9TH INTERNATIONAL DESIGN STRUCTURE MATRIX CONFERENCE, DSM'07
16 – 18 OCTOBER 2007, MUNICH, GERMANY

PRODUCT, PROCESS AND NETWORK DOMAIN INTERFACE MODELLING

Niko Salonen
Rolls-Royce Oy Ab, Tampere University of Technology

Keywords: concept modelling, conceptual design structure domains, interfaces

1 INTRODUCTION

There is a business need to describe three different domains of conceptual design structures as part of the early design process and identify interfaces between the domains to support analysis and overall management of manufacturing and assembly of conceptual product family architecture. The model of this study is the part of the definitions of conceptual design for manufacture and assembly (C_DFMA) methodology. C_DFMA is based on large Finnish research program including global manufacturing companies and several universities and national technology institute TEKES. This study concentrates to identify the structure of different domains to match the needs of interacting factors between the domains in the conceptual design phase of a product family. This study is giving early identification of the possible solution architecture of a product, process and network (PPN) domain model.

2 FRAMEWORK

The framework of the C_DFMA methodology is consisting areas of interest and describing problems studied before by C.H. Fine [4], [5], A. Takeishi [2], [3], T. Fujimoto [3] and I. Lapinleimu [1]. All of these studies contain same domains that are presented in this study. The PPN model is build in object-oriented structures and uses design structure matrixes as a tool to describe links between domain and domain internal links. The DSM model enables us to include mathematical models and systematic schemes of data analysis and clustering of the interface data. The object-oriented structure is only an building tool and viewing tool. These possible methods would include analysis of existing data and new design option comparison to existing data. The analysis is tested in few company cases during autumn 2007.

3 DOMAIN INTERFACES

The product, process and network domain in Figure 1 shows the relations between product, process and network domains using visual and DSM presentation methods. Product domain is populated with module concepts defined in earlier study by N. Salonen [6]. Concept modules can be structured consisting itself of process, function, organ and part domains, but this study uses only the part domain.

The process domain defines a process through lifecycle system of concept modules mapped in the product domain. Network domain again shows the global infrastructure that is required and available to meet the process and product domain mapping. Figure 1 also shows the relations in specific domain between defined objects. Third different relation DSM is built between specific domains internal relations, but this is not shown in the figure.

The domain interfaces are presented as the overlapping areas of domains. The centre area of the overlapping domains is presenting the decision point against set criteria. The actual design can be done in more meaningful and visual way as shown in Figure 1.

4 CONCLUSIONS

The PPN domain model and the process for conceptual design for manufacture and assembly are developed during the research program. The current model shows the same basics as CH. Fine 3-DCE's overlapping responsibilities, now including the DSM links between the domains and in the domains. The next phase of the research is to map properties against the different domain objects and formulate the systematic approach to analyse the interactions.

