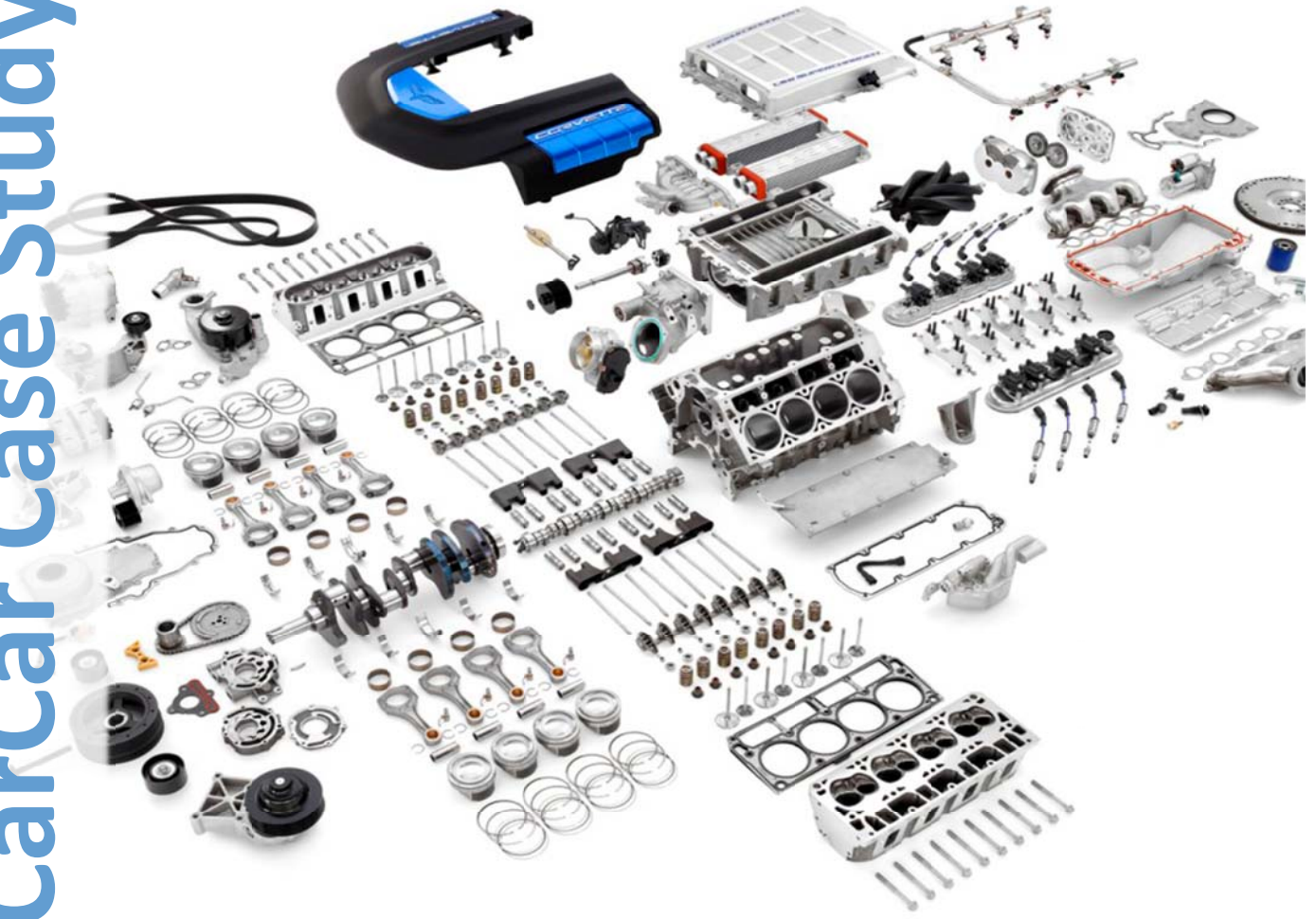


CarCar Case Study



ID _____

Before you begin

You have an online questionnaire where you have to introduce the results of the tasks developed and your opinions about the method. There is also a pre-exercise questionnaire with a set of questions you should fill-in about your previous background. Once you have finished with the first sheet of the questionnaire the system will show you a break screen for you to put the time when you start the task 1.

Please, do not close the web browser until the end of the exercise.

The questionnaire is at:

https://docs.google.com/forms/d/1wyKNk95tfwiS_byzTD98801vAMDv8shsgMbxR2C7TwQ/viewform

Problem Description

The CarCarSPL is Software Company which develops control systems for the automotive domain. They integrate sensors and computation nodes from different vendors and on top of that, they build their vehicle control system software. For managing the huge possible number of configurations, they are applying the software product line approach.

Now, one of their customers, BMW, a multinational automotive company is opening new market niches and has started to modify one of their cars, their top-class W5 station-wagon to become an ambulance (called W5-Ambu).

The Application Requirements Engineer has captured the customer requirements, and now we should configure the “best” possible vehicle control system.

System Requirements

The first point about the requirements is that they do not have, initially, budget constraints, the Control System’s cost is going to be added to their production costs, so what they need is a configuration that fulfills their requirements.

The system should integrate the highest possible number of security and multimedia systems but, at least to have a Control System that has ABS, traction control and the stability control, the GPS-Navigator and the cruise control are also desirable. The description of the different features can be found in Annex I.

They have also a lot of non-functional requirements. Our customer plans to sell their ambulances to EU countries, and there is an EU council regulation which establishes that ambulances should pass some safety tests and their control system should be considered as

“Safety Critical System”. This implies that the Vehicle Control System should have minimum levels of reliability, and some constraints are also defined for the system’s performance.

