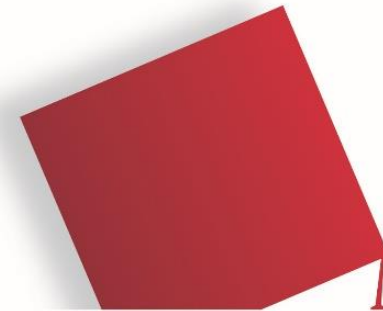


# HOW TO DESIGN PRODUCT LINES BY MEANS OF MBSE

Prof. Dr. Claudio Zuccaro, HS München  
Andreas Korff, PTC



ptc



UNIVERSITY  
OF APPLIED SCIENCES  
**MUNICH**



- Short Introduction to Orthogonal Variability Modeling (OVM)
  - Approaches for Variant Modeling with OMG SysML
  - Model Elements of OVM
- How to construct a Product Line Model in SysML
  - Vs. „normal Generalizations“/Redefinitions (helpful, but not here)
- Example to make decisions and generate a Product Model
  - Check Consistency (using automatic Verification), e.g. missing Traceability
- Extending OVM
  - Example Parametric Variability
- External vs. Internal Variability
  - Optimizing Product Line Model and Variability Model
- Q&A

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# SHORT INTRODUCTION TO OVM

# THE PROBLEM



Systems modelling language **SysML**:  
There are **no** elements explicitly  
depicting product variability



1 variant

However, since a while, most systems  
belong to **product lines with many  
variants**:



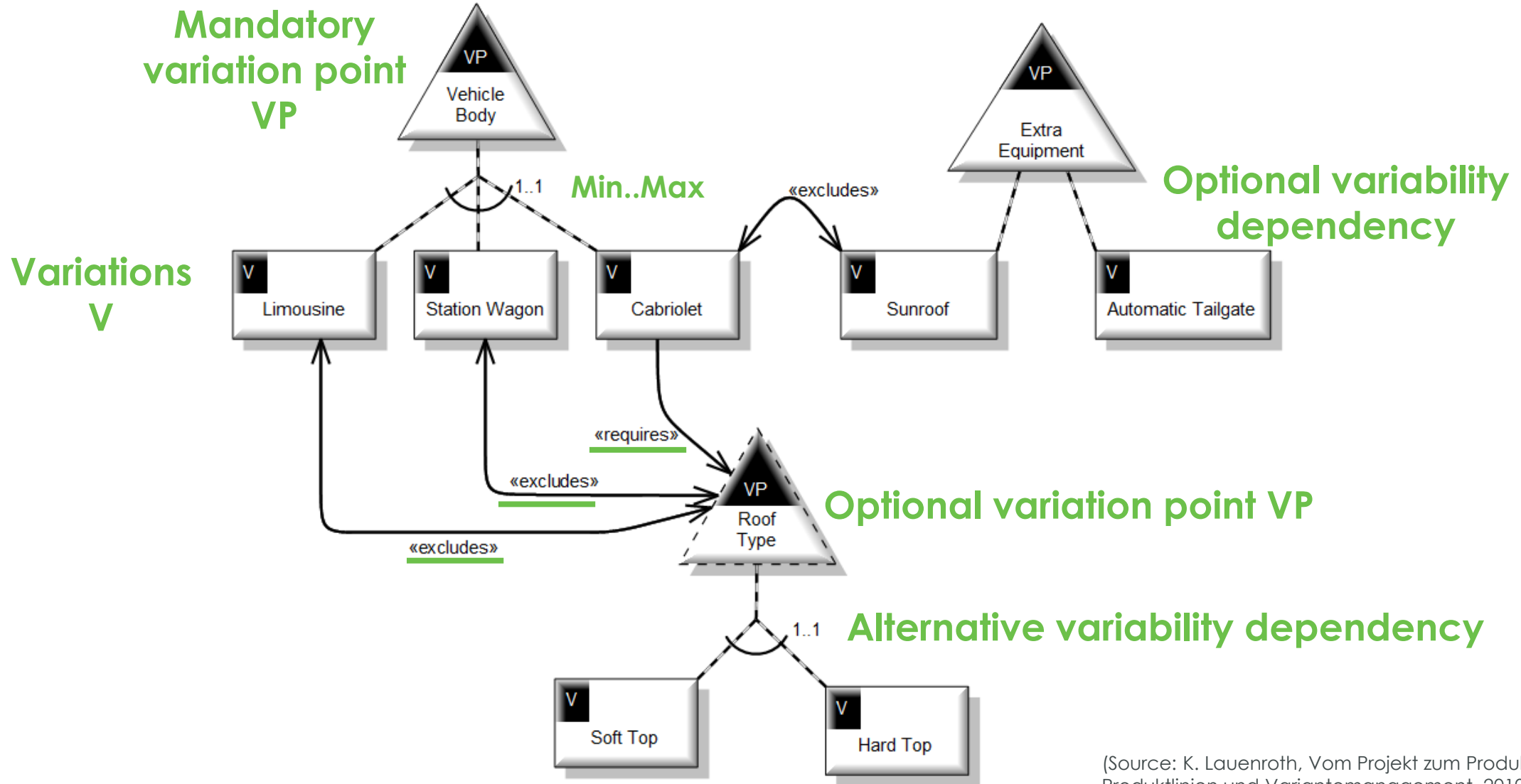
>  $10^{23}$  variants



Several approaches exist to extend SysML:

