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   http://www.omg.org/spec/SPEM/2.0/
1 Introduction and functional Overview

1.1 Variant Handling in AUTOSAR

Release 4 of AUTOSAR has added support for Variant Handling, which contributes two new aspects to the AUTOSAR metamodel as it was defined in release 3.

First, variation points have been introduced to AUTOSAR models. An AUTOSAR model with variation points describes a set of AUTOSAR models which have a common structure but differ at certain locations. A variant-free AUTOSAR model is created from such a model by binding the variation points, that is, by keeping some variations and discarding others.

Second, AUTOSAR defines means to express what constitutes a specific variant, for example which variation points are selected in an “economy” variant and which variation points are selected in a “luxury” variant. This is necessary because an AUTOSAR model with variation points may describe a very large number of variants, but few of them are actually used.

Variant Handling in AUTOSAR is described in chapter on variant handling of the Generic Structure Template [1].

1.2 The case for Feature Models

To summarize the previous section, AUTOSAR Variation points are intended to exchange information about where variation occurs in an AUTOSAR model, and to state what the relevant variants are. There are however two aspects that are not yet covered by this concept:

- Variation points are expressed on a rather low level. For example, the variants 'economy' and 'luxury' typically consist of a large number of variation points, but the fact that these variation points act conjointly is not explicitly visible in the model.

- There are dependencies between variation points. For example, 'economy' and 'luxury' variants are mutually exclusive, but this relationship is again not explicitly visible in the model. For variation points that are not PostBuild, this could be implemented by appropriately extending the formula language used for the conditions, although this would be difficult to maintain and would also intertwine two independent concepts, variation points and feature modeling. However, such an extension would not work for PostBuild because such variation points only use simple conditions.

The Feature Model Exchange Format which we are presenting in this document covers these additional aspects.
1.3 Sample Feature Model

An example for a feature model is shown in Figure 1.1.

![Feature Model](image)

Figure 1.1: A sample Feature Model

1.4 Overview

1. Features reside in the “problem domain”. They are even independent from the implementation respectively the product architecture. They are much more abstract than variation points which reside in the “solution domain”. Features express common and variable characteristics of the finished product instead of annotating individual locations in a model. A feature model provides a high-level view of an AUTOSAR model with variations.

2. A feature model describes the dependencies between individual features. Examples for dependencies include hierarchical structuring of features, features that model alternatives, and features that require or prohibit other features.
3. An individual product can be described by selecting a set of features. Of course, such a selection has to obey the dependencies stated in the feature model. A mapping from features to variation points\(^1\) specifies which variation points are affected by the selection.

4. The Feature Model Exchange Format establishes an efficient way to exchange feature models between different feature modeling tools.

5. Feature models will be optional in AUTOSAR. This means that feature models are an extension; it is still possible to develop and use AUTOSAR models that do not contain feature models.

1.5 Document Conventions

Technical terms are typeset in mono spaced font, e.g. PortPrototype. As a general rule, plural forms of technical terms are created by adding "s" to the singular form, e.g. PortPrototypes. By this means the document resembles terminology used in the AUTOSAR XML Schema.

This document contains constraints in textual form that are distinguished from the rest of the text by a unique numerical constraint ID, a headline, and the actual constraint text starting after the ⌈ character and terminated by the ⌋ character.

The purpose of these constraints is to literally constrain the interpretation of the AUTOSAR meta-model such that it is possible to detect violations of the standardized behavior implemented in an instance of the meta-model (i.e. on M1 level).

Makers of AUTOSAR tools are encouraged to add the numerical ID of a constraint that corresponds to an M1 modeling issue as part of the diagnostic message issued by the tool.

The attributes of the classes introduced in this document are listed in form of class tables. They have the form shown in the example of the top-level element AUTOSAR:

Please note that constraints are not supposed to be enforceable at any given time in an AUTOSAR workflow. During the development of a model, constraints may legitimately be violated because an incomplete model will obviously show inconsistencies.

However, at specific points in the workflow, constraints shall be enforced as a safeguard against misconfiguration.

The points in the workflow where constraints shall be enforced, sometimes also known as the “binding time” of the constraint, are different for each model category, e.g. on the classic platform, the constraints defined for software-components are typically enforced prior to the generation of the RTE while the constraints against the definition of an Ecu extract shall be applied when the Ecu configuration for the Com stack is created.

\(^1\)More precisely, features will be mapped to values of system constants, which in turn control variation points.
For each document, possible binding times of constraints are defined and the binding times are typically mentioned in the constraint themselves to give a proper orientation for implementers of AUTOSAR authoring tools.

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<td>Note</td>
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<td>Tags:</td>
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<td>aggr</td>
<td>This represents the administrative data of an Autosar file.</td>
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<tr>
<td>arPackage</td>
<td>ARPackage</td>
<td>*</td>
<td>aggr</td>
<td>This is the top level package in an AUTOSAR model.</td>
</tr>
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<td>fileInfoComment</td>
<td>FileInfoComment</td>
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<td>aggr</td>
<td>This represents a possibility to provide a structured comment in an AUTOSAR file.</td>
</tr>
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<td>DocumentationBlock</td>
<td>0..1</td>
<td>aggr</td>
<td>This represents an introduction on the Autosar file. It is intended for example to represent disclaimers and legal notes.</td>
</tr>
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</table>

Table 1.1: AUTOSAR

The first rows in the table have the following meaning:

**Class**: The name of the class as defined in the UML model.

**Package**: The UML package the class is defined in. This is only listed to help locating the class in the overall meta model.

**Note**: The comment the modeler gave for the class (class note). Stereotypes and UML tags of the class are also denoted here.

**Base Classes**: If applicable, the list of direct base classes.

The headers in the table have the following meaning:

**Attribute**: The name of an attribute of the class. Note that AUTOSAR does not distinguish between class attributes and owned association ends.

**Type**: The type of an attribute of the class.

**Mul.**: The assigned multiplicity of the attribute, i.e. how many instances of the given data type are associated with the attribute.
Kind: Specifies, whether the attribute is aggregated in the class (aggr aggregation), an UML attribute in the class (attr primitive attribute), or just referenced by it (ref reference). Instance references are also indicated (iref instance reference) in this field.

Note: The comment the modeler gave for the class attribute (role note). Stereotypes and UML tags of the class are also denoted here.

Please note that the chapters that start with a letter instead of a numerical value represent the appendix of the document. The purpose of the appendix is to support the explanation of certain aspects of the document and does not represent binding conventions of the standard. The verbal forms for the expression of obligation specified in [TPS_STDT_00053] shall be used to indicate requirements, see Standardization Template, chapter Support for Traceability ([2]).

The representation of requirements in AUTOSAR documents follows the table specified in [TPS_STDT_00078], see Standardization Template, chapter Support for Traceability ([2]).

[TPS_FMDT_00064] Usage of Life Cycle

Life Cycles in the FeatureModelExchangeFormat are described by making use of the Life Cycle Support as described in the Generic Structure Template [1]. (RS_FMDT_00012)

1.6 Requirements Tracing

The following table references the requirements specified in [3] and links to the fulfillments of these.

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Table 1.2: Requirements Tracing
2 Terminology

Figure 2.1: Overview of Feature Model Terminology

Figure 2.1 presents an overview of the terminology used for feature modeling. We define seven terms that are specific to the Feature Model Exchange Format, namely Feature, Feature Selection, Feature Model, Product Model, Product Line Model, Product and Product Line:

- **[TPS_FMDT_00002] Definition of Feature**
  
  A Feature describes an essential characteristic of a product. Features usually differentiate one product from similar products – in our context, features differentiate the individual products in a product line.\(\text{[RS_FMDT_00002]}\)

- **[TPS_FMDT_00003] Definition of Feature Selection**
  
  A Feature Selection is a set of Features that describes a specific product. A Feature Selection is always paired with a Feature Model. All dependencies and relations that are defined in the Feature Model shall be obeyed.\(\text{[RS_FMDT_00003]}\)

- **[TPS_FMDT_00004] Definition of Feature Model**
  
  A Feature Model describes the available features of a product line and their interrelations / interdependencies. In other words, a Feature Model describes a Product Line Model in the problem domain.

  For example, a car may have either a gasoline or a diesel engine, so the features Gasoline and Diesel are alternatives. A seven-seat configuration of a car might require air conditioning, so the feature Seven Seats requires the feature Air Conditioning.
A Feature Model is usually paired with a Product Line Model. [RS_FMDT_00001]

- **[TPS_FMDT_00005] Definition of Product Model**
  A Product Model describes a product. A Product Model does not contain variation points anymore (except for PostBuild variation points). It is derived from the Product Line Model by “binding” the variation points.

In AUTOSAR, a Product Model is a collection of M1 artifacts that describes a particular Product.

Except for PostBuild variation points, The Product Model conforms to the Pure Metamodel as defined in the chapter on variant handling in the Generic Structure Template [1]. [RS_FMDT_00001]

- **[TPS_FMDT_00006] Definition of Product Line Model**
  A Product Line Model is similar to a Product Model, but contains variation points of all binding times. A Product Model is created out of a Product Line Model by keeping certain variations, and discarding others (i.e., binding). The only variation points that are still allowed in a Product Model are PostBuild variation points.

In the context of feature modeling, this selection process is steered by a Feature Selection (more precisely, the variant selection Process (binding) is controlled by variant selectors (SwSystemconst) who’s values in turn may be derived from Feature selection).

In AUTOSAR, A Product Line Model is a collection of M1 artifacts which describe a set of Product Models with common characteristics. A Product Line Model is an instance of an extended metamodel as defined in the chapter on variant handling in the Generic Structure Template [1]. [RS_FMDT_00001]

- **[TPS_FMDT_00007] Definition of Product**
  A Product is an artifact that is the outcome of some type of process, for example a software that runs on one or more ECUs.

In AUTOSAR, a Product is a collection of M0 artifacts. In our terminology, it is described by a Product Model on M1 Level. [RS_FMDT_00001]

- **[TPS_FMDT_00008] Definition of Product Line**
  A Product Line is a collection of Products that are related. A Product Line usually consists of a set of Products that have a certain amount of common aspects and a number of aspects that differentiate the individual Products from each other.

In our terminology, a Product Line is described by a Product Line Model, which in turn is described by a Feature Model. [RS_FMDT_00001]

A note on the terminology

In this section, we define several terms that already have a meaning in AUTOSAR or elsewhere. This is especially true for the terms Feature and Product. A more concise definition might be AUTOSAR Featuremodel Feature or AUTOSAR Featuremodel Product.
However, it is easy to see that readability of this document would be significantly impacted by such a choice of words. Terms such as Feature have been established in the literature on feature modeling for some time, so using a different term would not be helpful for anybody familiar with the field.

Hence, we have decided to go with the established terms despite the overlap with existing AUTOSAR terminology. Since these terms are only used in the context of feature modeling, it should always be clear which definition is intended.

2.1 Terminology from graph theory

In this document, we do occasionally use concepts from graph theory to provide formal descriptions for constraints. The following sections defines these terms.

- A directed\(^1\) graph is a tuple \((V, E)\) where \(E \subseteq V \times V\). \(V\) are called the nodes of \(G\), and \(E\) are called the edges of \(G\).

- A path \(p\) in a graph \(G = (V, E)\) is a sequence \(p = v_1, v_2, \ldots, v_n\) of nodes with \(v_i \in V\) and \(\forall i \in \{1, \ldots, n-1\} : (v_i, v_{i+1}) \in E\). \(p\) starts at \(v_1\) and ends at \(v_n\).

- A circle in a graph \(G = (V, E)\) is a path \(v_1, v_2, \ldots, v_n\) where \(v_1 = v_n\).

- A self loop in a graph \(G = (V, E)\) is an edge \((v, v)\) \(\in E\).

- An isolated node in a graph \(G = (V, E)\) is a node \(v \in V\) where \(\neg \exists v' : ((v, v') \in E \lor (v', v) \in E)\). In other words, an isolated node is one that has no edges.

- A tree is a graph \(G = (V, E)\) with root \(r \in V\) that has the following properties:
  1. \(\forall v \in V : \exists \text{ path } p = \{r, v_2, \ldots, v\}\). In other words, for every node \(v \in V\), there exists a path that starts at \(r\) and ends at \(v\).
  2. \(\neg \exists v \in V : (v, r) \in E\). In other words, the root node has no incoming edge.
  3. \(\forall v \in V, v \neq r : \exists v' \in V : (v', v) \in E\). In other words, any node that is not the root node has exactly one incoming edge.
  4. \(G\) has no circles and no self loops.
  5. \(\text{size}(V) = \text{size}(E) + 1\).

Note: Items 4 and 5 are a consequence of items 1, 2 and 3.

\(^1\)In this document, we need only directed graphs, so we are using the term graph synonymous with directed graph.
3 Overview

An AUTOSAR feature model consists of three different structures: the feature model itself, the feature selection, and finally the feature map.

3.1 Feature Model

A feature model (FMFeatureModel) consists of a number of features (FMFeature), which are organized hierarchically (FMFeatureDecomposition). That is, each feature may contain a number of subfeatures, which in turn may contain subfeatures of their own and so on. In other words: a feature model consists of one or more feature trees.

As a special case, it is possible to distribute (split) feature models over several AUTOSAR files. It is also possible to partition a large feature tree into subtrees.

Also, there may be interdependencies between features. For example, features may represent alternatives and are thus mutually exclusive (FMFeatureDecomposition), or a feature may require one or more other features, contradict other features (FMFeatureRelation), or features may include an expression that restricts their applicability (FMFeatureRestriction).

3.2 Feature Selection

A feature selection is a set of features that describe an actual product. For example, a specific car model is described by its set of features. This is implemented by a FMFeatureSelectionSet, which contains a number of FMFeatureSelections, each of which defines the state of a FMFeature within this particular feature selection.

A feature selection is said to be valid if all the restrictions and relations defined for its features as well as the hierarchical structure of the feature model are obeyed.

Feature selections are handled separately from feature models because there usually are many different feature selections for a single feature model. For example, different cars are represented by different feature selections.

3.3 Feature Map

In AUTOSAR Variant Handling, variation points are controlled by system constants. An expression that is based on system constants is used to determine whether a particular

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1Many concepts described in this document are adapted from Generative Programming: Methods, Tools, and Applications, Krzysztof Czarnecki and Ulrich W. Eisenecker, ACM Press/Addison-Wesley Publishing Co, 2000
variation point is ‘on’ or ‘off’. One consequence is that the same system constant may be used to control several variation points.

Hence, features cannot be mapped directly to variation points, but need to choose values for the system constants which are used in the variation points’ expressions.

This is done by feature maps (FMFeatureMap). In a nutshell, each element of a feature map (FMFeatureMapElement) contains a set of conditions (FMFeatureMapCondition) that are based on features and feature attributes and a set of assertions (FMFeatureMapAssertion) that are based on features and system constants. If any of the conditions and all of the assertions evaluate to true, then the mapping lists a number of system constants and chooses values for them.
4 Feature Model

Figure 4.1: Class FMFeatureModel

4.1 Class FMFeatureModel

<table>
<thead>
<tr>
<th>Class</th>
<th>FMFeatureModel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
<tr>
<td>Note</td>
<td>A Feature model describes the features of a product line and their dependencies. Feature models are an optional part of an AUTOSAR model.</td>
</tr>
<tr>
<td>Tags</td>
<td>atp.recommendedPackage=FMFeatureModels</td>
</tr>
<tr>
<td>Base</td>
<td>ARElement, AObject, CollectableElement, Identifiable, MultilanguageReferrable, Packageable, Element, Referrable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
</table>

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### Class `FMFeatureModel`

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
<th>Min</th>
<th>Max</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>feature</td>
<td>FMFeature</td>
<td>*</td>
<td>ref</td>
<td></td>
</tr>
<tr>
<td>root</td>
<td>FMFeature</td>
<td>0..1</td>
<td>ref</td>
<td></td>
</tr>
</tbody>
</table>

- **Stereotypes:** `atpSplitable`
- **Tags:** `atp.Splitkey=feature`

#### Table 4.1: `FMFeatureModel`

A `FMFeatureModel` describes the available features of a product line, as defined in [TPS_FMDT_00004].

An AUTOSAR model that does not contain a feature model is still a valid AUTOSAR model.

Especially, feature models may be empty, i.e., contain no features.

If an AUTOSAR model contains more than one feature model, then these feature models may interact with each other in two ways. First, feature models may use other feature models as sub-models, as defined in Section 4.4.4. Second, restrictions (4.5) and relations (4.6) between features may refer to features that are defined in other feature models.

### 4.1.1 Reference `feature`

Each `FMFeatureModel` contains a number of `FMFeature` elements in the role `feature`. These elements represent the `features` of the feature model.

A `FMFeature` can only be part of a single `FMFeatureModel`:

[constr_5007] `FMFeature` shall only be referenced from one `FMFeatureModel` in the role `feature`.
Obviously, a \textit{FMFeatureModel} shall not contain the same feature twice.

\textbf{[constr\_5019]} \textit{FMFeatureModel} shall not contain the same \textit{FMFeature} twice

\[\text{Let } F \text{ be a } \textit{FMFeatureModel}, \text{ and let } f, f' \text{ be } \textit{FMFeatures} \text{ that are referenced from } F \text{ in the role } \textit{feature}. \text{ Then } f \neq f'.\]

On the other hand, there are no “isolated” features; every \textit{FMFeature} is part of a \textit{FMFeatureModel}.