The reliability characteristic in our systems is broken down in:

- **Fault Tolerance:** the degree to which a system, product or component operates as intended despite the presence of hardware or software faults.
- **Maturity:** the degree to which a system meets needs for reliability under normal operation.

We measure the fault tolerance with, among others, the probability of failure of each system¹ which is extracted from the architecture.

The *probability of failure* of our systems usually is below 0.00006 but *in this specific case* the requirements state that the probability of failure should be below 0.00004.

For achieving the levels of reliability to meet the safety critical system consideration, some non-functional requirements are defined related to the reliability of the system. Safety Critical Systems should also have a maximum level of CPU utilization so as to assure that, in every single situation, the systems is able to compute a response in less than a specific time (a.k.a *Latency time*) that also is critical for safety critical embedded systems. In addition, since the system is going to be deployed in a new set of distributed high-performance set of embedded computation nodes, the memory needs to be also reduced. The performance in our systems is broken down in:

- **Time behavior:** the response and processing times and throughput rates of a system when performing its function, under stated conditions in relation to an established benchmark.
- **Resource Utilization:** the amounts and types of resources used when the software performs its function under stated conditions in relation to an established benchmark.

We measure the time behavior of our system among others with the *latency time*. Latency time measures the time elapsed between the reception of an input event and the computation of the results. The resource utilization is measured by means of the CPU utilization and the memory consumption

In this *specific* case, the systems *should* have a *latency time* that goes below the common specific level established for the products of the Vehicle Control System which is 55 μ s. our customer needs, to accomplish the regulations, the systems to be below 50 μ s.

The Resource Utilization is also critical. EU regulations establish that a safety critical system should *have* a *CPU utilization* of less than 80%. The threshold for our vehicle control systems SPL establishes a maximum CPU utilization of 85% and all the possible combinations are below the 85% level. However the most CPU-intensive features will

¹ We will use the term system to refer also to the system (ABS, Traction Control etc.) that integrates the Vehicle Control System

make the vehicle control system as a whole to be consuming more than 80%, so probably some features will need to be discarded. You have also to consider that the CPU-Utilization can be improved by upgrading the hardware in which the vehicle control system is deployed but some other requirements cannot be achieved in such a simple way (e.g., fault tolerance).

The last quality characteristic is a domain specific quality characteristic for the automotive industry, which are the different levels of safety that a car offers to the passengers. In the European Union there are different levels of Safety and are certified through the EuroNCAP safety level. CarCar only develops security systems for EuroNCAP level 4 and EuroNCAP level 5. The different levels of EuroNCAP are obtained by the crash tests results and the number and reliability of the safety systems available in the car. In this specific case the requirement specification specifies that EuroNCAP level 4 is mandatory, but it would be also desirable to achieve the EuroNCAP level 5.

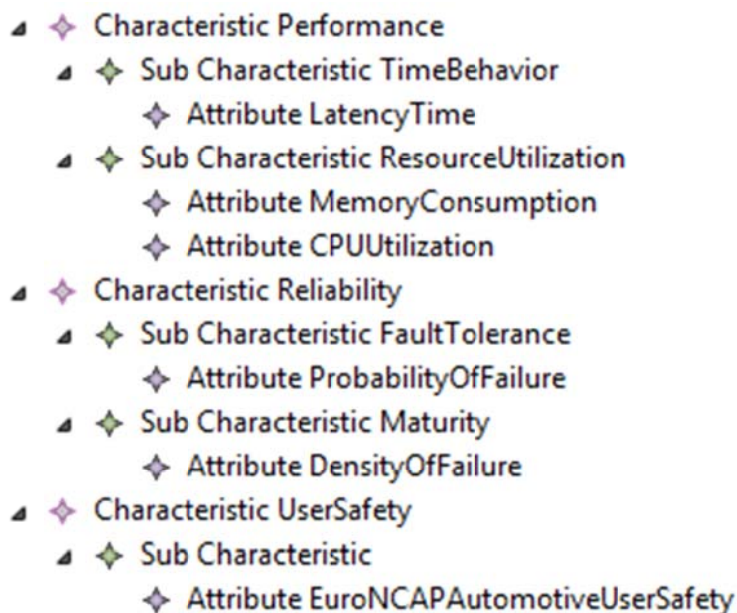


Figure 1 Quality-Model Structure

Please go to the questionnaire and fill in the start time of task 1.

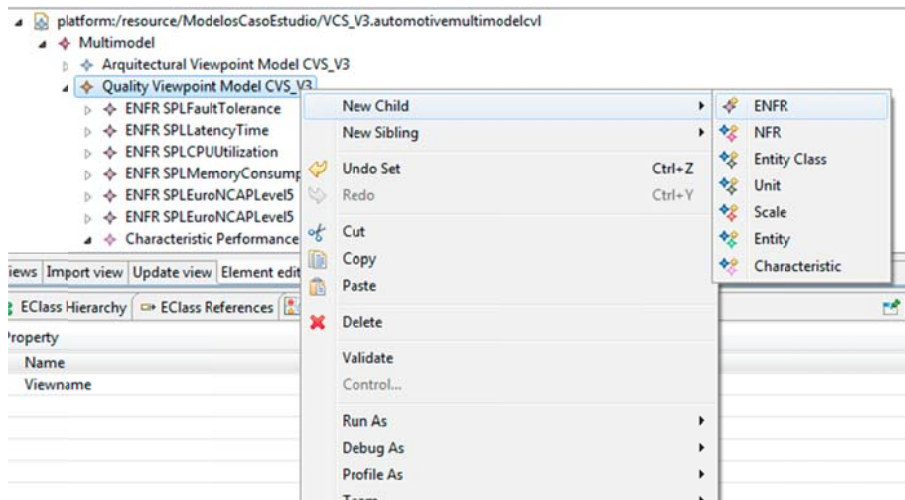
Task 1: Product NFRs definition

Define the Non-Functional requirements that are specific for the product under development. For doing that you should consider the non- SPL functional requirements aforementioned and define new ones when required². Remember that, if you define a new NFR that goes further the definition of a SPL's please check both when you configure the product. You have to introduce a new ENFR (Extended NFRs defined in the multimodel) in the QuaDAI tool, following the instructions described below:

² Please do not change the NFR definition, if you need additional requirements, define the ones you need.