- **VAMOS method** by Tim Weilkiens uses the profile mechanism of SysML to extend the language with a concept for variant modeling
  - Variability model and system model are not separate (not orthogonal)
- **Feature models** (feature trees) and the **Orthogonal Variability Modelling Language OVM** (\*) depict only the variability of product lines
  - Variability model is linked to a separate 150% system model
- The concepts of **OVM** are defined in **ISO 26550:2015**
  - ✓ Orthogonality of OVM facilitates model verification
  - ✓ OVM is aligned to a standard

# ORTHOGONAL VARIABILITY MODELING LANGUAGE (OVM)



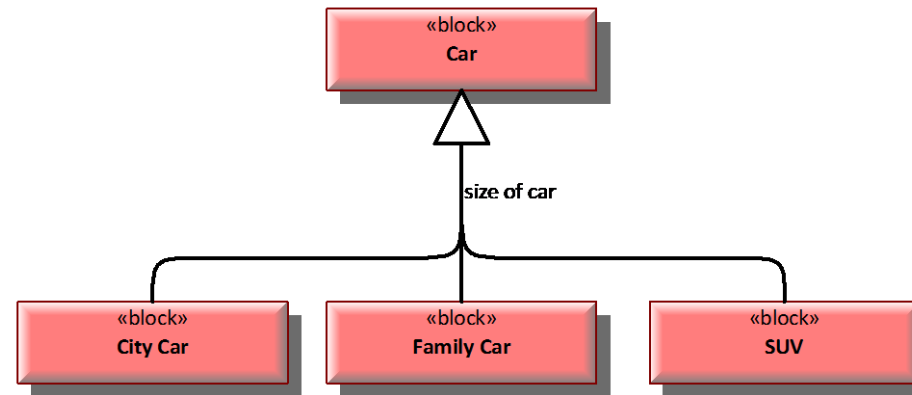
(Source: K. Lauenroth, Vom Projekt zum Produkt durch Produktlinien und Variantemanagement, 2010)

# 2

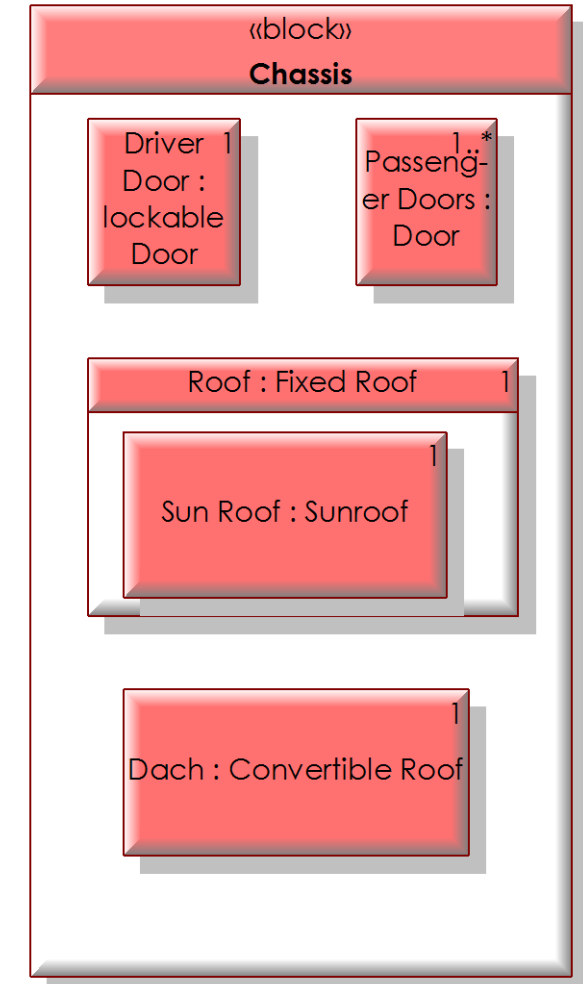
## HOW TO CONSTRUCT A PRODUCT LINE MODEL IN SYSML

- In SysML, there are means to express similarities and for reuse

- Generalization
- Type and Usage for
  - Blocks, Parts and Ports
  - Activities
  - State Machines
  - Interactions
  - Etc.