\textbf{[constr\_5020]} Every \textit{FMFeature} shall be contained in a \textit{FMFeatureModel} \\
\[\text{For every } \textit{FMFeature } f, \text{ there shall be a } \textit{FMFeatureModel} \text{ that refers to } f \text{ in the role } \textit{feature}.\]

Constraint \textbf{[constr\_5020]} makes sure that there are no “standalone” features, which would be technically possible because \textit{FMFeature} is an \textit{ARElement}, but is not useful in this context.

Finally, feature models can be distributed over several physical ARXML files if necessary.

\textbf{[TPS\_FMDT\_00047]} Feature models are splitable \\
\[\text{The relation } \textit{feature} \text{ has the stereotype } \ll \text{atpSplitable}\gg \text{. That is, a } \textit{FMFeatureModel} \text{ may be distributed over several ARXML files.}\]

\textbf{4.1.2 Reference root}

As the features of a feature model are organized in a tree structure (see Section 4.4), there is exactly one feature that sits at the top of the tree. The feature model has an extra reference \textit{root} which points to that feature.

\textit{Root} is not strictly necessary because it would be possible to infer the root feature from the hierarchical structure of a feature model (see Section 4.4). However, \textit{root} is included for convenience and to assist tools in checking the integrity of the model.

\textbf{[TPS\_FMDT\_00036]} Definition of Root Feature of a \textit{FMFeatureModel} \\
\[\text{Let } F \text{ be a } \textit{FMFeatureModel} \text{ that refers to a } \textit{FMFeature } f \text{ in the role } \textit{root}. \text{ Then } f \text{ is called the root feature of } F.\]

We need to define two constraints for the root feature. First, if the feature model is not empty – that is, it has features – then one feature shall be the root feature:

\textbf{[constr\_5009]} Root feature shall be present if and only if the feature model is not empty

\[\text{If a } \textit{FMFeatureModel} \text{ refers to one or more } \textit{FMFeature} \text{ elements in the role } \textit{feature}, \text{ then exactly one of them shall be referenced by } \textit{FMFeatureModel} \text{ in the role } \textit{root}.\]

On the contrary, if \textit{FMFeatureModel} does not refer to any \textit{FMFeatures} in the role \textit{feature}, then \textit{root} shall be empty.

Second, the root feature of a feature model shall be one of its own features:
[constr_5008] If present, the root feature shall be part of the feature model.

Let \( r \) be the \( \text{FMFeature} \) referenced from \( \text{FMFeatureModel} \) in the role \( \text{root} \), and \( \{ f_1, f_2, \ldots, f_n \} \) the set of features referenced from the same \( \text{FMFeatureModel} \) in the role \( \text{feature} \).

Then the following condition shall hold: \( r \in \{ f_1, f_2, \ldots, f_n \} \).

We will come back to the root feature later with constraint [constr_5022] where we require that the root feature points to the root of the feature tree, and [constr_5010] where we allow a feature to use the root feature (but only that) of another feature model as a subfeature.

### 4.2 Class FMFeature

Each \( \text{FMFeatureModel} \) consists of a number of \( \text{FMFeatures} \), which in turn are organized in a hierarchical, tree-like structure. This hierarchy establishes a parent-child relation among features, where every feature that is not the root feature has exactly one parent, and any number of children, including zero.

<table>
<thead>
<tr>
<th>Class</th>
<th>FMFeature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSAR::FeatureModel::FeatureModelTemplate</td>
</tr>
<tr>
<td><strong>Note</strong></td>
<td>A ( \text{FMFeature} ) describes an essential characteristic of a product. Each ( \text{FMFeature} ) is contained in exactly one ( \text{FMFeatureModel} ).</td>
</tr>
<tr>
<td><strong>Tags</strong></td>
<td>atp.recommendedPackage::FeatureModel::FeatureModel</td>
</tr>
</tbody>
</table>
| **Base**                   | \( \text{ARElement} \), \( \text{ARObject} \),  
|                            | \( \text{CollectableElement} \), \( \text{Identifiable} \),  
|                            | \( \text{MultilanguageReferrable} \), \( \text{Packageable} \) |  
| Attribute                  | Type                                           | Mult. | Kind | Note |
| attributeDef               | \( \text{FMAttributeDef} \)                    | *     | agrr | This defines the attributes of the given feature. |
| decomposition              | \( \text{FMFeatureDecomposition} \)             | *     | agrr | Lists the sub-features of a feature. |
| maximum IntendedBinding Time | BindingTimeEnum                                | 0..1  | attr | Defines an upper bound for the binding time of the variation points that are associated with the \( \text{FMFeature} \). This attribute is meant as a hint for the development process. |
| minimum IntendedBinding Time | BindingTimeEnum                                | 0..1  | attr | Defines a lower bound for the binding time of the variation points that are associated with the \( \text{FMFeature} \). This attribute is meant as a hint for the development process. |
| relation                   | \( \text{FMFeatureRelation} \)                 | *     | agrr | Defines relations for \( \text{FMFeatures} \), for example dependencies on other \( \text{FMFeatures} \), or conflicts with other \( \text{FMFeatures} \). A \( \text{FMFeature} \) can only be part of a \( \text{FMFeatureSelectionSet} \) if all its relations are fulfilled. |
| restriction                | \( \text{FMFeatureRestriction} \)              | *     | agrr | Defines restrictions for \( \text{FMFeatures} \). A \( \text{FMFeature} \) can only be part of a \( \text{FMFeatureSelectionSet} \) if at least one of its restrictions evaluates to true. |

| Table 4.2: FMFeature |

[TPS_FMDT_00042] Purpose of \( \text{FMFeature} \): [A \( \text{FMFeature} \) describes an essential characteristic of a product, as defined in [TPS_FMDT_00002].] (RS_FMDT_00002)

A \( \text{FMFeature} \) aggregates the following elements:
**FMFeatureDecomposition** A *decomposition* defines how features are organized hierarchically. It also imposes certain constraints among features: there are *mandatory*, *optional*, *alternative* and *multiple*-features.

Feature decomposition is described in Section 4.4.

**FMFeatureRestriction** A *restriction* contains a formula that constrains the inclusion of a feature into a valid *feature selection* ([TPS_FMDT_00030]). There may also be more than one restriction. A feature may only be part of a valid feature selection if at least one its restrictions evaluates to *true*.

Feature restrictions are described in Section 4.5.

**FMFeatureRelation** A *relation* expresses constraints among features. A relation points from one feature to one or more other features and defines a relationship between these features. For example, relationships may be used to express that one feature *requires* another feature, or *conflicts* with several other features.

Feature relations are described in Section 4.6.

**FMAttributeDef** An *attribute* defines a numerical attribute of a feature. Attributes are used by restrictions (see Section 4.5) and feature maps (see Section 6 6.4). Features themselves define only the attribute and an optional default value; the actual value may be further refined in a feature selection (Section 5).

Feature attributes are described in Section 4.3.

**FMFeature** has two attributes, *maximumIntendedBindingTime* and *minimumIntendedBindingTime*, which specify the intended binding time for the variation points that are associated with this feature (see Section 4.2.2).

### 4.2.1 Name and Documentation of a Feature

[TPS_FMDT_00039] Name of a **FMFeature** [The attribute *shortName* may be used to identify a feature. Furthermore, the attribute *longName* may be used to provide a human readable name for a **FMFeature**.](RS_FMDT_00004)

[TPS_FMDT_00040] Description for a **FMFeature** [The attributes *introduction* and *desc* may be used to provide a human readable description for a **FMFeature**.](RS_FMDT_00004)

As outlined in [1], *introduction* and *desc* are intended to be used as follows:

- *introduction* [TPS_GST_00103] contains introductory documentation about how the feature may be used.

- *desc* [TPS_GST_00100] contains a brief description about what the feature is.

The attributes *shortName*, *longName*, *introduction* and *desc* are not visible in Figure 4.1, but stem from the fact that **FMFeature** is based on **ARElement**, which in turn is based on **Identifiable** and **Referrable**.
4.2.2 Intended Binding Time

The class `FMFeature` contains two optional attributes `minimumIntendedBindingTime` and `maximumIntendedBindingTime`, which define lower and upper bounds for the intended binding time (binding times are explained in the AUTOSAR Methodology[4]) of the variation points that are associated with the `FMFeature`.

[TPS_FMDT_00054] Semantics of attributes `minimumIntendedBindingTime` and `maximumIntendedBindingTime` [Let \( f \) be a `FMFeature` and \( V \) be the set of affected variation points of \( f \) as defined in [TPS_FMDT_00038]. Then the following conditions are implied for every variation point \( v \in V \):

1. If the attribute `minimumIntendedBindingTime` exists and has value \( \text{min} \), then \( \text{min} \leq \text{bindingtime}(v) \).
2. If the attribute `maximumIntendedBindingTime` exists and has value \( \text{max} \), then \( \text{bindingtime}(v) \leq \text{max} \).

](RS_FMDT_00002, RS_FMDT_00015)

[TPS_FMDT_00054] refers to the variation points that are associated with a `FMFeature`. This information is not available through a `FMFeatureModel`, but is defined in a `FMFeatureMap` (see Section 6). Hence, the attributes `minimumIntendedBindingTime` and `maximumIntendedBindingTime` can only be interpreted when a `FMFeatureMap` is also available.

[TPS_FMDT_00024] Attributes `maximumIntendedBindingTime` and `minimumIntendedBindingTime` are only a hint [The values of `maximumIntendedBindingTime` and `minimumIntendedBindingTime` are only meant as a hint for the development process to guide the selection of correct variability implementation.](RS_FMDT_00002)

4.3 Attributes of a Feature

Each `FMFeature` aggregates zero or more `FMAttributeDef` elements, each of which defines an attribute of a feature.

<table>
<thead>
<tr>
<th>Class</th>
<th><code>FMAttributeDef</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td><code>M2::AUTOSARTemplates::FeatureModelTemplate</code></td>
</tr>
<tr>
<td>Note</td>
<td>This metaclass represents the ability to define attributes for a feature.</td>
</tr>
<tr>
<td>Base</td>
<td><code>ARObject</code>, <code>Identifiable</code>, <code>MultilanguageReferable</code>, <code>Referable</code></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>defaultValue</td>
<td>Numerical</td>
<td>0..1</td>
<td>attr</td>
<td>This represents the default value of the attribute.</td>
</tr>
<tr>
<td>max</td>
<td>Limit</td>
<td>1</td>
<td>attr</td>
<td>Maximum possible value for the value of this attribute</td>
</tr>
<tr>
<td>min</td>
<td>Limit</td>
<td>1</td>
<td>attr</td>
<td>Minimum possible value for the value of this attribute</td>
</tr>
</tbody>
</table>

Table 4.3: `FMAttributeDef`
**4.4 Class FMFeatureDecomposition**

Each FMFeature aggregates one or more FMFeatureDecomposition elements. A FMFeatureDecomposition contains references to other features, and thus establishes a hierarchical organization of features. This hierarchy imposes certain restrictions on FMFeatures, for example declares some features as optional or mutually exclusive. It may also connect one FMFeatureModel to another FMFeatureModel by referring to its root feature.

<table>
<thead>
<tr>
<th>Class</th>
<th>FMFeatureDecomposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
<tr>
<td>Note</td>
<td>A FMFeatureDecomposition describes dependencies between a list of features and their parent feature (i.e., the FMFeature that aggregates the FMFeatureDecomposition). The kind of dependency is defined by the attribute category.</td>
</tr>
<tr>
<td>Base</td>
<td>ARObjec</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>category</td>
<td>CategoryString</td>
<td>1</td>
<td>attr</td>
<td>The category of a FMFeatureDecomposition defines the type of dependency that is defined by the FMFeature Decomposition. There are four different categories: MANDATORYFEATURE, OPTIONALFEATURE, ALTERNATIVEFEATURE, and MULTIPLEFEATURE.</td>
</tr>
<tr>
<td>feature</td>
<td>FMFeature</td>
<td>1..*</td>
<td>ref</td>
<td>The features that are affected by the dependency defined by the FMFeatureDecomposition.</td>
</tr>
<tr>
<td>max</td>
<td>PositiveInteger</td>
<td>0..1</td>
<td>attr</td>
<td>For a dependency of category MULTIPLEFEATURE, this defines the maximum number of features allowed.</td>
</tr>
<tr>
<td>min</td>
<td>PositiveInteger</td>
<td>0..1</td>
<td>attr</td>
<td>For a dependency of category MULTIPLEFEATURE, this defines the minimum number of features allowed.</td>
</tr>
</tbody>
</table>

Table 4.4: FMFeatureDecomposition
Purpose of `FMFeatureDecomposition`

Each `FMFeature` aggregates zero or more `FMFeatureDecomposition` elements in the role decomposition. `FMFeatureDecomposition` thus establishes a hierarchical organization of `FMFeatures`.

A `FMFeature` that has no `FMFeatureDecomposition` is a leaf in the feature tree.

### 4.4.1 Constraints and Terminology for `FMFeatureDecomposition`

**Definition of Parent Feature, Child Feature**

Let `f` be a `FMFeature` which aggregates a `FMFeatureDecomposition` that references a `FMFeature` `f'` in the role feature. Then `f` is the parent feature of `f'`, and `f'` is a child feature of `f`.

Each feature has at most one parent feature, but can have any number of child features, including zero. This is established by the fact that a feature model is organized as a tree, as determined by constraint `[constr_5021]` below.

**FMFeature shall not be referenced from more than one `FMFeatureDecomposition`**

Let `f` be a `FMFeature` that is referenced from a `FMFeatureDecomposition` in the role feature. Then no other `FMFeatureDecomposition` shall reference `f` in the role feature.

Constraint `[constr_5005]` makes sure that every `FMFeature` has at most one parent feature (the number of child features is not limited for obvious reasons). This paves the way for the following definition of the underlying graph of a `FMFeatureModel`, which is in fact an underlying tree.

**Definition of Underlying Graph of a `FMFeatureModel`**

Let `F` be a `FMFeatureModel` and `{f_1, f_2, ..., f_n}` be the set of `FMFeatures` that are referenced from `F` in the role feature.

Then the underlying graph of `F` is a graph `G = (V, E)` where

\[
V = \{f_1, f_2, ..., f_n\}
\]

and

\[
E = \{(f_i, f_j) \mid f_i \text{ is the parent feature of } f_j\}
\]

**The root feature of a `FMFeatureModel` refers to the root of the underlying tree.**

Let `F` be a `FMFeatureModel` and `G` be the underlying graph of `F` as defined in `[TPS_FMDT_00034]`. Then `G` shall be a tree. Hence, we also refer to `G` as the underlying tree of `F`.

**The root feature of a `FMFeatureModel` refers to the root of the underlying tree.**

Let `F` be a `FMFeatureModel` and `G` be the underlying tree of `F` as defined in `[TPS_FMDT_00034]`. Furthermore, let `r` be the `FMFeature` referred to by the root feature of the `FMFeatureModel`. 
Then the node in $G$ which corresponds to $r$ is the root of the tree $G$.}

### 4.4.2 Categories of Feature Decompositions

The attribute category of a `FMFeatureDecomposition` defines the semantics for the `FMFeatures` referenced in the role `feature`. We define four categories for `FMFeatureDecomposition`, namely `MANDATORYFEATURE`, `OPTIONALFEATURE`, `ALTERNATIVEFEATURE` and `MULTIPLEFEATURE`:

- **[TPS_FMDT_00015] MANDATORYFEATURE** [All `FMFeatures` referenced in the role `feature` from a `FMFeatureDecomposition` that has the category `MANDATORYFEATURE` shall be present in a feature selection if and only if its parent `FMFeature` is included in the feature selection.]

- **[TPS_FMDT_00016] OPTIONALFEATURE** [`FMFeatures` referenced in the role `feature` from a `FMFeatureDecomposition` that has the category `OPTIONALFEATURE` may be present in a feature selection if and only if its parent `FMFeature` is included in the feature selection.]

- **[TPS_FMDT_00017] ALTERNATIVEFEATURE** [Exactly one of the `FMFeatures` referenced in the role `feature` from a `FMFeatureDecomposition` that has the category `ALTERNATIVEFEATURE` shall be present in a feature selection if and only if its parent `FMFeature` is included in the feature selection.]

- **[TPS_FMDT_00018] MULTIPLEFEATURE** [One or more of the `FMFeatures` referenced in the role `feature` from a `FMFeatureDecomposition` that has the category `MULTIPLEFEATURE` shall be present in a feature selection if and only if its parent `FMFeature` is included in the feature selection. This is further constrained by the attributes `min` and `max` (see [TPS_FMDT_00012] and [constr_5013]).]

These definitions are formalized in [TPS_FMDT_00046].

**[TPS_FMDT_00046] Semantics of `FMFeatureDecomposition`** [Let $S$ be a set of `FMFeatures` and let $f, f_1, f_2, \ldots, f_n$ be `FMFeatures` where $f$ is the parent feature for $f_1, f_2, \ldots, f_n$. Furthermore, let $d$ be the `FMFeatureDecomposition` that is aggregated by $f$ in the role `decomposition` where $\{f_1, f_2, \ldots, f_n\}$ are all referenced from $d$ in the role `feature`.