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- i) Select the Quality Viewpoint Model, and in the contextual menu that appears when right-clicking, select **ENFR**:

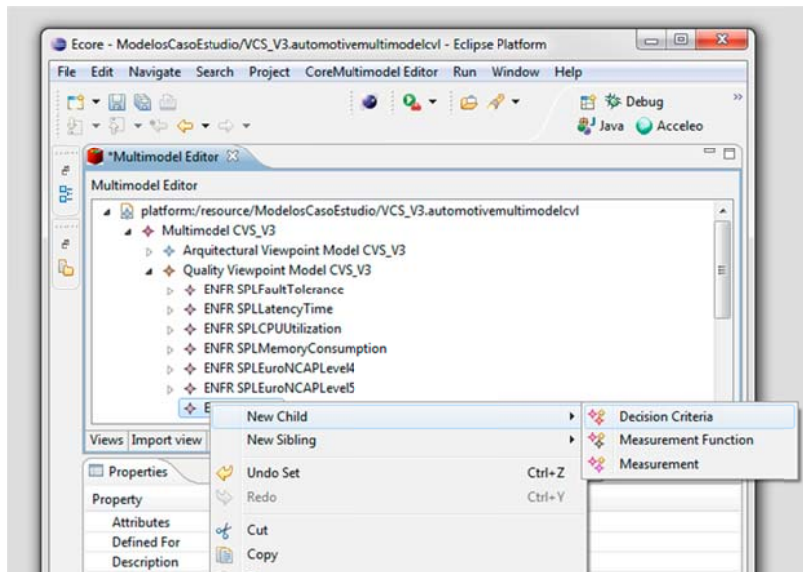


- ii) Fill in the data, the **Attributes**, **Description**, **Name** and **NL Restriction**. Be sure that the **multimodel** field shows the value *Multimodel* and the name of our multimodel. Otherwise please in the drop-down menu of the field select the proper value. The *mandatory* field is not required and the **selected** field should remain false until the configuration task.

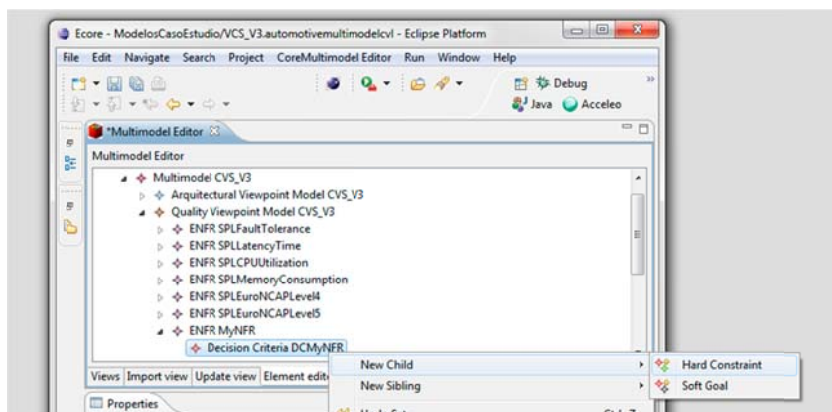
Property	Value
Attributes	
Defined For	
Description	
Mandatory	<input type="checkbox"/> false
Multimodel	
Name	
NL Restriction	
OCL Restriction	
Operationalization	
Selected	<input type="checkbox"/> false

- iii) The next step is to define the decision criteria that in which we will define the thresholds for our NFR. For the decision criteria the only thing I should enter is the **name** field.

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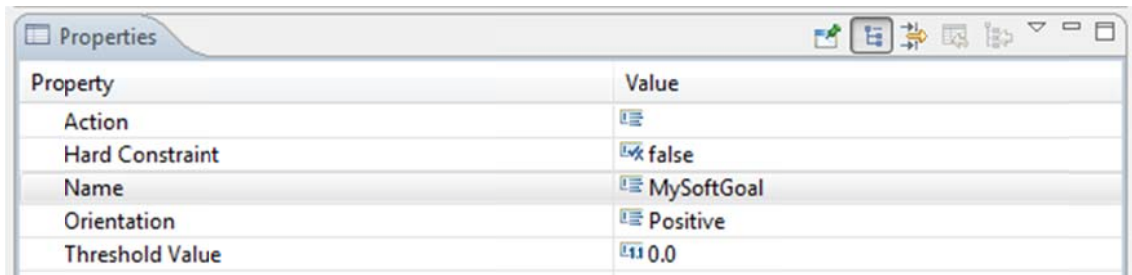
- iv) Now we should define the NFR's threshold as a hard constraint (if it is something that the product should accomplish) or a soft goal (if it is a desirable property) as shown.



- iv.a Hard Constraints: If we are defining a hard constraint we have to define the name, the Lower and Upper Bound for defining the range of acceptable values. For example the following threshold describes a NFR whose values are allowed to range from 0 to 99.

