions can be given using VXL, in which case they can be validated and – more importantly – parsed and translated to the respective expression languages used in the target frameworks.

Below, the complete syntax of VXL is given. As can be seen, it is not much different from that of other languages. Variables have to be the name of a Property in the scope of the owner of the Expression. The Variable may be followed by one or more accessors, e.g. for access to an array element (e.g. `foo[2]`) or a field (e.g. `foo.bar`), or combinations thereof (e.g. `foo[n+1].bar`); of course accessors can only be used if the target language and data type supports them.

```
Term:           Element (Operator Term)?;
Element:        BracketTerm | Negation | Minus | Card |
                List | Variable | Value;
BracketTerm:    "(" Term ";";
Negation:       "not" Element;
Minus:         "-" Element;
Card:          "#" Element;
List:          "[" (ListElement)? ";";
ListElement:    Term ("," ListElement)?;
Variable:       ID (Accessor)?;
Accessor:       ArrayAccessor | FieldAccessor;
```

```

ArrayAccessor: "[" Term "]" (Accessor)?;
FieldAccessor: "." ID (Accessor)?;
Value:         STRING | INT | FLOAT | "true" | "false" | "null";
Operator:      "<" | "<=" | "==" | "!=" | ">" | ">=" |
               "+" | "-" | "*" | "/" | "%" | "and" | "or" | "++";

```

## C.2. Operators and Comparisons

In Table C.1 we spell out the several operations and comparisons supported in VXL, most of which can be found in all the usual programming languages and do not require further explanation.

Table C.1.: VXL Operations and Comparisons

Operation	Symbol	Comparison	Symbol
Addition	+	Equal	==
Subtraction	-	Not Equal	!=
Multiplication	*	Lesser	<
Division	/	Lesser or Equal	<=
Modulo	%	Greater	>
Concatenation	++	Greater or Equal	>=
Cardinality	#		
Logical AND	and		
Logical OR	or		
Logical NOT	not		

The == comparison should test whether two values are *equal*, but not necessarily the *same*, and the semantics of != should be understood accordingly. The unary Cardinality operation can be used for retrieving the length of a list or a string, for getting the absolute value of a number, or for casting a boolean value to either 1 or 0. The Concatenation operation is used to combine lists or strings, such that [1,2]++[3,4] results in [1,2,3,4], whereas [1,2]+[3,4] results in [1,2,[3,4]]. The \* operator can be used to construct lists, e.g. [0]\*5 results in [0,0,0,0,0]

Note, that this is how these operators *should* be understood, and how the VSDT Interpreter interprets evaluates them. However, it is possible that parts of the language are not supported, or interpreted differently, in some transformation target languages.



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