Based on the category of the `FMFeatureDecomposition` $d$, the following conditions are defined:

**MANDATORYFEATURE**

$$f \in S \iff |\{f_1, f_2, \ldots, f_n\} \cap S| = n$$

**OPTIONALFEATURE**

$$f \in S \iff 0 \leq |\{f_1, f_2, \ldots, f_n\} \cap S| \leq n$$
ALTERNATIVEFEATURE

\[ f \in S \iff \left| \{ f_1, f_2, \ldots, f_n \} \cap S \right| = 1 \]

MULTIPLEFEATURE

\[ f \in S \iff \text{min} \leq \left| \{ f_1, f_2, \ldots, f_n \} \cap S \right| \leq \text{max} \]

\[ \text{(RS_FMDT_00006)} \]

Note that [TPS_FMDT_00046] does not require that the conditions are fulfilled. Only if \( S \) is a valid feature selection (see [TPS_FMDT_00030]), then all conditions have to be fulfilled. This is necessary because a feature selection may be incomplete, for example if features are selected in a step-by-step process where only the “final” feature selection fulfills all constraints.

4.4.3 Attributes \text{min} and \text{max}

If the optional attributes \text{min} and \text{max} are present, they restrict how many multiple features may be selected.

[TPS_FMDT_00012] Default values for attributes \text{min} and \text{max} of FMFeatureDecomposition [If \text{min} and \text{max} are missing, then the values 1 (for \text{min}) and \infty (for \text{max}) are assumed in [TPS_FMDT_00046].] (RS_FMDT_00007)

In other words, if \text{min} and \text{max} are not specified, then a valid feature selection shall contain at least one of the features, but there is no upper bound. Technically, \infty in [TPS_FMDT_00012] translates to the maximum number that can be represented by PositiveInteger.

[constr_5013] Attributes \text{min} and \text{max} of FMFeatureDecomposition reserved for category MULTIPLEFEATURE [The optional attributes \text{min} and \text{max} of FMFeatureDecomposition are only allowed to be present if the category of the FMFeatureDecomposition is MULTIPLEFEATURE.]

4.4.4 Hierarchical decomposition of Feature Models

There is a special case where FMFeatureDecomposition may reference a feature in another FMFeatureModel. This is useful for hierarchical decomposition of FMFeatureModels. However, this is only allowed if the referenced feature is the root feature.

[constr_5010] FMFeatureDecomposition may refer to a root feature of another feature model, but only once. [Let \( f_A \) be a FMFeature that is referenced by FMFeatureModel \( A \) in the role \text{feature}, but is also referenced from a FMFeatureDecomposition that is aggregated by a FMFeature \( f_B \) in the role \text{decomposition}.

Furthermore, let \( B \) be the FMFeatureModel that references \( f_B \) in the role \text{feature} with \( A \neq B \). That is, \( f_A \) and \( f_B \) belong to different feature models.
Then both the following conditions shall hold:

1. \( f_A \) is referenced from \( A \) in the role root.

2. There is no other \texttt{FMFeatureDecomposition} (neither in \( B \) nor in any other \texttt{FMFeatureModel}) that references \( f_B \) in the role feature.

The second condition in [\texttt{constr\_5010}] is necessary to make sure that the overall structure of the combined feature models is still a tree (see also [\texttt{TPS\_FMDT\_00034}] and [\texttt{constr\_5021}]).

### 4.4.5 Why use referencing for \texttt{FMFeature} instead of aggregation?

We could also have defined feature models such that \texttt{FMFeatureModel} aggregates a single \texttt{FMFeature} (the root feature), and \texttt{FMFeatureModel} then recursively aggregates other \texttt{FMFeatures}. With this approach, several of the constraints defined earlier in this section would have been unnecessary because this aggregation naturally forms a tree.

However, this approach would not work for the decomposition of feature models as described in Section 4.4.4. In this case, a \texttt{FMFeatureDecomposition} refers to the root of a different \texttt{FMFeatureModel}. This cannot easily be done by aggregation.

### 4.5 Class \texttt{FMFeatureRestriction}

The hierarchy established by \texttt{FMFeatureDecomposition} (see Section 4.4) covers many use cases for constraining the inclusion of a feature into a feature selection.

There are however circumstances where more elaborate constraints are necessary. \texttt{FMFeatureDecomposition} defines constraints for features which share the same parent features. For example, it may express that several features are alternatives within the context of their parent (typically, a “Car” either contains a “Diesel” or a “Gasoline” engine, but not both), but it cannot express that a \texttt{FMFeature} depends on another \texttt{FMFeature} across the tree, or contradicts a combination of two other features.

A \texttt{FMFeature} may aggregate a number of \texttt{FMFeatureRestriction} elements that further limit its inclusion in a feature selection. A \texttt{FMFeatureRestriction} aggregates a boolean\(^1\) expression in the role restriction which constrains whether a particular feature is allowed to become part of a \texttt{FMFeatureSelection}.

More precisely, a feature may only become part of a feature selection if \textit{at least one} of its restrictions evaluate to \texttt{true}. That is, all the restrictions are merged into a single boolean expression; the individual restrictions are combined by a \( \lor \) operator. For simplicity, there are no priorities among the restrictions.

\(\text{\^{1}I.e., its value is interpreted as a boolean value.}\)
**Class**| **FMFeatureRestriction**
---|---
**Package**| M2::AUTOSARTemplates::FeatureModelTemplate
**Note**| Defines restrictions for FMFeatures. A FMFeature can only be part of a FMFeatureSelectionSet if at least one of its restrictions evaluate to true.
**Base**| ARObject, Identifiable, MultilanguageReferrable, Referrable

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>restriction</td>
<td>FMConditionByFeaturesAndAttributes</td>
<td>1</td>
<td>aggr</td>
<td>A formula that contains the actual restriction.</td>
</tr>
</tbody>
</table>

### Table 4.5: FMFeatureRestriction

**[TPS_FMDT_00045]** Semantics of **FMFeatureRestriction**  
[Let $S$ be a feature selection for a FMFeatureModel, and $f$ be a FMFeature with a set of FMFeatureRestrictions $\{R_1, R_2, \ldots, R_n\}$. Let $\{C_1, C_2, \ldots, C_n\}$ be the FMFormulaByFeaturesAndAttributes elements that are aggregated by $R_i$ in the role restriction. Then the feature defines the following condition:

$$f \in S \Rightarrow C_1 = \text{true} \lor C_2 = \text{true} \lor \ldots \lor C_n = \text{true}$$

](RS_FMDT_00008)

Note that [TPS_FMDT_00045] only *defines* a condition, but does not require that the condition is fulfilled by the feature selection. Only a *valid feature selection* (see [TPS_FMDT_00030]) requires that the condition is fulfilled.

The condition stated in [TPS_FMDT_00045] works only in one direction. Even if all conditions are *true*, a specific feature may still be left out of a valid feature selection. On the contrary, if the feature is contained in a valid feature selection, at least one restriction has to be true. This is different from a FMFeatureRelation, which may force a feature to be part of a valid feature selection (see Section 4.6).

We do not impose further constraints on the restrictions that can be used with FMFeatureRestriction. This means that it is in the responsibility of the creator\(^2\) of the restriction to make sure that no circular dependencies or conflicts are introduced. For example, it is perfectly legal for a feature $f$ to have the restriction $\neq f$, although this may not very useful because the feature can never be selected.

### 4.5.1 Identifying and documenting **FMFeatureRestrictions**

Because FMFeatureRestriction is based on Identifiable, it may contain the optional attributes shortName, introduction, and desc.

**[TPS_FMDT_00062]** Identifying **FMFeatureRestrictions**  
[The attribute shortName can be used to distinguish relations in case a FMFeature aggregates several FMFeatureRestrictions.](RS_FMDT_00004)

\(^2\)The creator of the restriction can be one or more people, or even a tool.
4.5.2 Example

Consider a feature $f$ that has the following restriction:

$$f_1 \&\& f_2 \&\& f_3$$

This restriction defines that $f$ may only be part of a feature selection if $f_1$, $f_2$ and $f_3$ are also included in that feature selection. This cannot be expressed with a feature tree because $f$ would have to be a mandatory child of all three features, which is clearly a violation of the tree structure.

On the opposite side, it would be possible to define mandatory, optional, alternative and multiple features solely with restrictions. For example, the fact that features $f$ and $f'$ are mutually exclusive (that is, alternate features) could be expressed by assigning the restriction $\neg f'$ to $f$ and the restriction $\neg f$ to $f'$.

By extending this approach, it would be possible to replace the different categories defined for FMFeatureDecomposition in Section 4.4. We did not follow this direction because it would be easy to generate such restrictions from a decomposition, but it would be hard to translate them back into decompositions without proper annotation.

4.6 Class FMFeatureRelation

As we have seen in Section 4.5, a FMFeatureRestriction is a boolean expression that restricts whether a feature may be included in a feature selection or not. In this section, we define FMFeatureRelations, which work differently in that they impose requirements instead of restrictions.

For example, the relation $F_1$ requires $F_2$ states that the inclusion of feature $F_1$ in a feature selection requires that feature $F_2$ is also selected. Similarly, the relation $F_1$ excludes $F_2$ states that if feature $F_1$ is part of a feature selection then it is required that feature $F_2$ is not present.

Relations are implemented by the class FMFeatureRelation. A FMFeatureRelation refers to a number of FMFeatures in the role feature; these are the target features of the relation.
Class: FMFeatureRelation
Package: M2::AUTOSARTemplates::FeatureModelTemplate

Note: Defines relations for FMFeatures, for example dependencies on other FMFeatures, or conflicts with other FMFeatures. A FMFeature can only be part of a FMFeatureSelectionSet if all its relations are fulfilled.

Base: ARObjec, Identifiable, MultilanguageReferable, Referable

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>feature</td>
<td>FMFeature</td>
<td>1..*</td>
<td>ref</td>
<td>The FMFeature that is targeted by this FMFeature Relation.</td>
</tr>
<tr>
<td>restriction</td>
<td>FMConditionByFeatures</td>
<td>0..1</td>
<td>agr</td>
<td>If given, the condition shall evaluate to true, in order for the FMFeatureRelation to be active.</td>
</tr>
</tbody>
</table>

Table 4.6: FMFeatureRelation

[TPS_FMDT_00020] Structure of FMFeatureRelation [A FMFeatureRelation \( R \) establishes a binary relation between two features:

1. The FMFeature \( f \) which aggregates \( R \).
2. The FMFeature \( f' \) which \( R \) refers to in the role feature.

A FMFeatureRelation is always directed from \( f \) to \( f' \).

If \( R \) refers to features \( \{f_1, f_2, \ldots, f_n\} \) in the role feature, then \( R \) establishes \( n \) such binary relations.](RS_FMDT_00008)

The particular type of a relation is specified by its category attribute, which is covered in Section 4.6.1. We have defined a number of predefined relation types, which are listed in Section 4.6.3.

Obviously, a feature shall not establish a relation to itself.

[constr_5001] FMFeatureRelation shall not establish self-references [A FMFeatureRelation that is aggregated by a FMFeature \( f \) shall not reference \( f \) in the role feature. In other words: self-references are not allowed.](/)

[constr_5001] helps to avoid conflicting relations such as “\( f \) conflicts \( f \)”. Note that [constr_5001] cannot prevent all possible conflicts; for example a feature \( f \) might require a feature \( f' \) which in turn conflicts with \( f \). Since the category of a FMFeatureRelation is designed to be extensible (see [TPS_FMDT_00023]), it is not feasible to formulate constraints that cover all possible conflicts.

4.6.1 Attribute category

Because a FMFeatureRelation is an Identifiable, it has a category attribute.

[TPS_FMDT_00021] category attribute of FMFeatureRelation [The attribute category of a FMFeatureRelation specifies the kind of relation that is implemented here.](RS_FMDT_00008)

Section 4.6.3 presents an overview of all predefined relations.
[TPS_FMDT_00023] Extensibility of category attribute of FMFeatureRelation

The attribute category of FMFeatureRelation can be extended by proprietary relation types that go beyond those that are defined in this section. (RS_FMDT_00008)

For example, a company may define proprietary relations that are only used in-house (or shared with selected customers). It is obviously no longer possible to safely exchange such a model with everybody, but it is a valid use case for a limited audience.

4.6.2 Identifying and documenting FMFeatureRelations

Because FMFeatureRelation is based on Identifiable, it may contain the optional attributes shortName, introduction, and desc.

[TPS_FMDT_00052] Identifying FMFeatureRelations

The attribute shortName can be used to distinguish relations in case a FMFeature aggregates several FMFeatureRelations. (RS_FMDT_00004)

[TPS_FMDT_00061] Documenting FMFeatureRelations

The attributes introduction and desc may be used to provide a human readable description for a FMFeatureRelation. (RS_FMDT_00004)

4.6.3 Predefined Relations

[TPS_FMDT_00019] Predefined values for the category of FMFeatureRelation

In the following list, \( f \) is the feature that aggregates a FMFeatureRelation \( R \) in the role relation, and \( f_1, f_2, \ldots, f_n \) are the features that \( R \) refers to in the role feature.

REQUIRES \( f \) shall only be part of a feature selection if \( f_1, f_2, \ldots, f_n \) are also part of this feature selection.

EXCLUDES If \( f \) is part of a feature selection, then \( f_1, f_2, \ldots, f_n \) shall not be part of this feature selection.

RECOMMENDED_FOR If one or more of the referenced features are selected then it is recommended to also include this one.

DISCOURAGED_FOR Opposite of RECOMMENDED_FOR: it is not recommended to include this feature if one or more of the referenced features are selected.

IMPACTS Selecting this feature has impact on all of the referenced features. “Impacted by” means that if one or more of the referenced features are selected then this feature has impact on the selected referenced features.

FUNCTIONAL_DEPENDENT There is a functional dependency between this feature and the referenced features.
For the following relation, assume that \( \text{FMFeatures} \, f_1, f_2, \ldots, f_m \) is a set of features each of which aggregates a \( \text{FMFeatureRelation} \, R_i \) in the role \( \text{relation} \), and \( f_1, f_2, \ldots, f_n \) are the common\(^3\) features that all \( R_i \) refer to in the role \( \text{feature} \).

**PROVIDES** If \( f_1, f_2, \ldots, f_n \) are part of a feature selection, then at least one of \( f'_1, f'_2, \ldots, f'_m \) shall be part of this feature selection.

The details for \text{RECOMMENDED_FOR}, \text{DISCOURAGED_FOR}, \text{IMPACTS} and \text{FUNCTIONAL_DEPENDENT} shall be given in attributes \text{introduction} and \text{desc} because they cannot be formalized. For tools, this means that these relations give hints to the user making the configuration. In contrast, a corresponding restriction can be derived automatically for relations \text{REQUIRES} and \text{EXCLUDES}.

\[^{(RS_FMDT_00008)}\]

[TPS_FMDT_00044] **Semantics of \text{FMFeatureRelation}**  
Let \( S \) be a feature selection and \( f \) be a \text{FMFeature} with a \text{FMFeatureRelation} \( R \) that references \text{FMFeatures} \( f_1, f_2, \ldots, f_n \) in the role \( \text{feature} \). Then \( R \) defines the following conditions:

- **category** of \( R \) is \text{REQUIRES} 
  \[ \forall i \in \{1, \ldots, n\} : f \in S \Rightarrow f_i \in S \]

- **category** of \( R \) is \text{EXCLUDES} 
  \[ \forall i \in \{1, \ldots, n\} : f \in S \Rightarrow f_i \notin S \]

Next, \( S \) be a feature selection and \( f'_1, f'_2, \ldots, f'_m \) be \text{FMFeatures}, each of which aggregates a \text{FMFeatureRelation} \( R_i \) that references a set of features \text{FMFeatures} \( F_i \) in the role \( \text{feature} \). Assume that all \( R_i \) have the same **category**, and let \( \{f_1, f_2, \ldots, f_n\} = F_1 \cap F_2 \cap \ldots \cap F_m \) be the common features of all relations \( R_i \). Then \( R \) defines the following condition:

- **category** of \( R_i \) is \text{PROVIDES} 
  \[ \forall i \in \{1, \ldots, n\} : f_i \in S \Rightarrow \exists 1 \leq j \leq m : f'_j \in S \]

All other relations do not define formal relations. Instead, the attributes \text{introduction} and \text{desc} (which exist because \text{FMFeatureRelation} is based on \text{Identifiable}) may provide a human-readable description of the meaning of the restriction.

\[^{(RS_FMDT_00008)}\]

Note that a \text{FMFeatureRelation} just \textit{defines} a condition and does not demand that this condition is actually fulfilled. This is because a feature selection might be incomplete. Only in a \textit{valid feature selection} (see [TPS_FMDT_00030]) the conditions have to be obeyed.

\[^{3}\text{The individual } R_i \text{ may to refer to additional \text{FMFeatures}, but here we are only interested in the common subset.}\]
4.7 Hierarchy, Restrictions and Relations

In this chapter, we have defined three different ways to introduce relationships between features: the hierarchy (Section 4.4), restrictions (Section 4.5) and relations (Section 4.6):

1. The hierarchy (FMFeatureDecomposition) only affects features of the same category that have the same parent in the feature tree. That is, alternative features only depend on their parent and on siblings that are also alternative features, multiple features only depend on their parent and on siblings that are also multiple features, and optional and mandatory features only depend on their parent.

2. Features with restrictions (FMFeatureRestriction) depend on other features in the same feature model or even in another feature model. Unlike before, the relative position within the hierarchy does not play a role here.

   This is a more powerful approach than hierarchical dependencies, but restrictions need to be handled with more care than those defined by hierarchy. For example, it is easy to introduce circular dependencies or contradictions with restrictions.

3. Relations among features (FMFeatureRelation) may also introduce dependencies between features regardless of their position in the feature tree, but their scope is more limited.