Properties	
Property	Value
Action	
Hard Constraint	true
Lower Bound	0.0
Name	MyHardConstraint
Upper Bound	99.0

- iv.b Softgoals: If we are defining a soft goal, we have to define the name, the orientation (positive for the-higher-the-better NFRs and negative for the-lower-the-better ones). For example the following threshold a positive threshold with no minimum value.



Property	Value
Action	
Hard Constraint	false
Name	MySoftGoal
Orientation	Positive
Threshold Value	0.0

Once you have defined the NFRs in the multimodel, please return to the web browser and fill in the questionnaire with the information related to the task 1. You should introduce the product specific NFRs you have defined here.

Task 2: Configuration

Please fill in the start time in the questionnaire as soon as you start reading this

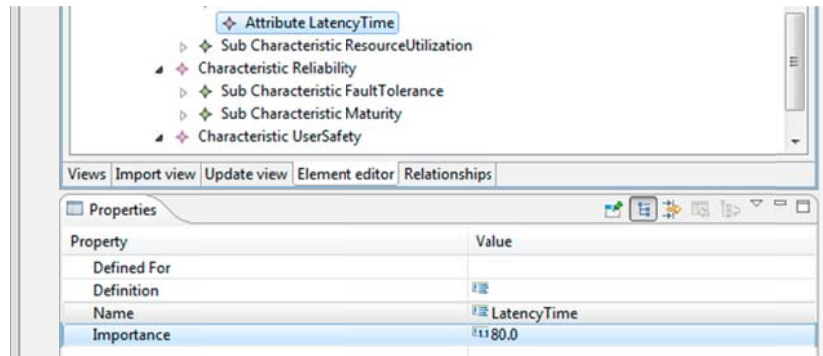
The next step is to define the configuration of the product. You have to select the set of features, the set of NFRs of the W5-Ambu and the prioritization of the quality attributes you want to take into account for solving the eventual design decisions that would appear. The details on how each of these processes should be performed are described below. The natural process could be firstly select the features, then validate the consistency of that features configuration. You will define a valid feature configuration from the point of view of the variability viewpoint. Next you will select the NFRs and probably obtain a configuration that is not valid from the point of view of quality and variability (there are some features that realize non-functional requirements and, if a NFR is selected, and you will need to reconfigure and again and again. Finally you will introduce the quality attributes priority and you will add a third constraint that will make you to re-do the previous steps.

The recommended workflow is as follows:

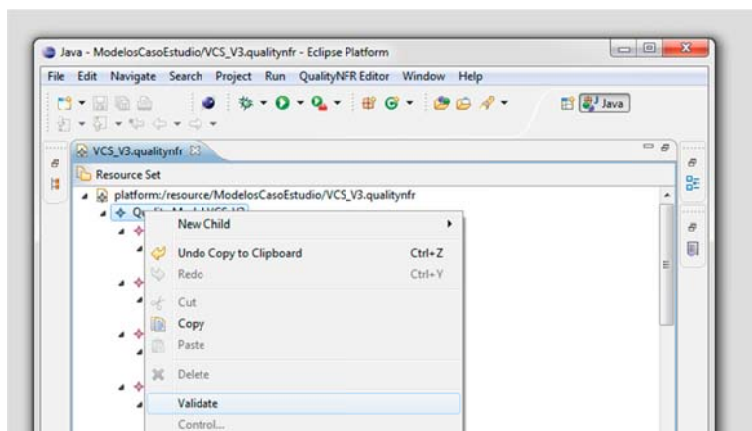
- **Task 2.1:** First, establish the priority of the quality attributes, by introducing a value ranging from 0 to 1. This value expresses the fraction of 1 that you assign to each attribute (1 for critical 0 for trivial). If a quality attribute is not important (or less important) keep it at 0 level. You have to take into account also that you should leave some degrees of freedom for i) these quality attributes that are impacted negatively by other prioritized quality attributes or ii) these quality attributes that, whereas having certain importance, do not reflect constraints or requirements on the product (the maps of impacts between attributes is described in annex II). These priorities are introduced in the Tool on the Importance Field of the EAttribute³:

³ This is only an example from other configuration; please use your own values.

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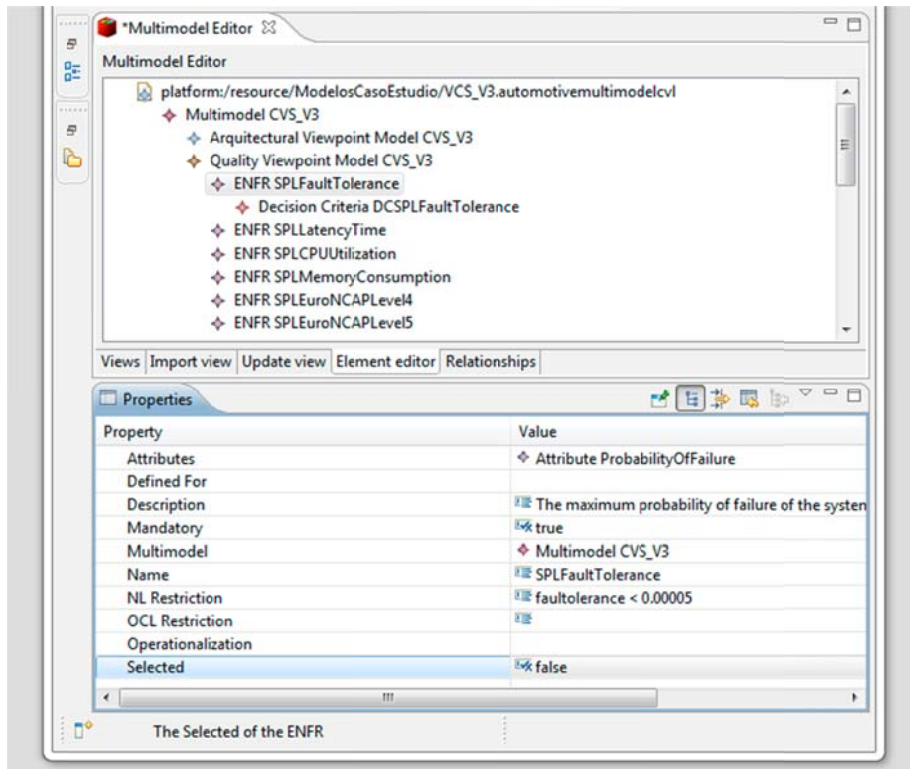