- Overloading a model from 100% product to a 150% product line is possible
  - Diagrams as filtered views can separate the distinct product perspectives
  - Example: More than just one roof in the car chassis



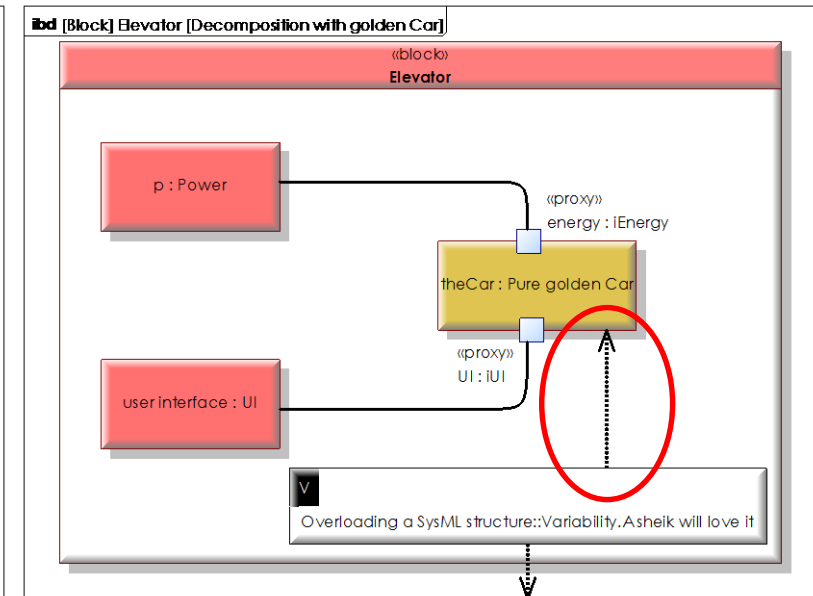
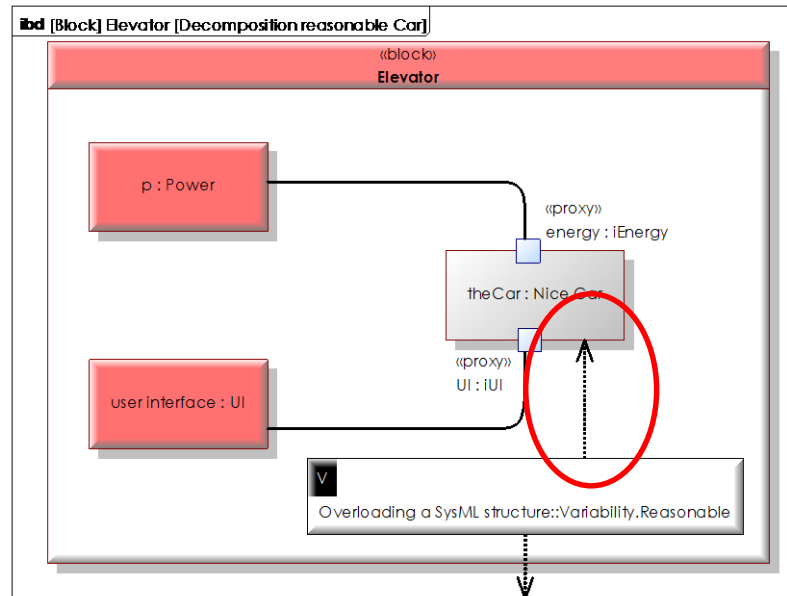
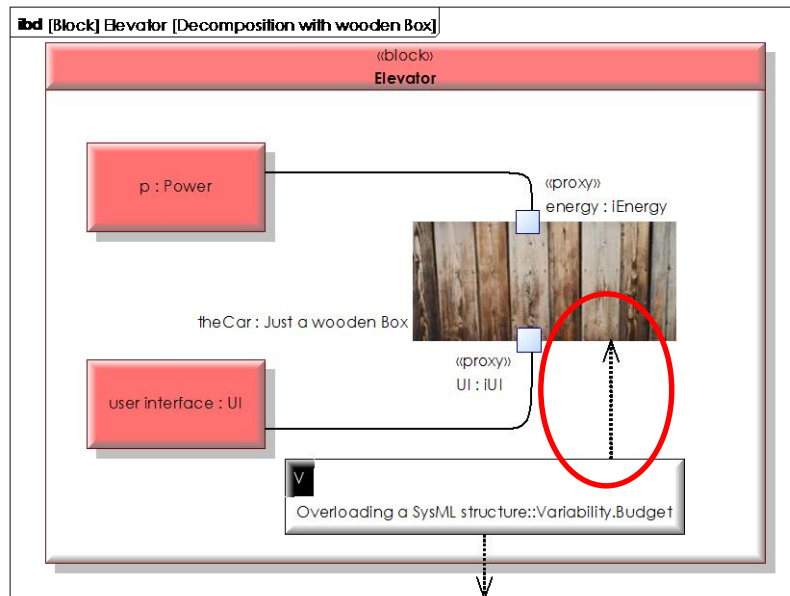