   However, unlike in a restriction, where a feature depends on other features, a relation may influence other features. If feature A requires feature B, then a feature selection which includes A also has to include B.

---

4More precisely, FMFeature which are referenced from the same FMFeatureDecomposition in the role feature.
5 Feature Selection

A feature model does not describe a single product, but a set of products with common characteristics – a product line. An individual product is described by a specific combination of features. To be valid, such a combination of features needs to adhere to the various constrains defined in the feature model: hierarchical structure (Section 4.4), restrictions (Section 4.5), and relations (Section 4.6).

[TPS_FMDT_00060] Purpose of FMFeatureSelectionSet [In AUTOSAR, a set of features that describes a product is implemented by the class FMFeatureSelectionSet.](RS_FMDT_00003)

![Figure 5.1: Class FMFeatureSelectionSet](image-url)
5.1 Example

Table 5.1 shows an example for a feature selection.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Gasoline Engine</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Diesel Engine</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Engine Controller</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Gasoline Engine Controller</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Diesel Engine Controller</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Doors</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Two Doors</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Four Doors</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Convertible</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Sunroof</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Electric window lift</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Halogen lights</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 5.1: Sample Feature Selection

We are re-using the example feature model 1.1 from Section 1.3 here. In our example, two feature selections are defined: Sports Edition and Family Edition, which correspond to two different car models. Some features, for example the halogen lights, are available in both models, while others are different: then Sports Edition uses a gasoline engine, while the Family Edition uses a diesel engine.

So, in its basic form, a feature selection is simply a list of features that are included in a variant\(^1\), as indicated by the plus sign in example 5.1.

In our specification, we also allow variants to inherit from other variants. For example, all feature selections that are specific for a particular country (the famous “wheel on left/right side” distinction) may be contained in a separate feature model. A car model that is destined for a particular country can then simply include the country specific feature model.

5.2 Class FMFeatureSelection

A FMFeatureSelection represents a single FMFeature. The FMFeatureSelection has three attributes, state, minimumSelectedBindingTime and maximumSelectedBindingTime. The attribute state defines whether the feature is actually selected or not, or whether this is not yet decided. The attributes minimumSelectedBindingTime and maximumSelectedBindingTime define at which binding time the selection is supposed to happen.

\(^1\)In our example, there are only variants for models of complete cars. This is of course an oversimplification; in the real world, variants are much more fine granular. For example, there could be country specific variants of Sports Edition or Family Edition.
**Class**

FMFeatureSelection

**Package**

M2::AUTOSARTemplates::FeatureModelTemplate

**Note**

A FMFeatureSelection represents the state of a particular FMFeature within a FMFeatureSelectionSet.

**Base**

ARObject, Identifiable, MultilanguageReferrable, Referrable

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>attributeValue</td>
<td>FMAttributeValue</td>
<td>*</td>
<td>aggr</td>
<td>This defines a value for the attribute that is referred to in the role definition. Note that a FMFeatureSelection cannot include two FMAttributeValues that refer to the same FMAttributeDef in the role definition.</td>
</tr>
<tr>
<td>feature</td>
<td>FMFeature</td>
<td>1</td>
<td>ref</td>
<td>The FMFeature whose state is defined by this FMFeature Selection.</td>
</tr>
<tr>
<td>maximum SelectedBinding Time</td>
<td>BindingTimeEnum</td>
<td>0..1</td>
<td>attr</td>
<td>Defines an upper bound for the binding time of the variation points that are associated with the FMFeature, and refines its maximumIntendedBindingTime. This attribute is meant as a hint for the development process.</td>
</tr>
<tr>
<td>minimum SelectedBinding Time</td>
<td>BindingTimeEnum</td>
<td>0..1</td>
<td>attr</td>
<td>Defines a lower bound for the binding time of the variation points that are associated with the FMFeature, and refines its minimumIntendedBindingTime. This attribute is meant as a hint for the development process.</td>
</tr>
<tr>
<td>state</td>
<td>FMFeatureSelection State</td>
<td>1</td>
<td>attr</td>
<td>Defines how the FMFeature that is described by this FMFeatureSelection contributes to the FMFeature SelectionSet. A FMFeature may have the state selected, deselected or undecided.</td>
</tr>
</tbody>
</table>

**Table 5.2: FMFeatureSelection**

5.2.1 **Reference feature**

The reference feature points to the feature that is described by this FMFeatureSelection.

5.2.2 **Attribute state**

FMFeatureSelection has an attribute state that defines how the feature referred to by feature contributes to the selection.
### FMFeatureSelectionState

<table>
<thead>
<tr>
<th>Enumeration</th>
<th>Description</th>
<th>Tags</th>
</tr>
</thead>
<tbody>
<tr>
<td>deselected</td>
<td>The feature is excluded from the selection.</td>
<td>atp.EnumerationLiteralIndex=0</td>
</tr>
<tr>
<td>selected</td>
<td>The feature is included in the selection.</td>
<td>atp.EnumerationLiteralIndex=1</td>
</tr>
<tr>
<td>undecided</td>
<td>It is not yet decided whether the feature shall be included into or excluded from the selection.</td>
<td>atp.EnumerationLiteralIndex=2</td>
</tr>
</tbody>
</table>

The value **undecided** needs further explanation. In a **FMFeatureSelectionSet** $F$ that is not included by another **FMFeatureSelectionSet**, the value **undecided** is not useful – in this case, a **FMFeature** should either have the **state selected** or **deselected** (or the **FMFeatureSelection** should be entirely missing).

However, if there is a **FMFeatureSelectionSet** $F'$ that includes $F$, then it may be useful to set the value of **state** of a particular feature **FMFeature** $f$ in $F'$, and not in $F$. This cannot be done if $f$ already has a **state** in $F'$ that is it is either **selected** or **deselected**. Hence, there is the need for a third value for **state** that can be overridden: **undecided**. For a more detailed explanation, see Section 5.4.

In example 5.1, ‘+’ corresponds to the state **selected**, and ‘−’ corresponds to the state **deselected**. There are no **undecided** features because the example has deliberately been kept simple and does not use feature selections that include other feature selections.

### FMAttributeValue

Each **FMFeatureSelection** aggregates a **FMAttributeValue** in the role **attributeValue**. This defines the value for a particular attribute of a feature in the context of this **FMFeatureSelection**.

<table>
<thead>
<tr>
<th>Class</th>
<th>FMAttributeValue</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
<td></td>
</tr>
<tr>
<td>Note</td>
<td>This defines a value for the attribute that is referred to in the role definition.</td>
<td></td>
</tr>
<tr>
<td>Base</td>
<td>AObject</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>definition</td>
<td>FMAttributeDef</td>
<td>1</td>
<td>ref</td>
<td>This refers to the definition of this attribute.</td>
</tr>
<tr>
<td>value</td>
<td>Numerical</td>
<td>1</td>
<td>attr</td>
<td>This represents the value of this attribute.</td>
</tr>
</tbody>
</table>

Stereotypes: atpIdentityContributor
Semantics of `FMAttributeValue` - A `FMAttributeValue` defines a value for the `FMAttributeDef` that is referenced in the role definition. The particular value is stored in the attribute `value`.

Semantics of attributes `max` and `min` of `FMAttributeDef` in class `FMAttributeValue` - Let `v` be the attribute value of an `FMAttributeValue` `V` that refers to `FMAttributeDef` `D` in the role definition. Furthermore, let `min` and `max` be the values of the attributes `min` and `max` of `D`.

The following condition shall hold true:

\[
min \leq v \leq max
\]

Obviously, we do not want two `FMAttributeValue`s that refer to the same `FMAttributeDef`. Otherwise, it would not be clear which value to choose.

**5.2.3.1 Example**

A feature may define an attribute named "pc" that specifies the power consumption for this feature, and whose values need to lie between 0 and 1000 milliwatt. In this case, the feature defines a `FMAttributeDef` where attribute `min` has the value 0, and `max` has the value 1000.

Furthermore, assume that `FMFeature f` has child features `f_1`, `f_2`, `f_3`, and `f_4` that are all optional. All these features define an attribute named "pc". Then `f` could add a `FMFeatureRestriction` to make sure that the power consumption of its child features does not exceed the power consumption allocated for `f`:

\[
f_1.pc + f_2.pc + f_3.pc + f_4.pc < f.pc
\]

This can be useful if not every combination of `f_1`, `f_2`, `f_3`, and `f_4` adheres to the allocated power consumption for `f`.

Furthermore, assume that the allowed power consumption of `f` depends on the car type. In this case, the `FMFeatureSelection` that refers `f` in the role feature
may define a FMAttributeValue that overrides the default value given in f’s FMAttributeDef.

5.2.4 Selected Binding Time

[TPS_FMDT_00055] Semantics of minimumSelectedBindingTime and maximumSelectedBindingTime [These two attributes refine the attributes minimumIntendedBindingTime and minimumIntendedBindingTime that are defined at the FMFeature to which the FMFeatureSelection refers to in the role feature.] (RS_FMDT_00002, RS_FMDT_00016)

[TPS_FMDT_00056] minimumSelectedBindingTime and maximumSelectedBindingTime are only hints [The attributes minimumSelectedBindingTime and maximumSelectedBindingTime are only meant as hints for the development process to guide the selection of correct variability implementation.] (RS_FMDT_00002)

5.3 Class FMFeatureSelectionSet

A FMFeatureSelectionSet aggregates an arbitrary number of FMFeatureSelection elements in the role of selection. Each FMFeatureSelection corresponds to a particular feature in a feature model, and states whether this feature is included into the selection or not.

<table>
<thead>
<tr>
<th>Class</th>
<th>FMFeatureSelectionSet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
<tr>
<td>Note</td>
<td>A FMFeatureSelectionSet is a set of FMFeatures that describes a specific product.</td>
</tr>
<tr>
<td></td>
<td>Tags: atp.recommendedPackage=FMFeatureModelSelectionSets</td>
</tr>
<tr>
<td>Base</td>
<td>ARElement, ARObject, CollectableElement, Identifiable, MultilanguageReferrable, Packageable, Element, Referrable</td>
</tr>
<tr>
<td>Attribute</td>
<td>Type</td>
</tr>
<tr>
<td>featureModel</td>
<td>FMFeatureModel</td>
</tr>
<tr>
<td>include</td>
<td>FMFeatureSelectionSet</td>
</tr>
<tr>
<td>selection</td>
<td>FMFeatureSelection</td>
</tr>
</tbody>
</table>

Table 5.5: FMFeatureSelectionSet

5.3.1 Terminology and constraints

FMFeatureSelectionSet aggregates its FMFeatureSelections, so it is not possible that a particular FMFeatureSelection is contained twice in a FMFeatureSelectionSet. However, two or more FMFeatureSelections could refer to the same
FMFeature in the role feature, which could introduce ambiguities if the state of the FMFeatureSelections is different. Hence, we do not allow this.

[constr_5018] FMFeatureSelectionSet shall not include the same feature twice [Let \{s_1, s_2, \ldots, s_n\} be the set of FMFeatureSelection elements that are aggregated by a FMFeatureSelectionSet in the role selection. Furthermore, for each s_i, let f_i be the FMFeature that is referred to in the role feature. Then the following condition shall hold true:

\[ \forall i, j \in \{1, 2, \ldots, n\} : i \neq j \Rightarrow f_i \neq f_j \]

Constraint [constr_5018] makes sure that a FMFeatureSelectionSet assigns a unique state to each FMFeature in its associated FMFeatureModel.

[TPS_FMDT_00009] Definition of Feature Set of a FMFeatureSelectionSet [Let S be a FMFeatureSelectionSet and \{s_1, s_2, \ldots, s_n\} be the set of FMFeatureSelections aggregated by S in the role selection. Then the feature set of S is the set of FMFeatures \{f_1, f_2, \ldots, f_n\} where s_i refers to f_i in the role feature.]

[constr_5018] makes sure that if a FMFeatureSelectionSet aggregates n FMFeatureSelections, then its feature set also has the size n. However, a FMFeatureSelectionSet does not need to enumerate all FMFeatures of the associated FMFeatureModel. Nevertheless, all FMFeatures need to come from the same FMFeatureModel, as outlined in [constr_5023]:

[constr_5023] FMFeatureSelectionSet may only refer to FMFeatures from the associated FMFeatureModel [Let S be a FMFeatureSelectionSet, and \{f_1, f_2, \ldots, f_n\} be its feature set ([TPS_FMDT_00009]). Furthermore, let \{g_1, g_2, \ldots, g_m\} be the combined feature sets of the FMFeatureModels to which S refers to in the role featureModel. Then the following condition shall hold: \{f_1, f_2, \ldots, f_n\} \subseteq \{g_1, g_2, \ldots, g_m\].

Note that if a FMFeature f is missing from a FMFeatureSelectionSet S, its state is not automatically equivalent to deselected. This would only be the case if S does not include another FMFeatureSelectionSet and is not included in another FMFeatureSelectionSet (see also 5.4).

5.3.2 Relation include

A FMFeatureSelectionSet may refer to other FMFeatureSelectionSets in the role include. If FMFeatureSelectionSet A includes FMFeatureSelectionSet B, then the total features selected by A is the sum of the features selected by A and the features selected by B.
[constr_5024] **FMFeatureSelectionSet shall not include itself**  [Let $S$ be a FMFeatureSelectionSet and let $S'$ be the FMFeatureSelectionSet to which $S$ refers to in the role include. Then the following condition shall hold: $S \neq S'$.]

Next, we define a graph structure that describes the include relations among FMFeatureSelectionSets:

[TPS_FMDT_00032] **Inclusion graph for FMFeatureSelectionSets**  [Let \{S_1, S_2, \ldots, S_n\} be the set of all FMFeatureSelectionSets in an AUTOSAR model. Then the inclusion graph for all FMFeatureSelectionSets is a graph $G = (V, E)$ where

$$V = \{S_1, S_2, \ldots, S_n\}$$

$$E = \{(S_i, S_j) \mid S_i \text{ refers to } S_j \text{ in the role include }\}$$

](RS_FMDT_00003)

Obviously, the inclusion graph for an AUTOSAR model is allowed to contain isolated nodes – FMFeatureSelectionSets that stand on their own and do not include other FMFeatureSelectionSet or are included elsewhere.

[constr_5024] can also be described in terms of the inclusion graph: the inclusion graph does not allow self loops. With the next constraint, we generalize this constraint and disallow cycles in the include relations:

[constr_5002] **FMFeatureSelectionSet shall not have cycles in the include relation**  [Let $S$ be a FMFeatureSelectionSet and let $G$ be the inclusion graph for all FMFeatureSelectionSets as defined in [TPS_FMDT_00032]. There shall be no cycles in the inclusion graph.]

5.4 **state and include**

Consider the following situation. FMFeatureSelectionSets $S$, $S_1$ and $S_2$ include FMFeatureSelections that refer to the same FMFeature $f$. Let $s$, $s_1$ and $s_2$ be the value of the attribute state of the FMFeatureSelection that refers to $f$ in $S$, $S_1$ and $S_2$, respectively.

Two questions arise from that:

1. If $S$ includes $S_1$, which values may $s$ assume?
2. If $S$ includes $S_1$ and $S_2$, which combination of values for $s_1$ and $s_2$ are allowed and which values may $s$ assume?

In case 1, $s$ should never override $s_1$. That is, if $s_1$ is already selected, then $s$ cannot be deselected, but it may be undecided. Vice versa, if $s_1$ is already deselected,
then $s$ cannot be selected, but it may be undecided. Finally, if $s_1$ is undecided, then $s$ may assume any value.

[constr_5003] **FMFeatureSelectionSet** shall not overwrite the state of included features [Let $S$ be a FMFeatureSelectionSet that aggregates a FMFeatureSelection that has the state $s$ and which refers to a FMFeature $f$ in the role feature. Furthermore, let $S_1$ be a FMFeatureSelectionSet that aggregates a FMFeatureSelection that has the state $s_1$ and refers to the same FMFeature $f$ in the role feature. Finally assume that $S$ refers to $S_1$ in the role include. Then the following conditions shall hold:

1. If the value of the attribute state of $s_1$ is undecided, then the value of the attribute state of $s$ may be one of selected, deselected, and undecided.

2. If the value of the attribute state of $s_1$ is selected or deselected, then the value of the attribute state of $s$ shall be the same as the attribute state in $s_1$, or undecided.

3. Any other constellation is considered an error.

<table>
<thead>
<tr>
<th>$s$ (state in $S$)</th>
<th>$s_1$ (state in $S_1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>valid</td>
<td>selected</td>
</tr>
<tr>
<td>valid</td>
<td>selected</td>
</tr>
<tr>
<td>valid</td>
<td>undeclared</td>
</tr>
<tr>
<td>invalid</td>
<td>selected</td>
</tr>
<tr>
<td>invalid</td>
<td>deselected</td>
</tr>
<tr>
<td>valid</td>
<td>deselected</td>
</tr>
<tr>
<td>valid</td>
<td>deselected</td>
</tr>
<tr>
<td>valid</td>
<td>deselected</td>
</tr>
<tr>
<td>valid</td>
<td>deselected</td>
</tr>
<tr>
<td>valid</td>
<td>deselected</td>
</tr>
<tr>
<td>valid</td>
<td>undecided</td>
</tr>
<tr>
<td>valid</td>
<td>selected</td>
</tr>
<tr>
<td>valid</td>
<td>deselected</td>
</tr>
<tr>
<td>valid</td>
<td>undecied</td>
</tr>
<tr>
<td>valid</td>
<td>selected</td>
</tr>
<tr>
<td>valid</td>
<td>deselected</td>
</tr>
<tr>
<td>valid</td>
<td>undecied</td>
</tr>
</tbody>
</table>

Table 5.6: Summary: **FMFeatureSelectionSet** $S$ includes $S_1$.