Each time you need to validate whether your priorities are consistent with the impacts described in annex II or not, you can validate the configuration through the validation menu item in the contextual menu.

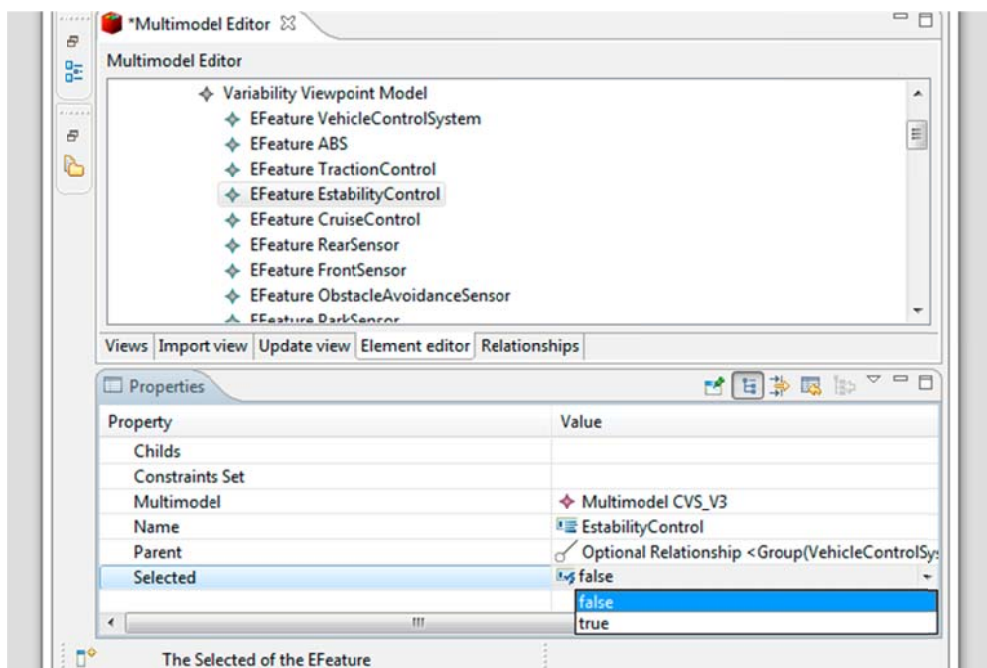


- **Task 2.2:** Second, select the SPL and the product specific NFRs the product has to fulfill. Remember, if a product specific NFRs restricts a SPL's NFR, please select both (this will help because the relationships with the features are, at the moment, defined with the SPL's NFR not with the product-specific NFRs).

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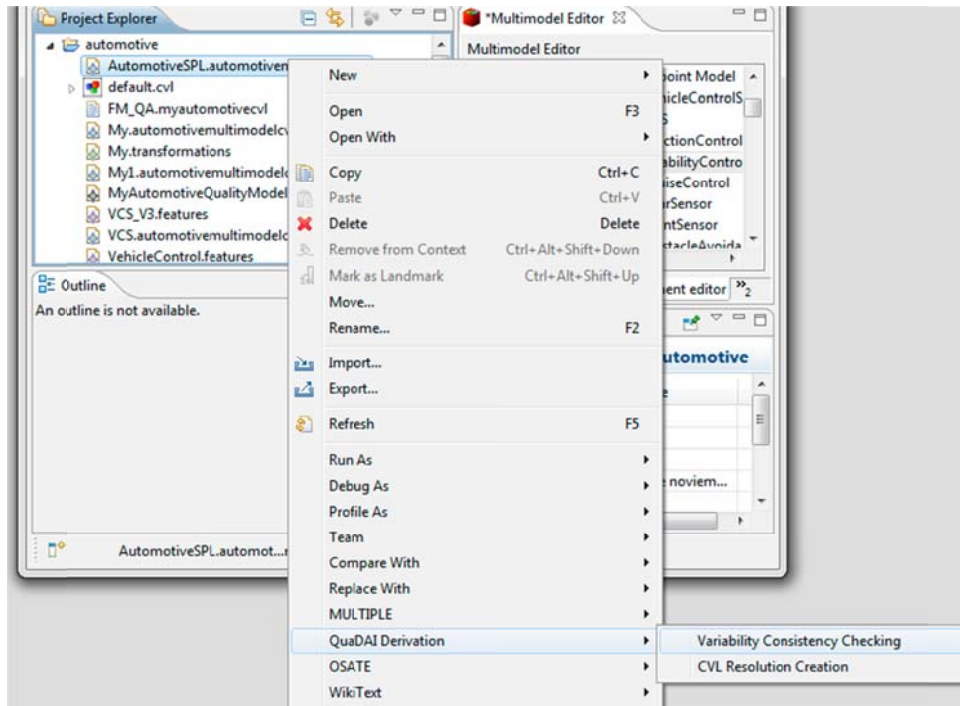


- **Task 2.3:** Finally, select the features you want the product to have by checking them in the tool.