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# EXAMPLE TO MAKE DECISIONS AND GENERATE A PRODUCT MODEL

# PRODUCT LINE MODEL MECHANISMS

- Instead of copying similar elements between different product models, the similarities exist only once in one model.
- Specific elements for a product must be marked as variable
  - Linked with an OVM Artifact Dependency to a variable element
  - Decisions on the variability can be then traced to the linked modeling elements
    - If I want a low-budget elevator, I get a wooden box as the car



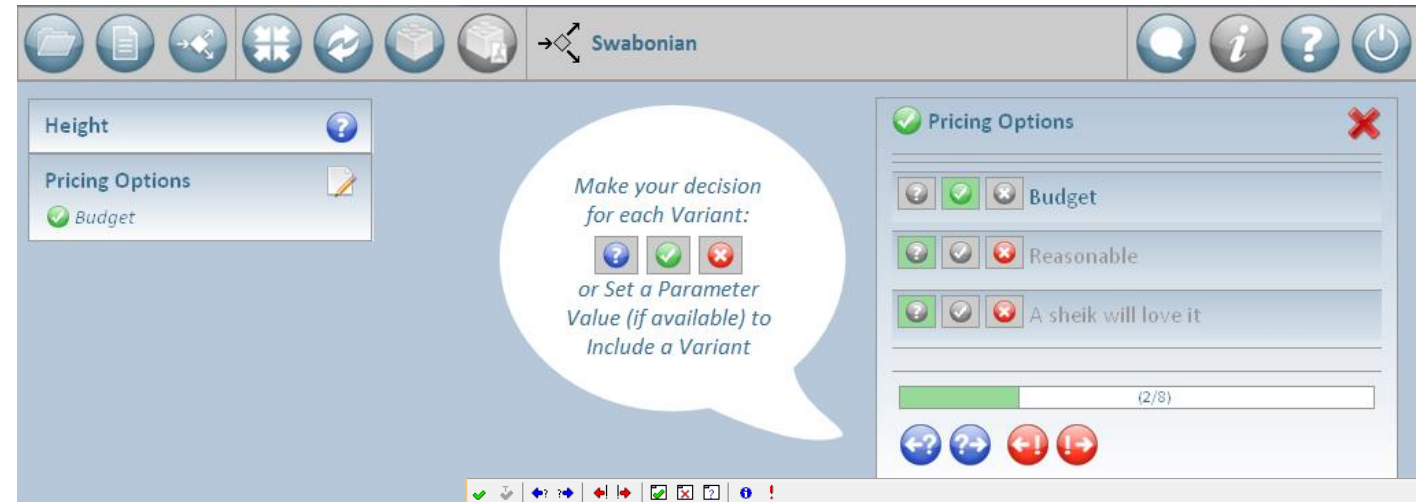
# HOW TO MAKE DECISIONS IN THE VARIABILITY MODEL



- OVM DecisionSets contain
  - explicitly included
  - explicitly excluded
  - (Variability Parameter Values)

- Implicit Decisions can be calculated
  - Using Variability Dependencies
    - Requires/excludes

- DecisionSets can be
  - Complete
  - Incomplete
  - Consistent
  - Inconsistent
    - Only here a product model cannot be generated



Model	Decision Set
\\Enabler\AKORFF11\KnowEnterprise\OVM Modeling for Schindler\3	Overloading a SysML structure:Variability.Swabonian

Variability Items				
Name	Decision	Value	Status	Overloading a SysML structure
Overloading a SysML structure:Variability.Height			Undecided	
Overloading a SysML structure:Variability.Elevator Height	Undecided	<none>	Undecided	
Overloading a SysML structure:Variability.Pricing Options			Included	Overloading a SysML structure:Variability.Pricing Options.Alternative Choice1
Overloading a SysML structure:Variability.Budget	Included	<none>	Included	
Overloading a SysML structure:Variability.Reasonable	Undecided	<none>	Excluded	
Overloading a SysML structure:Variability.A sheik will love it	Undecided	<none>	Excluded	
Overloading a SysML structure:Variability.Renaming?			Included	Overloading a SysML structure:Variability.Pricing Options.Alternative Choice1
Overloading a SysML structure:Variability.diagName 1	Undecided	[Block] Elevator [Decomposition]	Included	Overloading a SysML structure:Variability.Pricing Options.Alternative Choice1
Overloading a SysML structure:Variability.Car Colour			Undecided	
Overloading a SysML structure:Variability.Number of Building Stories (first attempt)			Undecided	
Overloading a SysML structure:Variability.Number of Building Stories			Undecided	
Overloading a SysML structure:Variability.Time between loading			Undecided	
Overloading a SysML structure:Variability.Battery Type in Use			Undecided	