The behavior is summarized in Table 5.6. Some combinations are labeled as invalid; these are the cases where the state of a feature that is already selected or deselected would be overwritten with a different value.

In case 2, the difference is that there is not just a $s_1$, but also a $s_2$. So, we need to make sure that $s_1$ and $s_2$ do not make contradictory statements about $f$. That is, it should not happen that $s_1$ is selected and $s_2$ is deselected, or vice versa. Again, an undecided in $s_1$ or $s_2$ is uncritical.

[constr_5025] **FMFeatureSelectionSet** shall not overwrite the state of included features [Let $S$ be a FMFeatureSelectionSet that aggregates a FMFeatureSelection that has the state $s$ and which refers to a FMFeature $f$ in the role feature. Furthermore, let $S_1$ ($S_2$) be a FMFeatureSelectionSet that aggregates a FMFeatureSelection that has the state $s_1$ ($s_2$) and refers to the same FMFeature $f$ in the role feature. Finally assume that $S$ refers to $S_1$ and $S_2$ in the role include.
Then the following conditions shall hold:

1. If the values of the attributes `state` of \( s_1 \) and \( s_2 \) are both undecided, then the value of the attribute `state` of \( s \) may be selected, deselected or undecided.

2. If the value of the attribute `state` of \( s_1 \) is undecided and the value of the attribute `state` of \( s_2 \) is selected or deselected, then the value of the attribute `state` of \( s \) shall be the same as the attribute `state` in \( s_2 \), or undecided.

3. If the value of the attribute `state` of \( s_2 \) is undecided and the value of the attribute `state` of \( s_1 \) is selected or deselected, then the value of the attribute `state` of \( s \) shall be the same as the attribute `state` in \( s_1 \), or undecided.

4. If the values of the attributes `state` of \( s_1 \) and \( s_2 \) are both either selected or deselected, then the value of the attribute `state` of \( s \) shall be the same as in attribute \( s_1 \), or undecided.

5. Any other constellation is considered an error.

This behavior is summarized in Table 5.7.

<table>
<thead>
<tr>
<th>( s ) (state in ( S ))</th>
<th>( s_1 ) (state in ( S_1 ))</th>
<th>( s_2 ) (state in ( S_2 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>valid selected</td>
<td>selected</td>
<td>selected</td>
</tr>
<tr>
<td>invalid selected</td>
<td>selected</td>
<td>deselected</td>
</tr>
<tr>
<td>valid selected</td>
<td>selected</td>
<td>undecided</td>
</tr>
<tr>
<td>invalid selected</td>
<td>deselected</td>
<td>selected</td>
</tr>
<tr>
<td>invalid selected</td>
<td>deselected</td>
<td>deselected</td>
</tr>
<tr>
<td>valid selected</td>
<td>undecided</td>
<td>selected</td>
</tr>
<tr>
<td>invalid selected</td>
<td>selected</td>
<td>deselected</td>
</tr>
<tr>
<td>invalid selected</td>
<td>deselected</td>
<td>deselected</td>
</tr>
<tr>
<td>valid deselected</td>
<td>deselected</td>
<td>deselected</td>
</tr>
<tr>
<td>invalid deselected</td>
<td>selected</td>
<td>selected</td>
</tr>
<tr>
<td>valid deselected</td>
<td>deselected</td>
<td>undecided</td>
</tr>
<tr>
<td>invalid deselected</td>
<td>selected</td>
<td>deselected</td>
</tr>
<tr>
<td>valid deselected</td>
<td>undecided</td>
<td>deselected</td>
</tr>
<tr>
<td>invalid deselected</td>
<td>selected</td>
<td>deselected</td>
</tr>
<tr>
<td>valid deselected</td>
<td>deselected</td>
<td>undecided</td>
</tr>
<tr>
<td>invalid deselected</td>
<td>selected</td>
<td>deselected</td>
</tr>
<tr>
<td>valid deselected</td>
<td>undecided</td>
<td>deselected</td>
</tr>
<tr>
<td>invalid deselected</td>
<td>selected</td>
<td>deselected</td>
</tr>
</tbody>
</table>

Table 5.7: Summary: `FMFeatureSelectionSet` \( S \) includes \( S_1 \) and \( S_2 \).
5.5 Valid Feature Selection

[TPS_FMDT_00030] Definition of **Valid Feature Selection** [Let \( S \) be a FMFeature-SelectionSet and \( F \) be the feature set of \( S \). \( S \) is a valid feature selection if all the following constraints are obeyed:

- [TPS_FMDT_00046] (Semantics of FMFeatureDecomposition)
- [TPS_FMDT_00045] (Semantics of FMFeatureRestriction)
- [TPS_FMDT_00044] (Semantics of FMFeatureRelation)

\((RS_FMDT_00003, RS_FMDT_00005, RS_FMDT_00008)\)
6 Feature Map

In AUTOSAR variant handling, variation points are controlled by system constants. Each variation point contains a boolean expression\(^1\) which determines whether this variation point is “on” or “off”. The AUTOSAR formula language allows references to SwSystemconsts as operands (see [TPS_GST_00001]). This is the same type of expressions that are used to model restrictions for FMFeatures, except that those are based on references to other FMFeatures in place of references to SwSystemconsts.

So, in order to associate features with variation points, we need a data structure that assigns values to SwSystemconsts based on which features are selected. This is implemented by the class FMFeatureMap.

6.1 Example

In example 1.1, we introduced an optional feature “Four Doors” which adds two more doors to the car model. Example 6.1 shows a small clipping of the XML representation for a car model which contains two SwComponentPrototypes named LeftDoorController and RightDoorController that are subject to variation.

Listing 6.1: Sample variation points LeftDoorController and RightDoorController

```xml
<SW-COMPONENT-PROTOTYPE>
  <SHORT-NAME>LeftDoorController</SHORT-NAME>
  <TYPE-TREF DEST="APPLICATION-SW-COMPONENT-TYPE">
    DoorController
  </TYPE-TREF>
  <VARIATION-POINT>
    <SHORT-LABEL>Left</SHORT-LABEL>
    <SW-SYSCOND BINDING-TIME="SYSTEM-DESIGN-TIME">
      <SYSC-REF DEST="SW-SYSTEMCONST">HAS_LEFT_DOOR_CNTL</SYSC-REF> == 1
    </SW-SYSCOND>
  </VARIATION-POINT>
</SW-COMPONENT-PROTOTYPE>

<SW-COMPONENT-PROTOTYPE>
  <SHORT-NAME>RightDoorController</SHORT-NAME>
  <TYPE-TREF DEST="APPLICATION-SW-COMPONENT-TYPE">
    DoorController
  </TYPE-TREF>
  <VARIATION-POINT>
    <SHORT-LABEL>Right</SHORT-LABEL>
    <SW-SYSCOND BINDING-TIME="SYSTEM-DESIGN-TIME">
      <SYSC-REF DEST="SW-SYSTEMCONST">HAS_RIGHT_DOOR_CNTL</SYSC-REF> == 1
    </SW-SYSCOND>
  </VARIATION-POINT>
</SW-COMPONENT-PROTOTYPE>
```

\(^1\)We are simplifying here a bit; this is strictly true only for non-PostBuild variation points. PostBuild variation points do not use expressions, but compare the value of a system constant to a particular PostBuildVariantCondition.
The conditions for the variation points are in lines 9 and 21. In these conditions, we refer to system constants `HAS_LEFT_DOOR_CNTLR` and `HAS_RIGHT_DOOR_CNTLR` and check whether they have the value 1.

Assume we have a `FMFeatureSelectionSet` which contains a `FMFeatureSelection` that refers to the feature named “Four Doors” and has the state selected (see Section 5.2.2). Then we need to make sure that the value 1 gets assigned to both the system constants `HAS_LEFT_DOOR_CNTLR` and `HAS_RIGHT_DOOR_CNTLR`. In a pseudo programming language notion, this would look as follows:

```plaintext
if has_feature('Four Doors') == 1 then
    set_sysc('HAS_LEFT_DOOR_CNTLR', 1)
    set_sysc('HAS_RIGHT_DOOR_CNTLR', 1)
end
```

This shows that a feature can affect more than one system constant.

To extend our example further, let's assume that there is a constraint that prevents the controllers in this example to be used in non-european countries. (This could also be added as a restriction to the feature model, but such technical constraints are sometimes handled as part of the mapping.) Instead, an alternate controller is used in these countries. We need to extend the above pseudo code accordingly:

```plaintext
if has_feature('Four Doors') == 1 && has_feature('EuropeanCountry') == 1 then
    set_sysc('HAS_LEFT_DOOR_CNTLR', 0)
    set_sysc('HAS_RIGHT_DOOR_CNTLR', 0)
end
if has_feature('Four Doors') == 1 && has_feature('EuropeanCountry') == 0 then
    set_sysc('HAS_ALTERNATE_LEFT_DOOR_CNTLR', 1)
    set_sysc('HAS_ALTERNATE_RIGHT_DOOR_CNTLR', 1)
end
```

Now, we have two sets of assignments to system constants as well as complex conditions.
6.2 Overview

A `FMFeatureMap` aggregates a number of `FMFeatureMapElement`:

- In the simplest case, a `FMFeatureMapElement` chooses a value for a system constant if a certain feature is selected or deselected.

- In the general case, a `FMFeatureMapElement` chooses values for a set of system constants and postbuild variant criteria if a certain combination of features is selected.

We use the term “chooses” instead of “assigns” in the previous paragraph because an assignment would imply that a system constant behaves like a variable in a typical programming language that can be declared, perhaps initialized and later assigned a value.

This is not the case here. First, AUTOSAR does not have a concept akin to “assign a value later”. System constants can only be declared and initialized, but not changed afterwards. Second, feature models are optional, so all systems constants need to be declared and initialized in the non-optional part of the AUTOSAR model, which does not (and cannot) know about feature models.
6.3 Class **FMFeatureMap**

A **FMFeatureMap** aggregates a number of **FMFeatureMapElements** in the role mapping.

<table>
<thead>
<tr>
<th>Class</th>
<th>FMFeatureMap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
</tbody>
</table>

**Note**
A **FMFeatureMap** associates **FMFeatures** with variation points in the AUTOSAR model. To do this, it defines value sets for system constants and postbuild variant criterions that shall be chosen whenever a certain combination of features (and system constants) is encountered.

**Tags:** atp.recommendedPackage=FMFeatureMaps

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>mapping</td>
<td>FMFeatureMapElement</td>
<td>*</td>
<td>aggr</td>
<td>Set of mappings defined by this <strong>FMFeatureMap</strong>.</td>
</tr>
</tbody>
</table>

**Table 6.1: FMFeatureMap**

6.4 Class **FMFeatureMapElement**

<table>
<thead>
<tr>
<th>Class</th>
<th>FMFeatureMapElement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
</tbody>
</table>

**Note**
Defines value sets for system constants and postbuild variant criterions that shall be chosen whenever a certain combination of features (and system constants) is encountered.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>assertion</td>
<td>FMFeatureMap Assertion</td>
<td>*</td>
<td>aggr</td>
<td>Defines a boolean expression based on features and system constants which needs to evaluate to true for this mapping to become active.</td>
</tr>
<tr>
<td>condition</td>
<td>FMFeatureMap Condition</td>
<td>*</td>
<td>aggr</td>
<td>Defines a condition which needs to be fulfilled for this mapping to become active.</td>
</tr>
<tr>
<td>postBuildVariant</td>
<td>CriterionValueSet</td>
<td>*</td>
<td>ref</td>
<td>Selects a set of values for postbuild variant criterions.</td>
</tr>
<tr>
<td>sw Systemconstant</td>
<td>ValueSet</td>
<td>*</td>
<td>ref</td>
<td>Selects a set of values for system constants.</td>
</tr>
</tbody>
</table>

**Table 6.2: FMFeatureMapElement**

Each **FMFeatureMapElement** contains two kinds of assertions:

- A number of **FMFeatureMapConditions** in the role **condition**.
  A **FMFeatureMapCondition** aggregates a boolean expression of class **FMFormulaByFeaturesAndAttributes** in the role **fmCond** (see Section 7.2.1). This is the same kind of expression that is used by **FMFeature** to implement **FMFeatureRestrictions**. In fact, it serves a very similar purpose: the **FMFeatureMapElement** is only active if at least one of its **FMFeatureMapConditions** evaluates to **true**.

- A number of **FMFeatureMapAssertions** in the role **assertion**.
An `FMFeatureMapAssertion` aggregates a boolean expression `FMConditionByFeaturesAndSwSystemconsts` in the role `fmSyscond` (see Section 7.2.4). The `FMFeatureMapElement` is only active if all its `FMFeatureMapAssertions` (more precisely, the formulas aggregated in the role `fmSyscond`) evaluate to `true`.

Both `FMFeatureMapCondition` and `FMFeatureMapAssertion` are Identifiables, which means that each of them has a `shortName` attribute that can be used to identify individual conditions and assertions, as well as `desc` and `introduction` for documentation purposes.

There are also two elements that choose values for system constants resp. values for postbuild variant criteria:

- A number of `SwSystemconstantValueSet` that are referenced in the role `swSystemconstantValueSet`.
- A number of `PostBuildVariantCriterionValueSets` that are referenced in the role `postBuildVariantCriterionValueSet`.

The rationale for using choosing values for more than one system constant or postbuild variant criterion per feature is that features are a more high-level concept than variation points. For example, a feature that switches between two different software components (such as a “basic” and a “comfort” variant) actually triggers several variation points: not just the software components change, but also their ports and their connectors. Unless all variation points depend on the same system constant, this means that we need to choose values for several system constants.

### 6.5 Relationship with PredefinedVariant

The classes `SwSystemconstantValueSet` and `PostBuildVariantCriterionValueSet` are originally part of the `PredefinedVariant` structure from variant handling ([1]). A `PredefinedVariant` represents a particular variant as a given combination of settings of variant selectors represented by `SwSystemconstValue` respectively `PostBuildVariantCriterionValue` ([TPS_GST_00280]).

A `PredefinedVariant` can be seen as a list of `SwSystemconstantValueSets` and `PostBuildVariantCriterionValueSets`. This is very similar to a mapping that has no conditions and no assertions.

Indeed, we could have used a reference to a `PredefinedVariant` instead of references to `SwSystemconstantValueSets` and `PostBuildVariantCriterionValueSets`. However, `PredefinedVariants` usually have a much coarser granularity than what is needed in a `FMFeatureMapElement`. So, instead of requiring to adapt the granularity of `PredefinedVariants`, we refer to individual `SwSystemconstantValueSets` and `PostBuildVariantCriterionValueSets`. Usually, these will be a subset of the same `PredefinedVariant`. 
A typical way to construct a \texttt{FMFeatureMapElement} is to look at the corresponding \texttt{PredefinedVariant} and then select those \texttt{SwSystemconstantValueSets} and \texttt{PostBuildVariantCriterionValueSets} that are relevant for the given mapping.

### 6.6 So, how does it work?

\textbf{[TPS\_FMDT\_00037]} Semantics of \texttt{FMFeatureMapElement}. Let $M$ be a \texttt{FMFeatureMapElement}. If the following expressions evaluate to \textit{true}:

1. At least one of the \texttt{FMFeatureMapCondition} elements that are referenced from $M$ in the role \texttt{condition}

2. All \texttt{FMFeatureMapAssertion}s that are referenced from $M$ in the role \texttt{assertion}

then a processor shall use the \texttt{SwSystemconstantValueSets} which are referenced from $M$ in the role \texttt{swSystemconstantValueSet} as well as the \texttt{PostBuildVariantCriterionValueSets} which are referenced from $M$ in the role \texttt{postBuildVariantCriterionValueSet} to choose values for the associated \texttt{SwSystemconst}s respectively \texttt{PostBuildVariantCriterion}s.\textbf{[RS\_FMDT\_00010]}

<table>
<thead>
<tr>
<th>Class</th>
<th>FMFeatureMapCondition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
<tr>
<td>Note</td>
<td>Defines a condition which needs to be fulfilled for this mapping to become active. The condition is implemented as formula that is based on features and attributes and is defined by fmCond.</td>
</tr>
<tr>
<td>Base</td>
<td>ARObject, Identifiable, MultilanguageReferrable, Referrable</td>
</tr>
<tr>
<td>Attribute</td>
<td>Type</td>
</tr>
<tr>
<td>fmCond</td>
<td>FMConditionByFeatures AndAttributes</td>
</tr>
</tbody>
</table>

\textbf{Table 6.3: FMFeatureMapCondition}

<table>
<thead>
<tr>
<th>Class</th>
<th>FMFeatureMapAssertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
<tr>
<td>Note</td>
<td>Defines a boolean expression which shall evaluate to true for this mapping to become active. The expression is a formula that is based on features and system constants, and is defined by fmSyscond.</td>
</tr>
<tr>
<td>Base</td>
<td>ARObject, Identifiable, MultilanguageReferrable, Referrable</td>
</tr>
<tr>
<td>Attribute</td>
<td>Type</td>
</tr>
<tr>
<td>fmSyscond</td>
<td>FMConditionByFeatures AndSwSystemconsts</td>
</tr>
</tbody>
</table>

\textbf{Table 6.4: FMFeatureMapAssertion}
### 6.7 Which variation points are affected by a particular FMFeature?