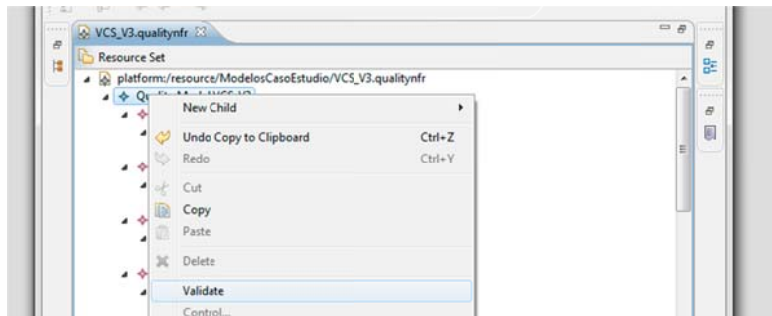


You can validate that the selected features met the restrictions defined in the features model by executing the Variability Consistency Checking, selecting the multimodel in the project explorer, right-clicking and selecting the QuaDAI Derivation/Variability Consistency Checking option

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You will have to, validate the consistency as a whole during the process by using the validate option of the contextual menu over an entity in the multimodel, to check that the features that you select meet also the restrictions defined among quality attributes and non-functional requirements through the validation menu item in the contextual menu. These relationships are described in the annex III.

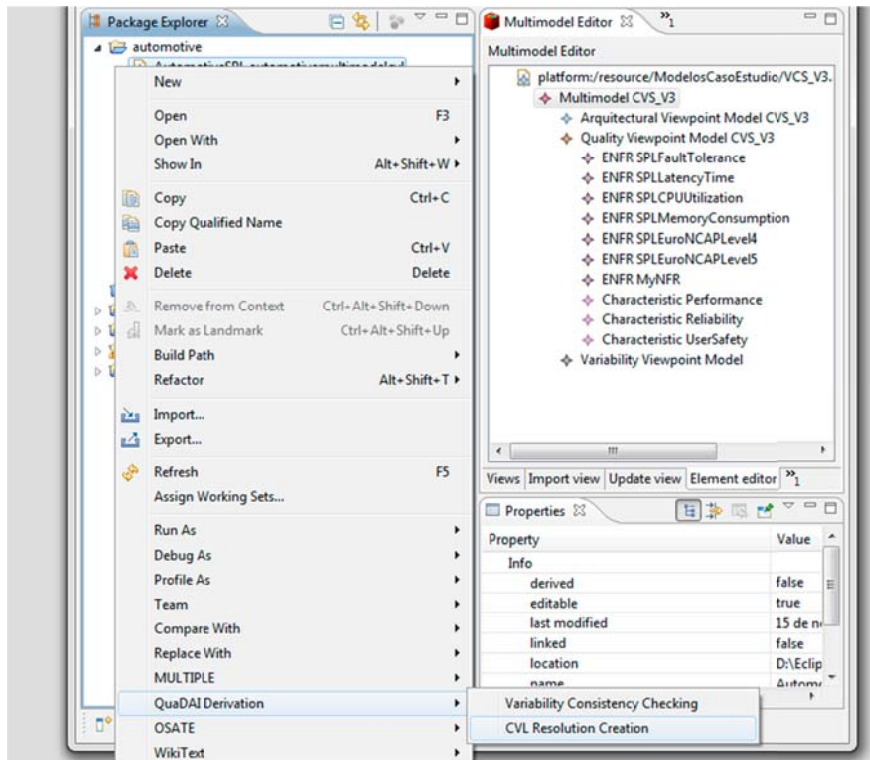


We are aware that the Features are the first-class citizens in SPL and the idea is to select the maximum number of features (functionality), but we first define the restrictions so as to simplify the process. You first prune the search space and then decide which features you want to select. Our CarCarSPL's feature model can produce (without NFR and Quality attributes restrictions) 305 valid products, and thus, it is better to first constrain the problem space and then select the ones that best fit the functional requirements.

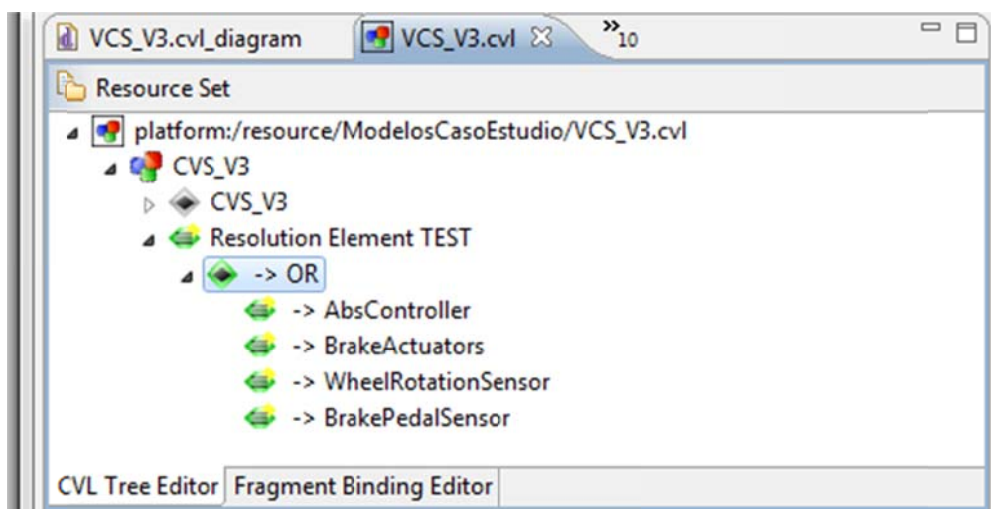
Now is time to introduce the results of the process in the questionnaire.