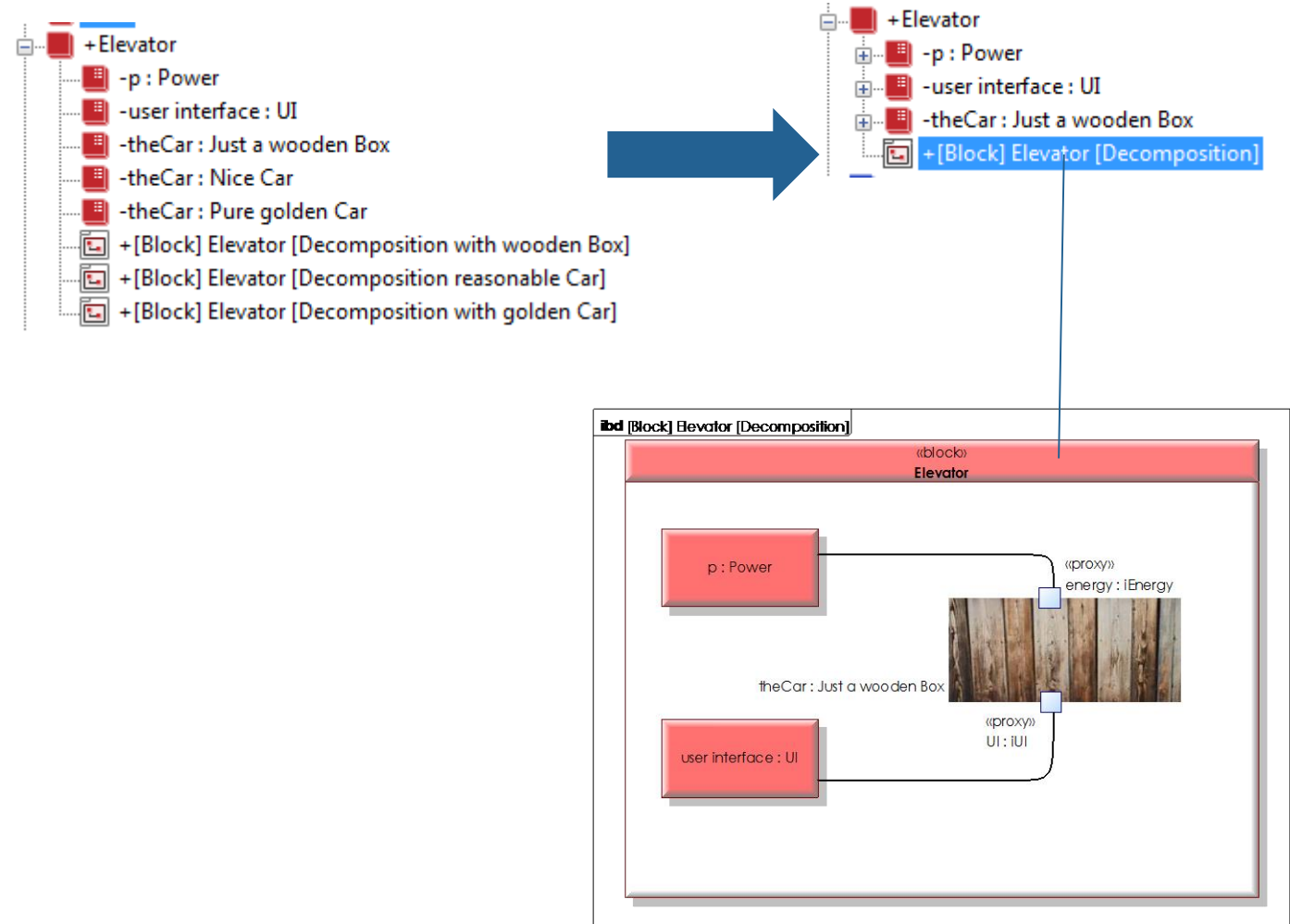
  

Name	Decision	Value	Status	Included By	Excluded By	Reason
△ Height			Undecided			
□ Elevator Height	Undecided	<x>	Undecided			
△ Pricing Options			Included	Overloading a SysML structure:Variability.Pricing Options.Alternative Choice1		
□ Budget	Include		Included			
□ Reasonable	Undecided		Excluded		Overloading a SysML structure:Variability.Pricing Options.Alternative Choice1	
□ A sheik will love it	Undecided		Excluded		Overloading a SysML structure:Variability.Pricing Options.Alternative Choice1	
△ Renaming?			Included	Overloading a SysML structure:Variability.Pricing Options.Alternative Choice1		
△ Car Colour			Undecided			
△ Number of Building Stories (first attempt)			Undecided			
△ Number of Building Stories			Undecided			
△ Time between loading			Undecided			
△ Battery Type in Use			Undecided			