Because a FMFeatureMap does not directly refer to VariationPoint elements, it is not straightforward to see which variation points are affected by a particular feature.

First, we need to look at SwSystemconstantValueSet and PostBuildVariantCriterionValueSet to see which SwSystemconst and PostBuildVariantCriterion elements are actually affected by these. Figures 6.2 and 6.3 illustrate this.
Next, we need to look at all variation points to see where those `SwSystemconst` and `PostBuildVariantCriterion` are referenced. Figure 6.4 shows the structure of a variation point. While the `PostBuildVariantCriterion` is directly visible in Figure 6.4, a `SwSystemconst` would be referenced from a `ConditionByFormula`. 
The algorithm to find out which variation points are affected by a single FMFeatureMapElement is outlined in [TPS_FMDT_00025].

[TPS_FMDT_00025] Set of affected variation points for a FMFeatureMapElement

1. Let e be a FMFeatureMapElement.
2. Let $S = \{s_1, s_2, \ldots, s_n\}$ be the set of SwSystemconstantValueSet elements aggregated by e in the role swSystemconstantValueSet.
3. Each SwSystemconstantValueSet $s_i$ aggregates a number of SwSystemconstValue elements in the role swSystemconstValue, which in turn refer to a single SwSystemconst element in the role swSystemconst. Let $SC_i$ be the set of these SwSystemconst elements for each $s_i$.
4. Each SwSystemconst in $SC_i$ is used in the condition of one or more VariationPoints. More precisely, the SwSystemconst elements are referenced from the ConditionByFormula elements$^2$ that are aggregated by the VariationPoint in the role swSyscond. Let $V_i$ be the set of these variation points for all elements in $SC_i$.

$^2$ConditionByFormula elements are expressions which use SwSystemconst elements as variables.
5. Let \( P = \{p_1, p_2, \ldots, p_m\} \) be the set of PostBuildVariantCriterionValue-Set elements aggregated by \( e \) in the role postBuildVariantCriterionValueSet.

6. Each PostBuildVariantCriterionValueSet \( p_j \) aggregates a number of PostBuildVariantCriterionValue elements in the role postBuildVariantCriterionValue, which in turn refer to a PostBuildVariantCriterion in the role variantCriterion. Let \( PC_j \) be the set of PostBuildVariantCriterion elements.

7. Each PostBuildVariantCriterion element is used in a variation point. More precisely, a VariationPoint aggregates a PostBuildVariantCondition which in turn references a PostBuildVariantCriterion. Let \( V_j \) be the set of these variation points for all elements in \( PC_j \).

The affected variation points for the FMFeatureMapElement \( e \) is now defined as follows:

\[
\text{affected variation points}(e) = \bigcup_i V_i \cup \bigcup_j V_j
\]

\( (RS_FMDT_00010) \)

With [TPS_FMDT_00025] in place, we can now collect the affected variation points for a FMFeature.

[TPS_FMDT_00038] Definition of Affected Variation Points for a FMFeature

1. Let \( f \) be a FMFeature.

2. Let \( C \) be the set of FMFeatureMapElement elements that aggregate a FMFeatureMapCondition in the role fmCond whose aggregated FMFormulaByFeaturesAndAttributes element refers to \( f \).

3. Let \( A \) be the set of FMFeatureMapAssertion elements that aggregate a FMFeatureMapAssertion in the role fmSyscond whose aggregated FMCConditionByFeaturesAndSwSystemconsts element refers to \( f \).

\[
\text{affected variation points}(f) = \text{affected variation points}(C) \cup \text{affected variation points}(A)
\]

\( (RS_FMDT_00010) \)
7 Common Concepts

7.1 Special Data in Context of Feature Models

Usually, a feature model is maintained in an external system, and the AUTOSAR representation of a feature model is an export of that model. In order to maintain the relationship with the external model (or with other systems that might interact with the feature model), it is usually necessary to add application specific data, for example a custom identifier, to the feature model.

[TPS_FMDT_00033] Special data for feature models [Several of the major classes in the feature model concept are based on the abstract class ARElement:]

- FMFeatureModel
- FMFeature
- FMFeatureSelectionSet
- FMFeatureMap

The following classes are based on the abstract class Identifiable:

- FMFeatureRestriction
- FMFeatureRelation
- FMAtributeDef
- FMFeatureMapCondition
- FMFeatureMapAssertion

These classes aggregate AdminData in the role adminData, which aggregates a Sdg (special data group) in the role sdg. Sdg is a container that is designed to hold proprietary, application specific data that may be used by the application that exports the feature model into the AUTOSAR model to add its own data.](RS_FMDT_00001, RS_FMDT_00012, RS_FMDT_00013)

Obviously, this also means that the data that is contained in the Sdg is not suited for exchange between arbitrary parties, but only between those who know how to interpret it.
7.2 Formulas that use Features

![Diagram of formulas used in Feature Modeling]

**7.2.1 FMFormulaByFeaturesAndAttributes**

<table>
<thead>
<tr>
<th>Class</th>
<th>&lt;&lt;&lt;atpMixedString&gt;&gt; FMFormulaByFeaturesAndAttributes (abstract)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
<tr>
<td>Note</td>
<td>An expression that has the syntax of the AUTOSAR formula language but uses only references to features or feature attributes (not system constants) as operands.</td>
</tr>
<tr>
<td>Base</td>
<td>ARObject, FormulaExpression</td>
</tr>
<tr>
<td>Subclasses</td>
<td>FMConditionByFeaturesAndAttributes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
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<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>attribute</td>
<td>FMAttributeDef</td>
<td>1</td>
<td>ref</td>
<td>An expression of type FMFormulaByFeaturesAndAttributes may refer to attributes of FMFeatures.</td>
</tr>
</tbody>
</table>
The class `FMFormulaByFeaturesAndAttributes` defines expressions that employ the same structure as the standard AUTOSAR formula language (see [1]), but use features and feature attributes instead of system constants.

This is expressed by the abstract class `FMFormulaByFeaturesAndAttributes`, which is based on `FormulaExpression` but restricts formulas so that they can only refer to `FMFeature`s and `FMAtributeDefs`, but not to `SwSystemconsts`.

**[constr_5011]** `FMFormulaByFeaturesAndAttributes` can refer to `FMFeature`s and `FMAtributeDefs`, but not to system constants. (A formula of class `FMFormulaByFeaturesAndAttributes` is an expression that can use `FMFeatures` and `FMAtributeDefs`, but is not allowed to use `SwSystemconsts`.)}

System constants are not allowed in this class of formulas because system constants are considered part of the implementation, whereas features (and feature attributes) abstract from the implementation.

### 7.2.2 `FMConditionByFeaturesAndAttributes`

<table>
<thead>
<tr>
<th>Class</th>
<th>&lt;&lt;atpMixedString&gt;&gt; <code>FMConditionByFeaturesAndAttributes</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::FeatureModelTemplate</td>
</tr>
<tr>
<td>Note</td>
<td>A boolean expression that has the syntax of the AUTOSAR formula language but uses only references to features or feature attributes (not system constants) as operands.</td>
</tr>
<tr>
<td>Base</td>
<td><code>ARObject</code>, <code>FMFormulaByFeaturesAndAttributes</code>, <code>FormulaExpression</code></td>
</tr>
<tr>
<td>Attribute</td>
<td>Type</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**[TPS_FMDT_00049]** The result of `FMConditionByFeaturesAndAttributes` is interpreted as a boolean value. (The result of a formula of class `FMConditionByFeaturesAndAttributes` shall be interpreted as a boolean value where 0 shall be interpreted as `false` and any value different from 0 shall be interpreted as `true`. This is the same approach as used by `ConditionByFormula`.)(**RS_FMDT_00008, RS_FMDT_00010**)

An element of class `FMConditionByFeaturesAndAttributes` is aggregated by class `FMFeatureRestriction` in the role `restriction` and by class `FMAtributeMapCondition` in the role `fmCond`. 
7.2.3 FMFormulaByFeaturesAndSwSystemconsts

The class `FMFormulaByFeaturesAndSwSystemconsts` uses the standard AUTOSAR formula language but extends it with features. That is, unlike `SwSystemconstDependentFormula`, which only allows references to `SwSystemconsts`, `FMFormulaByFeaturesAndSwSystemconsts` allows references to `SwSystemconsts` and `FMFeatures`.

[TPS_FMDT_00048] `FMFormulaByFeaturesAndSwSystemconsts` can refer to features and system constants. [A formula of class `FMFormulaByFeaturesAndSwSystemconsts` is an expression that can use both `FMFeatures` and `SwSystemconsts`.] *(RS_FMDT_00008, RS_FMDT_00010)*

7.2.4 FMConditionByFeaturesAndSwSystemconsts

An element of class `FMConditionByFeaturesAndSwSystemconsts` is aggregated by `FMFeatureMapAssertion` in the role `fmSyscond` to define assertions for feature mappings.
7.2.5 Evaluating Expressions that use Features and Attributes

An expression that uses features or feature attributes can only be evaluated in the context of a `FMFeatureSelectionSet`. The reason is that in order to evaluate the expression, we need to substitute values for the references to features (1 if selected and 0 otherwise) and for the references to feature attributes (the default value or the one defined in the `FMFeatureSelection`). This information is only available as part of a `FMFeatureSelectionSet`.

First, we need to extend the definition of the feature set of a `FMFeatureSelectionSet` to add all features in the `include` and `FMFeatureSelectionSet`.

[TPS_FMDT_00059] Definition of recursive feature set of a `FMFeatureSelectionSet` [Let $S$ be a `FMFeatureSelectionSet` that refers to `FMFeatureSelectionSet`s $\{S_1, S_2, \ldots, S_n\}$ in the role `include`.

Then the recursive feature set of $S$ is defined as

\[
\text{recursive feature set}(S) = \text{feature set}(S) \cup \bigcup_{S_i} \text{recursive feature set}(S_i)
\]

](RS_FMDT_00003)

Next, we define the state of a `FMFeature` in a `FMFeatureSelectionSet`. Again, this definition includes all `include` and `FMFeatureSelectionSet`s:

[TPS_FMDT_00058] Definition of state of a `FMFeature` in a `FMFeatureSelectionSet` [Let $f$ be a `FMFeature` and $S$ be a `FMFeatureSelection` where $f$ is in the recursive feature set of $S$. Then the state of $f$ in $S$ is defined as follows:

1. If $f$ is in the feature set of $S$, let $s$ be the `FMFeatureSelection` that refers to $f$ in the role `feature`.

Then the state of $f$ in $S$ is the value of the attribute state of $s$.

2. If $f$ is not in the feature set of $S$, let $\{S_1, S_2, \ldots, S_n\}$ be the `FMFeatureSelectionSet`s that $S$ refers to in the role `include`. Because $f$ is in the recursive feature set of $S$, there shall be at least one $S_i$ that defines the state of $f$.

Then the state of $f$ in $S$ is the state of $f$ in $S_i$.

](RS_FMDT_00003)

Note that the second step in [TPS_FMDT_00058] retrieves a consistent result (i.e., no conflicting states such as selected and deselected) because of constraint [constr_5003] and constraint [constr_5025].

[TPS_FMDT_00057] Evaluating an Expression that uses Features and Attributes [Let $S$ be a `FMFeatureSelectionSet`. To evaluate an expression that uses attributes, the following steps shall be performed:

1. Replace all reference to `SwSystemConst`s by their values.

2. For each reference to a `FMFeature` $f$, we distinguish between two cases.
(a) $f$ is in the recursive feature set of $S$.
   
   i. If the state of $f$ in $S$ is selected, then the reference to $f$ is replaced by the value $1$.

   ii. If the state of $f$ in $S$ is deselected, then the reference to $f$ is replaced by the value $0$.

   iii. If the state of $f$ in $S$ is undecided, then this is considered an error.

(b) $f$ is not in the recursive feature set of $S$. This is considered an error.

3. For each reference to a $\text{FMAtributeDef}$,
   
   (a) If $S$ aggregates a $\text{FMFeatureSelection}$ $s$ in the role selection that aggregates an $\text{FMAtributeValue}$ $v$ which refers to $a$ in the role definition, then the reference is replaced by the contents of the attribute value of $v$.

   (b) Otherwise, let $\{S_1, S_2, \ldots, S_n\}$ be the $\text{FMFeatureSelectionSets}$ that $S$ refers to in the role include. Repeat the previous step recursively for all $S_i$ elements.

   (c) Otherwise, if $a$ has a $\text{defaultValue}$, then the reference is replaced by the contents of the attribute $\text{defaultValue}$ of $a$.

   (d) It is considered an error if none of the above steps can find a value.

$\text{RS}_{\text{FMDT}}\_00008, \text{RS}_{\text{FMDT}}\_00010$

Note that when we look for the value of an attribute in $\text{TPS}_{\text{FMDT}}\_00057$, then do not look at the state of a $\text{FMFeatureSelection}$. That is, $\text{FMAtributeValue}$ could also be taken from a $\text{FMFeatureSelection}$ whose state is deselected. It is up to the party that creates the feature model, feature selection and feature mapping to decide if this is appropriate and eventually adapt the condition appropriately.
A Glossary

Artifact This is a Work Product Definition that provides a description and definition for tangible work product types. Artifacts may be composed of other artifacts ([5]). At a high level, an artifact is represented as a single conceptual file.

AUTOSAR Tool This is a software tool which supports one or more tasks defined as AUTOSAR tasks in the methodology. Depending on the supported tasks, an AUTOSAR tool can act as an authoring tool, a converter tool, a processor tool or as a combination of those (see separate definitions).

AUTOSAR Authoring Tool An AUTOSAR Tool used to create and modify AUTOSAR XML Descriptions. Example: System Description Editor.

AUTOSAR Converter Tool An AUTOSAR Tool used to create AUTOSAR XML files by converting information from other AUTOSAR XML files. Example: ECU Flattener

AUTOSAR Definition This is the definition of parameters which can have values. One could say that the parameter values are Instances of the definitions. But in the meta model hierarchy of AUTOSAR, definitions are also instances of the meta model and therefore considered as a description. Examples for AUTOSAR definitions are: EcucParameterDef, PostBuildVariantCriterion, SwSystemconst.

AUTOSAR XML Description In AUTOSAR this means "filled Template". In fact an AUTOSAR XML description is the XML representation of an AUTOSAR model. The AUTOSAR XML description can consist of several files. Each individual file represents an AUTOSAR partial model and shall validate successfully against the AUTOSAR XML schema.

AUTOSAR Meta-Model This is an UML2.0 model that defines the language for describing AUTOSAR systems. The AUTOSAR meta-model is an UML representation of the AUTOSAR templates. UML2.0 class diagrams are used to describe the attributes and their interrelationships. Stereotypes, UML tags and OCL expressions (object constraint language) are used for defining specific semantics and constraints.

AUTOSAR Meta-Model Tool The AUTOSAR Meta-Model Tool is the tool that generates different views (class tables, list of constraints, diagrams, XML Schema etc.) on the AUTOSAR meta-model.

AUTOSAR Model This is a representation of an AUTOSAR product. The AUTOSAR model represents aspects suitable to the intended use according to the AUTOSAR methodology. Strictly speaking, this is an instance of the AUTOSAR meta-model. The information contained in the AUTOSAR model can be anything that is representable according to the AUTOSAR meta-model.
AUTOSAR Partial Model  In AUTOSAR, the possible partitioning of models is marked in the meta-model by `≪atpSplitable≫`. One partial model is represented in an AUTOSAR XML description by one file. The partial model does not need to fulfill all semantic constraints applicable to an AUTOSAR model.

AUTOSAR Processor Tool  An AUTOSAR Tool used to create non-AUTOSAR files by processing information from AUTOSAR XML files. Example: RTE Generator

AUTOSAR Specification Element  An AUTOSAR Specification Element is a named element that is part of an AUTOSAR specification. Examples: requirement, constraint, specification item, class or attribute in the meta model, methodology, deliverable, methodology activity, model element, bsw module etc.

AUTOSAR Template  The term "Template" is used in AUTOSAR to describe the format different kinds of descriptions. The term template comes from the idea, that AUTOSAR defines a kind of form which shall be filled out in order to describe a model. The filled form is then called the description.

In fact the AUTOSAR templates are now defined as a meta-model.

AUTOSAR Validation Tool  A specialized AUTOSAR Tool which is able to check an AUTOSAR model against the rules defined by a profile.

AUTOSAR XML Schema  This is a W3C XML schema that defines the language for exchanging AUTOSAR models. This Schema is derived from the AUTOSAR meta-model. The AUTOSAR XML Schema defines the AUTOSAR data exchange format.

Blueprint  This is a model from which other models can be derived by copy and refinement. Note that in contrast to meta model resp. types, this process is not an instantiation.

Instance  Generally this is a particular exemplar of a model or of a type.

Life Cycle  Life Cycle is the course of development/evolutionary stages of a model element during its life time.

Meta-Model  This defines the building blocks of a model. In that sense, a Meta-Model represents the language for building models.

Meta-Data  This includes pertinent information about data, including information about the authorship, versioning, access-rights, timestamps etc.

Model  A Model is an simplified representation of reality. The model represents the aspects suitable for an intended purpose.

Partial Model  This is a part of a model which is intended to be persisted in one particular artifact.