Task 3: Derivation

Once you have obtained the product configuration that fit the customer requirements, what we do is to derive the CVL resolution model as an intermediate step before obtaining the final architecture. What we simply do is to right-click on the project explorer and to select the CVL Resolution Creation. This will ask were to put the CVL file, and once introduced, it generates the CVL Resolution Model.



Next we show a test case in which we have selected only the ABS Feature and, with the relationships among features and variability points in the architectural view we can, by applying model transformation techniques of obtaining the CVL Resolution Model.



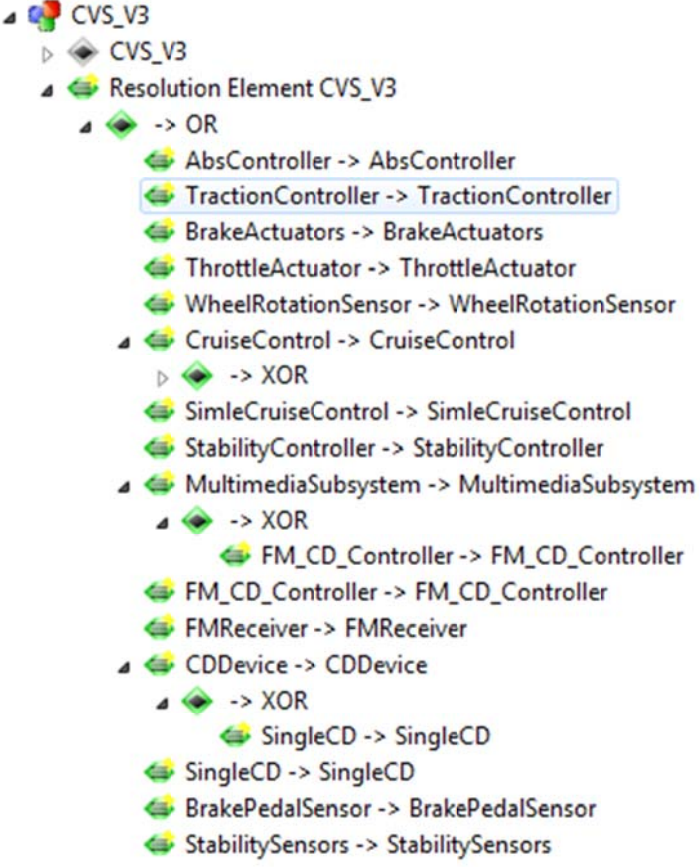
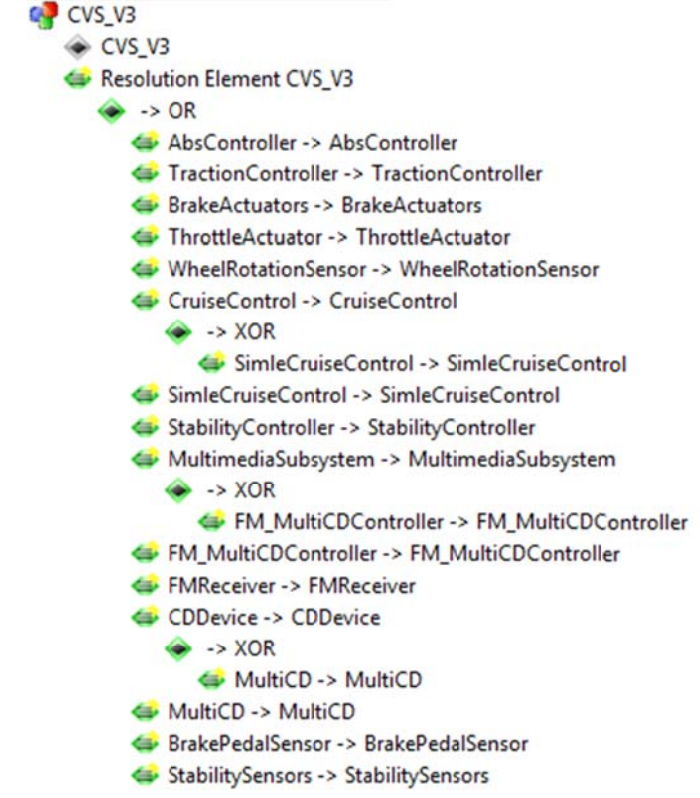
This is an important result because CVL allows to, with the resolution model, obtain the final models of the product architecture (in general CVL works with any kind of model).

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Now you have to introduce in the online questionnaire the results obtained