Variants: 4/23 | Variation Points: 2/8 | Inconsistent: 0 | Undecided Mandatory Variation Points: 5



- All explicitly excluded Variants can be pruned out
  - Including all artifacts linked to them
- All implicitly excluded Variants can be calculated and pruned out
  - Also including all artifacts linked to them
- Model element pruning needs to retain model consistency
  - Contained objects
  - Object links
  - Etc.



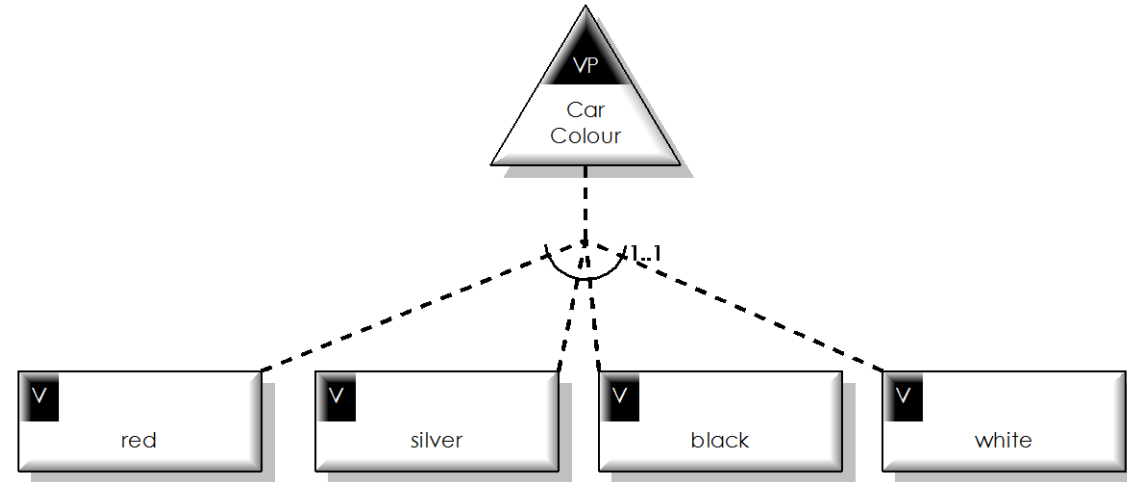
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## PARAMETRIC VARIABILITY AS OVM EXTENSION

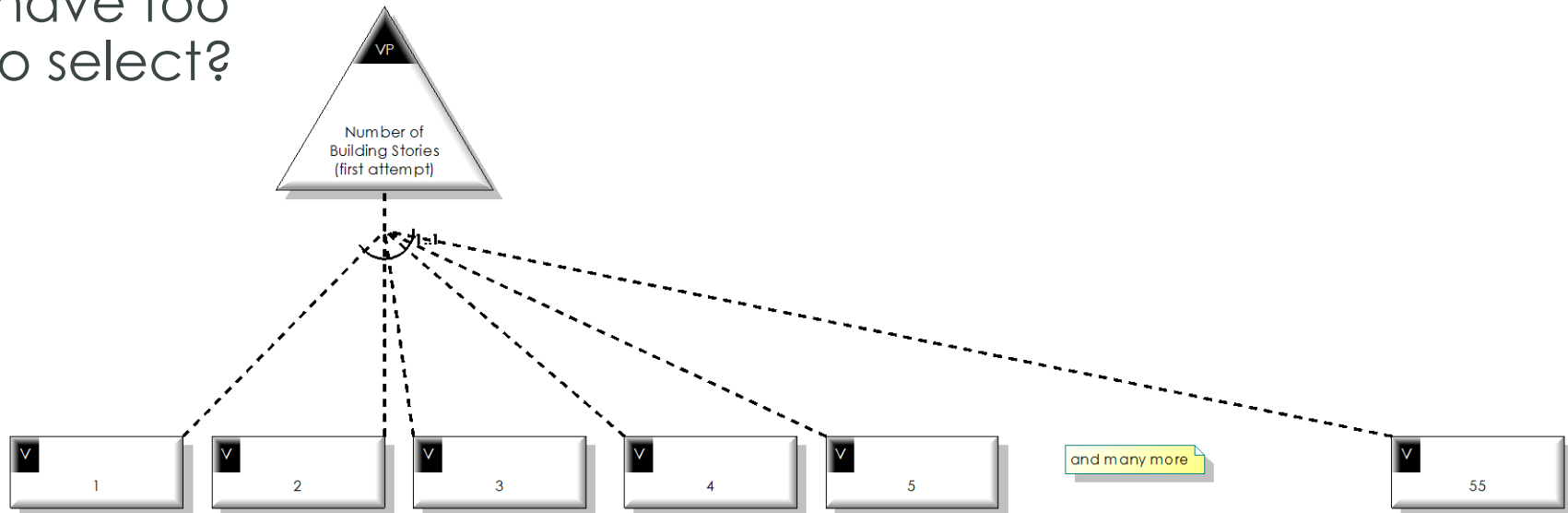
# PARAMETRIC VARIABILITY AS OVM EXTENSION