Pattern in GST  This is an approach to simplify the definition of the meta model by applying a model transformation. This transformation creates an enhanced model out of an annotated model.
Profile Authoring Support Data  Data that is used for efficient authoring of a profile. E.g. list of referable constraints, meta-classes, meta-attributes or other reusable model assets (blueprints)

Profile Authoring Tool  A specialized AUTOSAR Tool which focuses on the authoring of profiles for data exchange points. It e.g. provides support for the creation of existing profiles or composition of existing profiles.

Profile Compatibility Checker Tool  A specialized AUTOSAR Tool which focuses on checking the compatibility of profiles for data exchange. Note that this compatibility check includes manual compatibility checks by engineers and automated assistance using more formal algorithms.

Profile Consistency Checker Tool  A specialized AUTOSAR Tool which focuses on checking the consistency of profiles.

Property  A property is a structural feature of an object. As an example a “connector” has the properties “receive port” and “send port”

Properties are made variant by the $\text{atpVariation}$.

Prototype  This is the implementation of a role of a type within the definition of another type. In other words a type may contain Prototypes that in turn are typed by "Types". Each one of these prototypes becomes an instance when this type is instantiated.

Type  A type provides features that can appear in various roles of this type.

Value  This is a particular value assigned to a “Definition”.

Variability  Variability of a system is its quality to describe a set of variants. These variants are characterized by variant specific property settings and / or selections. As an example, such a system property selection manifests itself in a particular “receive port” for a connection.

This is implemented using the $\text{atpVariation}$.

Variant  A system variant is a concrete realization of a system, so that all its properties have been set respectively selected. The software system has no variability anymore with respect to the binding time.

This is implemented using EvaluatedVariantSet.

Variation Binding  A variant is the result of a variation binding process that resolves the variability of the system by assigning particular values/selections to all the system’s properties.

This is implemented by VariationPoint.

Variation Binding Time  The variation binding time determines the step in the methodology at which the variability given by a set of variable properties is resolved.
This is implemented by `vh.LatestBindingtime` at the related properties.

**Variation Definition Time** The variation definition time determines the step in the methodology at which the variation points are defined.

**Variation Point** A variation point indicates that a property is subject to variation. Furthermore, it is associated with a condition and a binding time which define the system context for the selection / setting of a concrete variant.

This is implemented by `VariationPoint`.

## B Mentioned Class Tables

<table>
<thead>
<tr>
<th>Class</th>
<th>ARElement (abstract)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::GenericStructure::GeneralTemplateClasses::ARPackage</td>
</tr>
</tbody>
</table>

**Note**

An element that can be defined stand-alone, i.e. without being part of another element (except for packages of course).

**Base**

`ARObject`, `CollectableElement`, `Identifiable`, `MultilanguageReferrable`, `PackageableElement`, `Referrable`

**Subclasses**

`AclObjectSet`, `AclOperation`, `AclPermission`, `AclRole`, `AliasNameSet`, `AutosarDataType`, `BaseType`, `BlueprintMappingSet`, `BuildActionManifest`, `CalibrationParameterValueSet`, `ClientIdDefinitionSet`, `Collection`, `CompuMethod`, `ConsistencyNeedsBlueprintSet`, `ConstantSpecification`, `ConstantSpecificationMappingSet`, `CryptoServiceKey`, `CryptoServicePrimitive`, `CryptoServiceQueue`, `DataConstr`, `DataExchangePoint`, `DataTransformationSet`, `DataTypeMappingSet`, `DiagnosticCommonElement`, `DiagnosticConnection`, `DiagnosticContributionSet`, `Documentation`, `E2EProfileCompatibilityProps`, `EndToEndProtectionSet`, `EthIpProps`, `EthTcpIpIcmpProps`, `EthTcpIpProps`, `EvaluatedVariantSet`, `FMFeature`, `FMFeatureMap`, `FMFeatureModel`, `FMFeatureSelectionSet`, `FunctionGroupSet`, `GeneralPurposeConnection`, `HwCategory`, `HwElement`, `HwType`, `IPSecConfigProps`, `IdsCommonElement`, `IdsDesign`, `InterpolationRoutineMappingSet`, `KeywordSet`, `LifeCycleInfoSet`, `LifeCycleStateDefinitionGroup`, `McFunction`, `McGroup`, `ModeDeclarationGroup`, `ModeDeclarationMappingSet`, `PhysicalDimension`, `PhysicalDimensionMappingSet`, `PlatformModuleEndpointConfiguration`, `PortInterface`, `PortInterfaceMappingSet`, `PortPrototypeBlueprint`, `PostBuildVariantCriterion`, `PostBuildVariantCriterionValueSet`, `PredefinedVariant`, `RapidPrototypingScenario`, `SdgDef`, `SignalServiceTranslationPropsSet`, `SoftwareCluster`, `SomeipSdClientEventGroupTimingConfig`, `SomeipSdClientServiceInstanceConfig`, `SomeipSdServerEventGroupTimingConfig`, `SomeipSdServerServiceInstanceConfig`, `SwAddrMethod`, `SwAxisType`, `SwComponentType`, `SwRecordLayout`, `SwSystemconst`, `SwSystemconstantValueSet`, `System`, `SystemSignal`, `SystemSignalGroup`, `TimingExtension`, `TvDataIdDefinitionSet`, `TransformationPropsSet`, `Unit`, `UnitGroup`, `ViewMapSet`

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
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<tr>
<td>–</td>
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Table B.1: ARElement

<table>
<thead>
<tr>
<th>Class</th>
<th>AdminData</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::MSR::AsamHdo::AdminData</td>
</tr>
</tbody>
</table>

**Note**

AdminData represents the ability to express administrative information for an element. This administrative information is to be treated as meta-data such as revision id or state of the file. There are basically four kinds of meta-data

- The language and/or used languages.
- Revision information covering e.g. revision number, state, release date, changes. Note that this information can be given in general as well as related to a particular company.
- Document meta-data specific for a company

**Base**

`ARObject`
### AdminData

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<tr>
<th>Class</th>
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<td>docRevision</td>
<td>DocRevision</td>
<td>*</td>
<td>aggr</td>
<td>This allows to denote information about the current revision of the object. Note that information about previous revisions can also be logged here. The entries shall be sorted descendant by date in order to reflect the history. Therefore the most recent entry representing the current version is denoted first. <strong>Tags:</strong> xml.roleElement=true xml.roleWrapperElement=true xml.sequenceOffset=50 xml.typeElement=false xml.typeWrapperElement=false</td>
</tr>
<tr>
<td></td>
<td>language</td>
<td>LEnum</td>
<td>0..1</td>
<td>attr</td>
<td>This attribute specifies the master language of the document or the document fragment. The master language is the one in which the document is maintained and from which the other languages are derived from. In particular in case of inconsistencies, the information in the master language is priority. <strong>Tags:</strong> xml.sequenceOffset=20</td>
</tr>
<tr>
<td></td>
<td>sdg</td>
<td>Sdg</td>
<td>*</td>
<td>aggr</td>
<td>This property allows to keep special data which is not represented by the standard model. It can be utilized to keep e.g. tool specific data. <strong>Stereotypes:</strong> atpSplitable <strong>Tags:</strong> atp.Splitkey=sdg, sdg.variationPoint.shortLabel xml.roleElement=true xml.roleWrapperElement=true xml.sequenceOffset=60 xml.typeElement=false xml.typeWrapperElement=false</td>
</tr>
<tr>
<td></td>
<td>usedLanguages</td>
<td>MultiLanguagePlainText</td>
<td>0..1</td>
<td>aggr</td>
<td>This property specifies the languages which are provided in the document. Therefore it should only be specified in the top level admin data. For each language provided in the document there is one entry in MultiLanguagePlainText. The content of each entry can be used for illustration of the language. The used language itself depends on the language attribute in the entry. <strong>Tags:</strong> xml.sequenceOffset=30</td>
</tr>
</tbody>
</table>

**Table B.2: AdminData**

<table>
<thead>
<tr>
<th>Class</th>
<th>Package</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;&lt;atpMixedString&gt;&gt;</td>
<td>M2::AUTOSARTemplates::GenericStructure::VariantHandling</td>
<td>This class represents a condition which is computed based on system constants according to the specified expression. The expected result is considered as boolean value. The result of the expression is interpreted as a condition. <strong>Base:</strong> ARObjec, FormulaExpression, SwSystemconstDependentFormula</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
</table>

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Class ConditionByFormula

| bindingTime | BindingTimeEnum | 1 | attr | This attribute specifies the point in time when condition may be evaluated at earliest. At this point in time all referenced system constants shall have a value. |

Table B.3: ConditionByFormula

Class FormulaExpression (abstract)

| Package | M2::AUTOSARTemplates::GenericStructure::FormulaLanguage |

Note This class represents the syntax of the formula language. The class is modeled as an abstract class in order to be specialized into particular use cases. For each use case the referable objects might be specified in the specialization.

Base ARObject

Subclasses CompuGenericMath, FMFormulaByFeaturesAndAttributes, SwSystemconstDependentFormula, TDEvent OccurrenceExpressionFormula, TimingConditionFormula

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Multi.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>atpReference</td>
<td>Referrable</td>
<td>*</td>
<td>ref</td>
<td>The referable object shall yield a numerical / boolean value.</td>
</tr>
<tr>
<td>atpString</td>
<td>Referrable</td>
<td>*</td>
<td>ref</td>
<td>The referable object shall yield a string value.</td>
</tr>
</tbody>
</table>

Table B.4: FormulaExpression

Class Identifiable (abstract)

| Package | M2::AUTOSARTemplates::GeneralTemplateClasses::Identifiable |

Note Instances of this class can be referred to by their identifier (within the namespace borders). In addition to this, Identifiables are objects which contribute significantly to the overall structure of an AUTOSAR description. In particular, Identifiables might contain Identifiables.

Base ARObject, MultilanguageReferrable, Referrable

### Class

**Identifiable (abstract)**


### Attribute

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>adminData</td>
<td>AdminData</td>
<td>0..1</td>
<td>aggr</td>
<td>This represents the administrative data for the identifiable object.</td>
</tr>
<tr>
<td>annotation</td>
<td>Annotation</td>
<td>*</td>
<td>aggr</td>
<td>Possibility to provide additional notes while defining a model element (e.g. the ECU Configuration Parameter Values). These are not intended as documentation but are mere design notes.</td>
</tr>
<tr>
<td>category</td>
<td>CategoryString</td>
<td>0..1</td>
<td>attr</td>
<td>The category is a keyword that specializes the semantics of the Identifiable. It affects the expected existence of attributes and the applicability of constraints.</td>
</tr>
<tr>
<td>desc</td>
<td>MultiLanguageOverviewParagraph</td>
<td>0..1</td>
<td>aggr</td>
<td>This represents a general but brief (one paragraph) description what the object in question is about. It is only one paragraph! Desc is intended to be collected into overview tables. This property helps a human reader to identify the object in question. More elaborate documentation, (in particular how the object is built or used) should go to “introduction”.</td>
</tr>
<tr>
<td>introduction</td>
<td>DocumentationBlock</td>
<td>0..1</td>
<td>aggr</td>
<td>This represents more information about how the object in question is built or is used. Therefore it is a DocumentationBlock.</td>
</tr>
<tr>
<td>uuid</td>
<td>String</td>
<td>0..1</td>
<td>attr</td>
<td>The purpose of this attribute is to provide a globally unique identifier for an instance of a meta-class. The values of this attribute should be globally unique strings prefixed by the type of identifier. For example, to include a DCE UUID as defined by The Open Group, the UUID would be preceded by “DCE:”. The values of this attribute may be used to support merging of different AUTOSAR models. The form of the UUID (Universally Unique Identifier) is taken from a standard defined by the Open Group (was Open Software Foundation). This standard is widely used, including by Microsoft for COM (GUIDs) and by many companies for DCE, which is based on CORBA. The method for generating these 128-bit IDs is published in the standard and the effectiveness and uniqueness of the IDs is not in practice disputed. If the id namespace is omitted, DCE is assumed. An example is “DCE:21ac1234-31b8-11b4-a222-08002b34c003”. The uuid attribute has no semantic meaning for an AUTOSAR model and there is no requirement for AUTOSAR tools to manage the timestamp.</td>
</tr>
</tbody>
</table>

Tags: **xml.sequenceOffset=-40**

Tags: **xml.sequenceOffset=-25**

Tags: **xml.sequenceOffset=-50**

Tags: **xml.sequenceOffset=-60**

Tags: **xml.sequenceOffset=-30**

**Table B.5: Identifiable**
Class | MultilanguageReferrable (abstract)
---|---
Package | M2::AUTOSARTemplates::GenericStructure::GeneralTemplateClasses::Identifiable
Note | Instances of this class can be referred to by their identifier (while adhering to namespace borders). They also may have a longName. But they are not considered to contribute substantially to the overall structure of an AUTOSAR description. In particular it does not contain other Referrables.
Base | ARObject, Referrable
Subclasses | Caption, DefItem, DocumentationContext, Identifiable, SdgCaption, TraceReferrable, Traceable
Attribute | Type | Mult. | Kind | Note
---|---|---|---|---
longName | MultilanguageLongName | 0..1 | aggr | This specifies the long name of the object. Long name is targeted to human readers and acts like a headline.

Table B.6: MultilanguageReferrable

Primitive | PositiveInteger
---|---
Package | M2::AUTOSARTemplates::GenericStructure::GenericTemplateClasses::PrimitiveTypes
Note | This is a positive integer which can be denoted in decimal, binary, octal and hexadecimal. The value is between 0 and 4294967295.
Tags: xml.xsd.customType=POSITIVE-INTEGER, xml.xsd.pattern=0[+]?[1-9][0-9]*|0[0-7]+|0[0-9a-fA-F][0-9a-fA-F][0-9a-fA-F][0-9a-fA-F][0-9a-fA-F][0-9a-fA-F][0-9a-fA-F][0-9a-fA-F]
xml.xsd.type=string

Table B.7: PositiveInteger

Class | PostBuildVariantCondition
---|---
Package | M2::AUTOSARTemplates::GenericStructure::VariantHandling
Note | This class specifies the value which shall be assigned to a particular variant criterion in order to bind the variation point. If multiple criterion/value pairs are specified, they shall all match to bind the variation point.
In other words binding can be represented by
(criterion1 == value1) && (condition2 == value2) ...
Base | ARObject
Attribute | Type | Mult. | Kind | Note
---|---|---|---|---
matchingCriterion | PostBuildVariantCriterion | 1 | ref | This is the criterion which needs to match the value in order to make the PostbuildVariantCondition to be true.
value | Integer | 1 | attr | This is the particular value of the post-build variant criterion.
Stereotypes: atpVariation
Tags: vh.latestBindingTime=preCompileTime

Table B.8: PostBuildVariantCondition

Class | PostBuildVariantCriterion
---|---
Package | M2::AUTOSARTemplates::GenericStructure::VariantHandling
Note | This class specifies one particular PostBuildVariantSelector.
Tags: atp.recommendedPackage=PostBuildVariantCriterions
Base | ARObject, ARObject, AtpDefinition, CollectableElement, Identifiable, MultilanguageReferrable, PackageableElement, Referrable
Attribute | Type | Mult. | Kind | Note
---|---|---|---|---
compuMethod | CompuMethod | 1 | ref | The compuMethod specifies the possible values for the variant criterion serving as an enumerator.

Table B.9: PostBuildVariantCriterion
### Class: PostBuildVariantCriterionValue

**Package**: M2::AUTOSARTemplates::GenericStructure::VariantHandling

**Note**: This class specifies the value which shall be assigned to a particular variant criterion in order to bind the variation point. If multiple criterion/value pairs are specified, they all shall match to bind the variation point.

**Base**: ARObj

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>annotation</td>
<td>Annotation</td>
<td>*</td>
<td>aggr</td>
<td>This provides the ability to add information why the value is set like it is.</td>
</tr>
<tr>
<td>value</td>
<td>Integer</td>
<td>1</td>
<td>attr</td>
<td>This is the particular value of the post-build variant criterion.</td>
</tr>
<tr>
<td>variantCriteron</td>
<td>PostBuildVariantCriterion</td>
<td>1</td>
<td>ref</td>
<td>This association selects the variant criterion whose value is specified.</td>
</tr>
</tbody>
</table>

#### Table B.10: PostBuildVariantCriterionValue

### Class: PredefinedVariant

**Package**: M2::AUTOSARTemplates::GenericStructure::VariantHandling

**Note**: This specifies one predefined variant. It is characterized by the union of all system constant values and post-build variant criterion values aggregated within all referenced system constant value sets and post build variant criterion value sets plus the value sets of the included variants.