Resolution	Items
Configuration 1	<pre> graph TD CVS_V3 --> RE_CVS_V3[Resolution Element CVS_V3] RE_CVS_V3 --> OR1[OR] OR1 --> AbsController --> AbsController OR1 --> TractionController --> TractionController OR1 --> BrakeActuators --> BrakeActuators OR1 --> ThrottleActuator --> ThrottleActuator OR1 --> WheelRotationSensor --> WheelRotationSensor OR1 --> StabilityController --> StabilityController OR1 --> MultimediaSubsystem --> MultimediaSubsystem OR1 --> XOR1[XOR] XOR1 --> FM_CD_Controller --> FM_CD_Controller XOR1 --> FM_CD_Controller --> FM_CD_Controller XOR1 --> FMReceiver --> FMReceiver OR1 --> XOR2[XOR] XOR2 --> CDDevice --> CDDevice XOR2 --> SingleCD --> SingleCD XOR2 --> SingleCD --> SingleCD OR1 --> BrakePedalSensor --> BrakePedalSensor OR1 --> StabilitySensors --> StabilitySensors </pre>
Configuration 2	<pre> graph TD CVS_V3 --> RE_CVS_V3[Resolution Element CVS_V3] RE_CVS_V3 --> OR1[OR] OR1 --> AbsController --> AbsController OR1 --> TractionController --> TractionController OR1 --> BrakeActuators --> BrakeActuators OR1 --> ThrottleActuator --> ThrottleActuator OR1 --> WheelRotationSensor --> WheelRotationSensor OR1 --> StabilityController --> StabilityController OR1 --> MultimediaSubsystem --> MultimediaSubsystem OR1 --> XOR1[XOR] XOR1 --> FM_MultiCDController --> FM_MultiCDController XOR1 --> FM_MultiCDController --> FM_MultiCDController XOR1 --> FMReceiver --> FMReceiver OR1 --> XOR2[XOR] XOR2 --> CDDevice --> CDDevice XOR2 --> MultiCD --> MultiCD XOR2 --> MultiCD --> MultiCD OR1 --> BrakePedalSensor --> BrakePedalSensor OR1 --> StabilitySensors --> StabilitySensors </pre>

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Configuration 3	 <pre> graph TD CVS_V3 --> CVS_V3_1[CVS_V3] CVS_V3_1 --> RE_CVS_V3[Resolution Element CVS_V3] RE_CVS_V3 --> OR1[OR] OR1 --> AbsController[AbsController -> AbsController] OR1 --> TractionController[TractionController -> TractionController] OR1 --> BrakeActuators[BrakeActuators -> BrakeActuators] OR1 --> ThrottleActuator[ThrottleActuator -> ThrottleActuator] OR1 --> WheelRotationSensor[WheelRotationSensor -> WheelRotationSensor] OR1 --> CruiseControl[CruiseControl -> CruiseControl] OR1 --> MultimediaSubsystem[MultimediaSubsystem -> MultimediaSubsystem] OR1 --> CDDevice[CDDevice -> CDDevice] OR1 --> StabilitySensors[StabilitySensors -> StabilitySensors] CruiseControl --> XOR1[XOR] XOR1 --> SimpleCruiseControl1[SimpleCruiseControl -> SimpleCruiseControl] XOR1 --> StabilityController[StabilityController -> StabilityController] MultimediaSubsystem --> XOR2[XOR] XOR2 --> FM_CD_Controller[FM_CD_Controller -> FM_CD_Controller] XOR2 --> FMReceiver[FMReceiver -> FMReceiver] CDDevice --> XOR3[XOR] XOR3 --> SingleCD[SingleCD -> SingleCD] XOR3 --> BrakePedalSensor[BrakePedalSensor -> BrakePedalSensor] </pre>
Configuration 4	 <pre> graph TD CVS_V3 --> CVS_V3_1[CVS_V3] CVS_V3_1 --> RE_CVS_V3[Resolution Element CVS_V3] RE_CVS_V3 --> OR1[OR] OR1 --> AbsController[AbsController -> AbsController] OR1 --> TractionController[TractionController -> TractionController] OR1 --> BrakeActuators[BrakeActuators -> BrakeActuators] OR1 --> ThrottleActuator[ThrottleActuator -> ThrottleActuator] OR1 --> WheelRotationSensor[WheelRotationSensor -> WheelRotationSensor] OR1 --> CruiseControl[CruiseControl -> CruiseControl] OR1 --> MultimediaSubsystem[MultimediaSubsystem -> MultimediaSubsystem] OR1 --> CDDevice[CDDevice -> CDDevice] OR1 --> StabilitySensors[StabilitySensors -> StabilitySensors] CruiseControl --> XOR1[XOR] XOR1 --> SimpleCruiseControl1[SimpleCruiseControl -> SimpleCruiseControl] XOR1 --> StabilityController[StabilityController -> StabilityController] MultimediaSubsystem --> XOR2[XOR] XOR2 --> FM_MultiCDController[FM_MultiCDController -> FM_MultiCDController] XOR2 --> FMReceiver[FMReceiver -> FMReceiver] CDDevice --> XOR3[XOR] XOR3 --> MultiCD[MultiCD -> MultiCD] XOR3 --> BrakePedalSensor[BrakePedalSensor -> BrakePedalSensor] </pre>

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Configuration 5	<div>  GPSCell -> GPSCell  BluetoothModule -> BluetoothModule  iSafeDialer -> iSafeDialer </div> <p style="text-align: center;">Configuration 1 +</p>
Configuration 6	<div>  GPSCell -> GPSCell  BluetoothModule -> BluetoothModule  iSafeDialer -> iSafeDialer </div> <p style="text-align: center;">Configuration 2 +</p>
Configuration 7	<div>  GPSCell -> GPSCell  BluetoothModule -> BluetoothModule  iSafeDialer -> iSafeDialer </div> <p style="text-align: center;">Configuration 3 +</p>
Configuration 8	<div>  GPSCell -> GPSCell  BluetoothModule -> BluetoothModule  iSafeDialer -> iSafeDialer </div> <p style="text-align: center;">Configuration 4 +</p>
None of the aforementioned	(In any other case)

The last thing to do is to fulfill the method survey. Please take into account that the survey is aimed to evaluate **the method not the tool**. We know that the tool has a lot of things that can be improved and you are invited to provide us feedback through the question 23 of the survey or by email to:

jagonzalez@dsic.upv.es

dblanes@dsic.upv.es