- Some selections are simple



- But what if we have too many options to select?

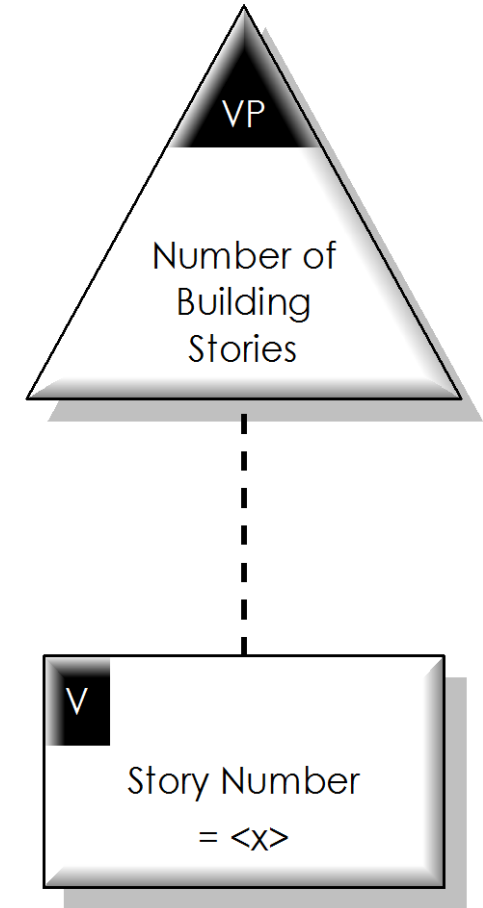
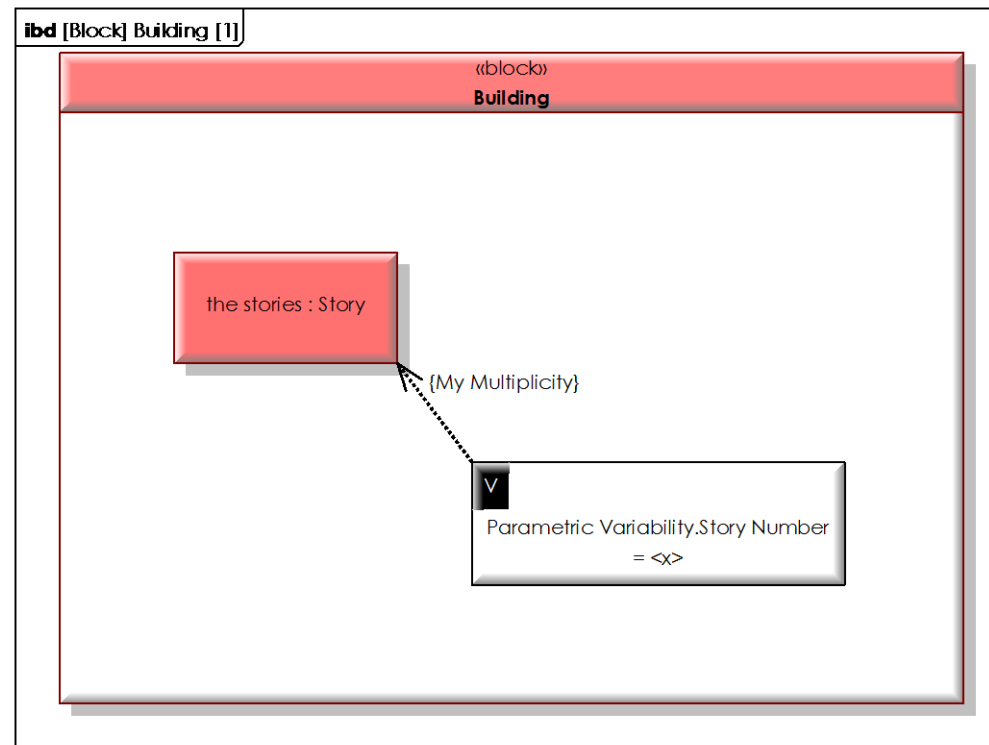


# PARAMETRIC VARIABILITY AS OVM EXTENSION



Solution:

- Extend OVM to use parameters
- This makes modeling of the Product Line Model much easier
- Parameters can be linked to meta model properties
  - Here: Multiplicity



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# EXTERNAL VERSUS INTERNAL VARIABILITY





## Design targets for product lines:

- Maximize external variability to maximize sales
- Minimize internal variability to minimize development efforts:
  - Increase usage of standard parts
  - Make sure that an **external variation point** is connected to only one **internal variation point**
  - ...