**Base**: ARElement, ARObj, CollectableElement, Identifiable, MultilanguageReferrable, PackageableElement, Referrable

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Mult.</th>
<th>Kind</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>includedVariant</td>
<td>PredefinedVariant</td>
<td>*</td>
<td>ref</td>
<td>The associated variants are considered part of this PredefinedVariant. This means the settings of the included variants are included in the settings of the referencing PredefinedVariant. Nevertheless the included variants might be included in several predefinded variants.</td>
</tr>
<tr>
<td>postBuildVariantCriterionValueSet</td>
<td>PostBuildVariantCriterionValueSet</td>
<td>*</td>
<td>ref</td>
<td>This is the postBuildVariantCriterionValueSet contributing to the predefined variant.</td>
</tr>
<tr>
<td>sw SystemconstantValueSet</td>
<td>SwSystemconstantValueSet</td>
<td>*</td>
<td>ref</td>
<td>This ist the set of Systemconstant Values contributing to the predefined variant.</td>
</tr>
</tbody>
</table>

#### Table B.11: PredefinedVariant

### Class: Referrable (abstract)

**Package**: M2::AUTOSARTemplates::GenericStructure::GeneralTemplateClasses::Identifiable

**Note**: Instances of this class can be referred to by their identifier (while adhering to namespace borders).

**Base**: ARObj
Class | Referable (abstract)


Attribute | Type | Mult. | Kind | Note
---|---|---|---|---
shortName | Identifier | 1 | attr | This specifies an identifying shortName for the object. It needs to be unique within its context and is intended for humans but even more for technical reference.
  Stereotypes: atpIdentityContributor
  Tags: xml.enforceMinMultiplicity=true, xml.sequenceOffset=-100

shortNameFragment | ShortNameFragment | * | aggr | This specifies how the Referable.shortName is composed of several shortNameFragments.
  Tags: xml.sequenceOffset=-90

Table B.12: Referable

Class | Sdg
Package | M2::MSR::AsamHdo::SpecialData

Note | Sdg (SpecialDataGroup) is a generic model which can be used to keep arbitrary information which is not explicitly modeled in the meta-model.
  Sdg can have various contents as defined by sdgContentsType. Special Data should only be used moderately since all elements should be defined in the meta-model.
  Thereby SDG should be considered as a temporary solution when no explicit model is available. If an sdgCaption is available, it is possible to establish a reference to the sdg structure.

Base | ARObject
Attribute | Type | Mult. | Kind | Note
---|---|---|---|---
gid | NameToken | 1 | attr | This attributes specifies an identifier. Gid comes from the SGML/XML Term "Generic Identifier" which is the element name in XML. The role of this attribute is the same as the name of an XML - element.
  Tags: xml.attribute=true

sdgCaption | SdgCaption | 0..1 | aggr | This aggregation allows to assign the properties of Identifiable to the sdg. By this, a shortName etc. can be assigned to the Sdg.
  Tags: xml.sequenceOffset=20

sdgContents | SdgContents | 0..1 | aggr | This is the content of the Sdg.
  Tags:
  xml.roleElement=false
  xml.roleWrapperElement=false
  xml.sequenceOffset=30
  xml.typeElement=false
  xml.typeWrapperElement=false

Table B.13: Sdg
### Table B.14: SwComponentPrototype

<table>
<thead>
<tr>
<th>Class</th>
<th>SwComponentPrototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::SWComponentTemplate::Composition</td>
</tr>
<tr>
<td>Note</td>
<td>Role of a software component within a composition.</td>
</tr>
<tr>
<td>Base</td>
<td>ARObjec, AtpFeature, AtpPrototype, Identifiable, MultilanguageReferrable, Referrable</td>
</tr>
<tr>
<td>Attribute</td>
<td>Type</td>
</tr>
<tr>
<td>type</td>
<td>SwComponentType</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table B.15: SwSystemconst

<table>
<thead>
<tr>
<th>Class</th>
<th>SwSystemconst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::MSR::DataDictionary::SystemConstant</td>
</tr>
<tr>
<td>Note</td>
<td>This element defines a system constant which serves an input to select a particular variation point. In particular a system constant serves as an operand of the binding function (swSyscond) in a Variation point. Note that the binding process can only happen if a value was assigned to the referenced system constants.</td>
</tr>
<tr>
<td>Base</td>
<td>ARObjec, AtpDefinition, CollectableElement, Identifiable, MultilanguageReferrable, PackageableElement, Referrable</td>
</tr>
<tr>
<td>Attribute</td>
<td>Type</td>
</tr>
<tr>
<td>swDataDefProps</td>
<td>SwDataDefProps</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table B.16: SwSystemconstDependentFormula

<table>
<thead>
<tr>
<th>Class</th>
<th>&lt;&lt;atpMixedString&gt;&gt; SwSystemconstDependentFormula (abstract)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::GenericStructure::VariantHandling</td>
</tr>
<tr>
<td>Note</td>
<td>This class represents an expression depending on system constants.</td>
</tr>
<tr>
<td>Base</td>
<td>ARObjec, FormulaExpression</td>
</tr>
<tr>
<td>Subclasses</td>
<td>AttributeValueVariationPoint, BlueprintFormula, ConditionByFormula, FMFormulaByFeaturesAndSwSystemconsts</td>
</tr>
<tr>
<td>Attribute</td>
<td>Type</td>
</tr>
<tr>
<td>sysc</td>
<td>SwSystemconst</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>syscall</td>
<td>SwSystemconst</td>
</tr>
</tbody>
</table>

### Table B.16: SwSystemconstDependentFormula
### Table B.17: SwSystemconstValue

<table>
<thead>
<tr>
<th>Class</th>
<th>SwSystemconstValue</th>
</tr>
</thead>
<tbody>
<tr>
<td>annotation</td>
<td>Annotation  * aggr</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>swSystemconst</td>
<td>SwSystemconst  1 ref</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>value</td>
<td>Numerical         1 attr</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table B.18: VariationPoint

<table>
<thead>
<tr>
<th>Class</th>
<th>VariationPoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>M2::AUTOSARTemplates::GenericStructure::VariantHandling</td>
</tr>
<tr>
<td>Note</td>
<td>This meta-class represents the ability to express a &quot;structural variation point&quot;. The container of the variation point is part of the selected variant if <code>swSyscond</code> evaluates to true and each <code>postBuildVariant</code> Criterion is fulfilled.</td>
</tr>
<tr>
<td>Base</td>
<td>ARObject</td>
</tr>
<tr>
<td>Attribute</td>
<td>Type</td>
</tr>
<tr>
<td>blueprint</td>
<td>DocumentationBlock</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>desc</td>
<td>MultiLanguageOverview Paragraph</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>formalBlueprintGenerator</td>
<td>BlueprintGenerator</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>postBuildVariantCondition</td>
<td>PostBuildVariant Condition</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>sdg</td>
<td>Sdg            0..1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Class</td>
<td>VariationPoint</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>shortLabel</td>
<td>Identifier</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>swSyscond</td>
<td>ConditionByFormula</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B.18: VariationPoint


## C Constraint History

### C.1 Change History for AUTOSAR R4.1.1

#### C.1.1 Added Constraints R4.1.1

<table>
<thead>
<tr>
<th>Id</th>
<th>Heading</th>
</tr>
</thead>
<tbody>
<tr>
<td>constr_5001</td>
<td>FMFeatureRelation shall not establish self-references</td>
</tr>
<tr>
<td>constr_5002</td>
<td>FMFeatureSelectionSet shall not have cycles in the include relation</td>
</tr>
<tr>
<td>constr_5003</td>
<td>FMFeatureSelectionSet shall not overwrite the state of included features</td>
</tr>
<tr>
<td>constr_5005</td>
<td>FMFeature shall not be referenced from more than one FMFeatureDecomposition</td>
</tr>
<tr>
<td>constr_5007</td>
<td>FMFeature shall only be referenced from one FMFeatureModel in the role feature</td>
</tr>
<tr>
<td>constr_5008</td>
<td>If present, the root feature shall be part of the feature model</td>
</tr>
<tr>
<td>constr_5009</td>
<td>Root feature shall be present if and only if the feature model is not empty</td>
</tr>
<tr>
<td>constr_5010</td>
<td>FMFeatureDecomposition may refer to a root feature of another feature model, but only once.</td>
</tr>
<tr>
<td>constr_5011</td>
<td>FMFormulaByFeaturesAndAttributes can refer to FMFeatures and FMAttributeDefs, but not to system constants</td>
</tr>
<tr>
<td>constr_5013</td>
<td>Attributes min and max of FMFeatureDecomposition reserved for category MULTIPLEFEATURE</td>
</tr>
<tr>
<td>constr_5018</td>
<td>FMFeatureSelectionSet shall not include the same feature twice</td>
</tr>
<tr>
<td>constr_5019</td>
<td>FMFeatureModel shall not contain the same FMFeature twice</td>
</tr>
<tr>
<td>constr_5020</td>
<td>Every FMFeature shall be contained in a FMFeatureModel</td>
</tr>
<tr>
<td>constr_5021</td>
<td>The underlying graph of a feature model shall be a tree.</td>
</tr>
<tr>
<td>constr_5022</td>
<td>The root feature of a FMFeatureModel refers to the root of the underlying tree.</td>
</tr>
<tr>
<td>constr_5023</td>
<td>FMFeatureSelectionSet may only refer to FMFeatures from the associated FMFeatureModel</td>
</tr>
<tr>
<td>constr_5024</td>
<td>FMFeatureSelectionSet shall not include itself</td>
</tr>
<tr>
<td>constr_5025</td>
<td>Multiple include in FMFeatureSelectionSet shall be consistent</td>
</tr>
<tr>
<td>constr_5026</td>
<td>Semantics of attributes min and max in class FMAttributeDef</td>
</tr>
<tr>
<td>constr_5027</td>
<td>Semantics of attributes max and min of FMAttributeDef in class FMAttributeValue</td>
</tr>
<tr>
<td>constr_5028</td>
<td>Only one FMAttributeValue per FMAttributeDef</td>
</tr>
</tbody>
</table>

Table C.1: changed Constraints in 4.1.1

#### C.1.2 Changed Constraints R4.1.1

none

#### C.1.3 Deleted Constraints R4.1.1

none
### C.1.4 Added Traceables R4.1.1

<table>
<thead>
<tr>
<th>Id</th>
<th>Heading</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS_FMDT_00001</td>
<td>Feature Models may be empty</td>
</tr>
<tr>
<td>TPS_FMDT_00002</td>
<td>Definition of Feature</td>
</tr>
<tr>
<td>TPS_FMDT_00003</td>
<td>Definition of Feature Selection</td>
</tr>
<tr>
<td>TPS_FMDT_00004</td>
<td>Definition of Feature Model</td>
</tr>
<tr>
<td>TPS_FMDT_00005</td>
<td>Definition of Product Model</td>
</tr>
<tr>
<td>TPS_FMDT_00006</td>
<td>Definition of Product Line Model</td>
</tr>
<tr>
<td>TPS_FMDT_00007</td>
<td>Definition of Product</td>
</tr>
<tr>
<td>TPS_FMDT_00008</td>
<td>Definition of Product Line</td>
</tr>
<tr>
<td>TPS_FMDT_00009</td>
<td>Definition of Feature Set of a FMFeatureSelectionSet</td>
</tr>
<tr>
<td>TPS_FMDT_00012</td>
<td>Default values for attributes <code>min</code> and <code>max</code></td>
</tr>
<tr>
<td>TPS_FMDT_00013</td>
<td>Feature Models are optional</td>
</tr>
<tr>
<td>TPS_FMDT_00014</td>
<td>Definition of Parent Feature, Child Feature</td>
</tr>
<tr>
<td>TPS_FMDT_00015</td>
<td>MANDATORYFEATURE</td>
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<td>TPS_FMDT_00016</td>
<td>OPTIONALFEATURE</td>
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<td>TPS_FMDT_00017</td>
<td>ALTERNATIVEFEATURE</td>
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<td>TPS_FMDT_00018</td>
<td>MULTIPLEFEATURE</td>
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<td>TPS_FMDT_00019</td>
<td>Predefined values for the <code>category</code> of FMFeatureRelation</td>
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<td>TPS_FMDT_00020</td>
<td>Structure of FMFeatureRelation</td>
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<td>TPS_FMDT_00021</td>
<td><code>category</code> attribute of FMFeatureRelation</td>
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<td>TPS_FMDT_00023</td>
<td>Extensibility of <code>category</code> attribute of FMFeatureRelation</td>
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<tr>
<td>TPS_FMDT_00024</td>
<td>Attributes <code>maximumIntendedBindingTime</code> and <code>minimumIntendedBindingTime</code> are only a hint</td>
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<tr>
<td>TPS_FMDT_00025</td>
<td>Set of affected variation points for a FMFeatureMapElement</td>
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<tr>
<td>TPS_FMDT_00030</td>
<td>Definition of Valid Feature Selection</td>
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<tr>
<td>TPS_FMDT_00032</td>
<td>Inclusion graph for FMFeatureSelectionSets</td>
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<tr>
<td>TPS_FMDT_00033</td>
<td>Special data for feature models</td>
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<td>TPS_FMDT_00034</td>
<td>Definition of Underlying Graph of a FMFeatureModel</td>
</tr>
<tr>
<td>TPS_FMDT_00035</td>
<td>Definition of Features of a FMFeatureModel</td>
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<td>TPS_FMDT_00036</td>
<td>Definition of Root Feature of a FMFeatureModel</td>
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<tr>
<td>TPS_FMDT_00037</td>
<td>Semantics of FMFeatureMapElement</td>
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<tr>
<td>TPS_FMDT_00038</td>
<td>Definition of Affected Variation Points for a FMFeature</td>
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<td>TPS_FMDT_00039</td>
<td>Name of a FMFeature</td>
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<td>TPS_FMDT_00040</td>
<td>Description for a FMFeature</td>
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<td>TPS_FMDT_00041</td>
<td>Purpose of FMFeatureDecomposition</td>
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<td>TPS_FMDT_00042</td>
<td>Purpose of FMFeature</td>
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<td>TPS_FMDT_00043</td>
<td>Purpose of FMFeatureModel</td>
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<td>Semantics of FMFeatureRelation</td>
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<td>Feature models are splittable</td>
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<td>TPS_FMDT_00048</td>
<td>FMFormulaByFeaturesAndSwSystemconsts can refer to features and system constants</td>
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<td>TPS_FMDT_00049</td>
<td>The result of FMConditionByFeaturesAndAttributes is interpreted as a boolean value.</td>
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<tr>
<td>TPS_FMDT_00050</td>
<td>The result of FMConditionByFeaturesAndSwSystemconsts is interpreted as a boolean value.</td>
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<tr>
<td>TPS_FMDT_00051</td>
<td>Purpose of FMAtributeDef</td>
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<tr>
<td>TPS_FMDT_00052</td>
<td>Identifying FMFeatureRelations</td>
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<tr>
<td>TPS_FMDT_00053</td>
<td>Semantics of FMAtributeValue</td>
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<tr>
<td>TPS_FMDT_00054</td>
<td>Semantics of attributes <code>minimumIntendedBindingTime</code> and <code>maximumIntendedBindingTime</code></td>
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</table>
### Table C.2: changed Constraints in 4.1.1

#### C.1.5 Changed Traceables R4.1.1

none

#### C.1.6 Deleted Traceables R4.1.1

none

### C.2 Change History for AUTOSAR R4.2.1 against R4.1.3

#### C.2.1 Added Constraints in 4.2.1

none

#### C.2.2 Changed Constraints in 4.2.1

none

#### C.2.3 Deleted Constraints in 4.2.1

none

#### C.2.4 Added Traceables in 4.2.1

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<th>Id</th>
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<tr>
<td>[TPS_FMDT_00064]</td>
<td>Usage of Life Cycle</td>
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### Table C.3: Added Traceables in 4.2.1
C.2.5  Changed Traceables in 4.2.1
none

C.2.6  Deleted Traceables in 4.2.1
none

C.3  Change History for AUTOSAR R4.2.2 against R4.2.1

C.3.1  Added Constraints in 4.2.2
none

C.3.2  Changed Constraints in 4.2.2
none

C.3.3  Deleted Constraints in 4.2.2
none

C.3.4  Added Traceables in 4.2.2
none

C.3.5  Changed Traceables in 4.2.2
none

C.3.6  Deleted Traceables in 4.2.2
none
C.4 Change History for AUTOSAR R4.3.0 against R4.2.2

C.4.1 Added Constraints in 4.3.0
none

C.4.2 Changed Constraints in 4.3.0
none

C.4.3 Deleted Constraints in 4.3.0
none

C.4.4 Added Traceables in 4.3.0
none

C.4.5 Changed Traceables in 4.3.0
none

C.4.6 Deleted Traceables in 4.3.0
none

C.5 Change History for AUTOSAR R4.3.1 against R4.3.0

C.5.1 Added Constraints in 4.3.1
none

C.5.2 Changed Constraints in 4.3.1
none
C.5.3  Deleted Constraints in 4.3.1
none

C.5.4  Added Traceables in 4.3.1
none

C.5.5  Changed Traceables in 4.3.1
none

C.5.6  Deleted Traceables in 4.3.1
none

C.6   Change History for AUTOSAR R4.4.0 against R4.3.1

C.6.1  Added Constraints in 4.4.0
none

C.6.2  Changed Constraints in 4.4.0
none

C.6.3  Deleted Constraints in 4.4.0
none

C.6.4  Added Traceables in 4.4.0
none
C.6.5  Changed Traceables in 4.4.0
none

C.6.6  Deleted Traceables in 4.4.0
none

C.7  Change History for AUTOSAR R19-11 against R4.4.0

C.7.1  Added Constraints in 19-11
none

C.7.2  Changed Constraints in 19-11
none

C.7.3  Deleted Constraints in 19-11
none

C.7.4  Added Traceables in 19-11
none

C.7.5  Changed Traceables in 19-11
none

C.7.6  Deleted Traceables in 19-11
none
C.8 Change History for AUTOSAR R20-11 against R19-11

C.8.1 Added Constraints in R20-11

none

C.8.2 Changed Constraints in R20-11

none

C.8.3 Deleted Constraints in R20-11

none

C.8.4 Added Traceables in R20-11

none

C.8.5 Changed Traceables in R20-11

none

C.8.6 Deleted Traceables in R20-11

none