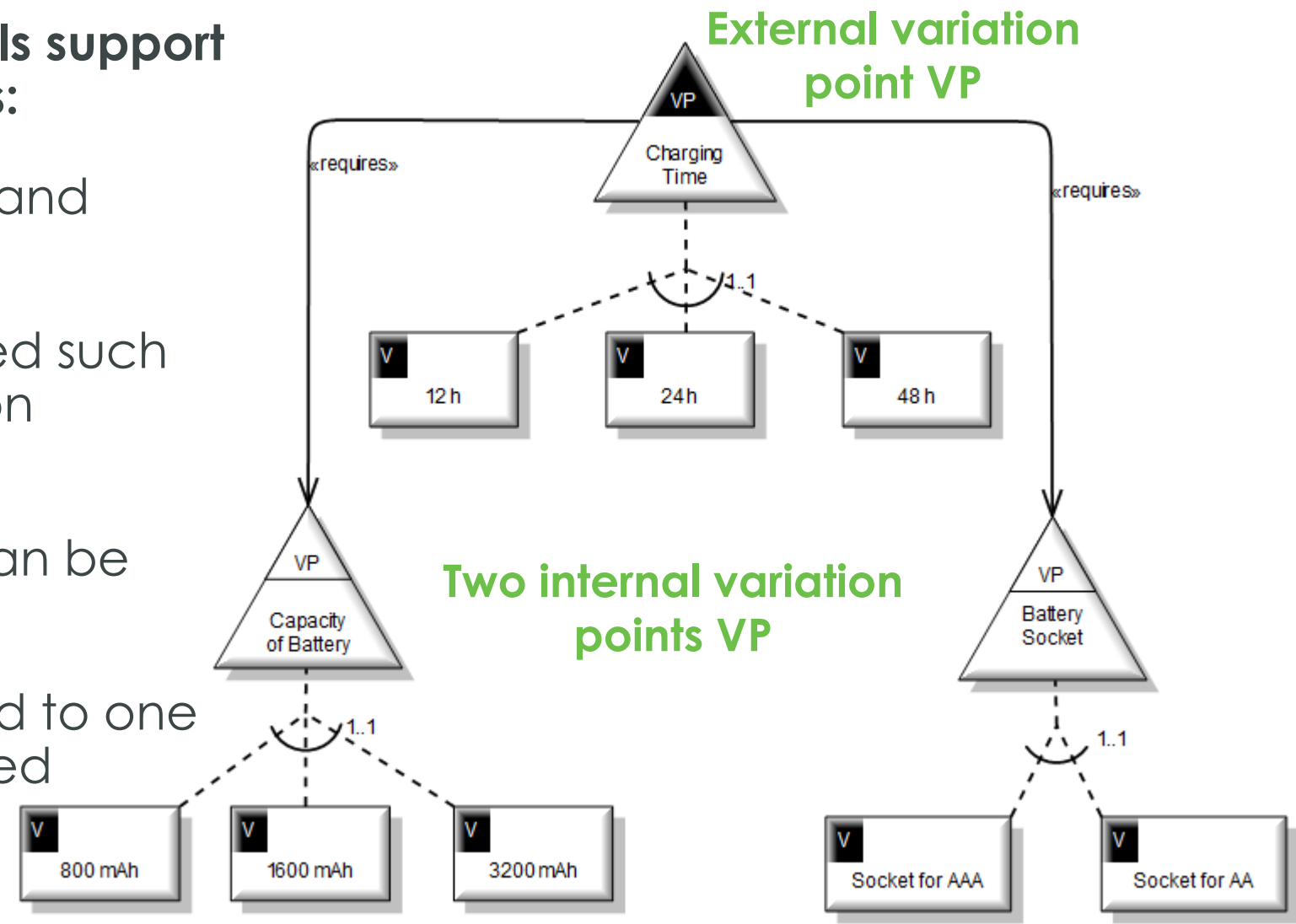
**Appropriate models and tools are needed for design for variability**

# EXTERNAL VERSUS INTERNAL VARIABILITY



OVM-based product line models support very well product line designers:

- Distinction between external and internal variation points
- Standard parts can be masked such that the designer can focus on variability issues
- Indicators like reuse factors can be calculated
- Number of internal VPs related to one external VP can be determined
- ...



# QUESTIONS AND ANSWERS