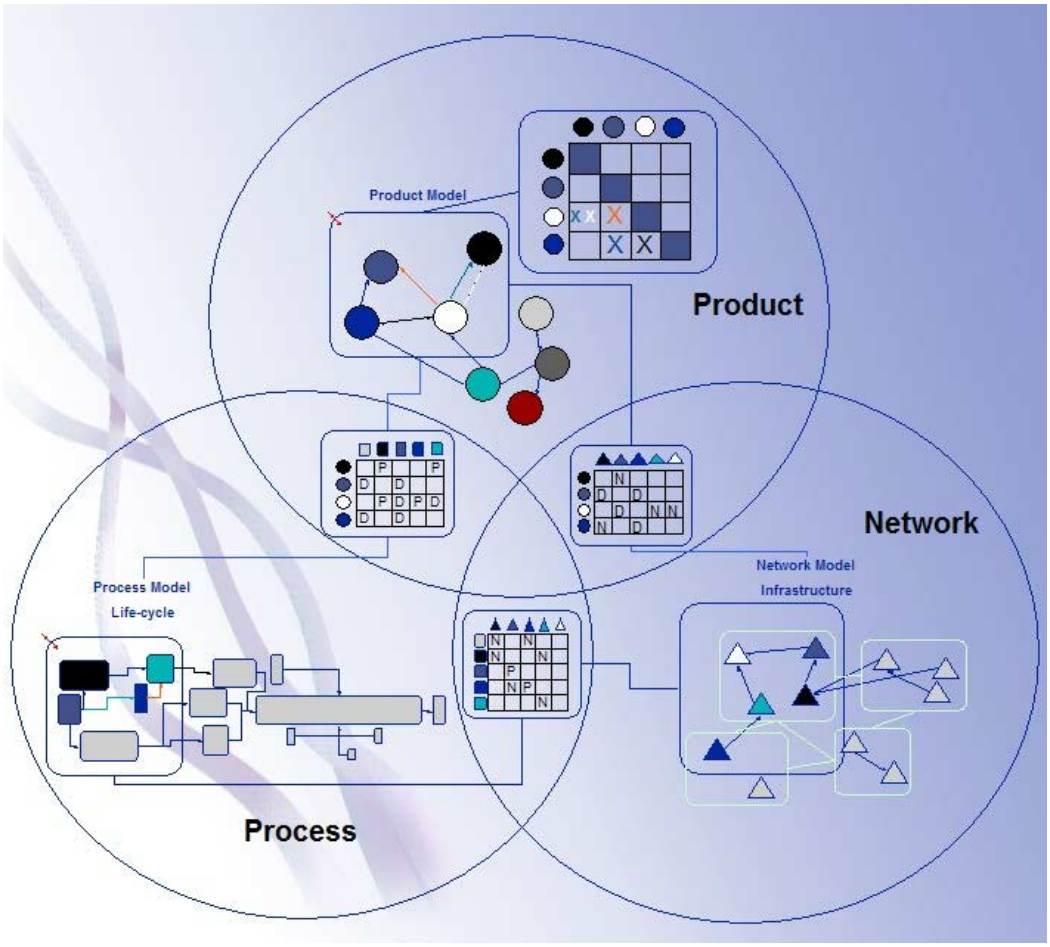


Figure 1. Product, process and network domain

REFERENCES

[1] Ilkka Lapinleimu. Ideaalitehdas, Tehtaan suunnittelun teorian kiteytys (Ideal Factory, The principle theory of factory design). *TEKES technology program report, 3rd edition 2007*, ISBN 952-15-0415-3, Pages 85-100

[2] Akira Takeishi. Bridging inter- and intra-firm boundaries: management of supplier involvement in automobile product development. *Strategic Management Journal, Volume 22, Number 5 / 2001*, Pages 403 – 433

[3] Akira Takeishi, Takahiro Fujimoto. Modularisation in the auto industry: interlinked multiple hierarchies of product, production and supplier systems. *International Journal of Automotive Technology and Management, Volume 1, Number 4 / 2001*, Pages 379 – 396

[4] Charles H. Fine. Optimal Investment in Product-Flexible Manufacturing Capacity. *Management Science, Volume 36, Number 4 / 1990*, Pages 449-466

[5] Charles H. Fine. Clock-based strategies for supply chain design. *Production and Operations Management, Volume 9, Number 3 / 2000*, Pages 213-221

[6] Niko Salonen. Dynamic product structure configuration of superimposed part structure solutions. *Research in Interactive Design*, Volume 2, Chapter 5 / 2006, Page 50

Contact: N. V. Salonen
Rolls-Royce Oy Ab, (Tampere University of Technology)
Product Management
Suojantie 5
PO Box 220, Rauma
Finland
Phone: +358 2 83791
Fax: +358 2 8379 4804
e-mail: niko.salonen@rolls-royce.com
URL: http://www.rolls-royce.com/marine

9TH INTERNATIONAL DSM CONFERENCE

PRODUCT, PROCESS AND NETWORK DOMAIN INTERFACE MODELLING

Niko Salonen

Rolls-Royce Oy, Tampere University of Technology
Finland

IN COOPERATION WITH BMW GROUP
CAPITALIZE ON COMPLEXITY

Rolls-Royce

Index

- Study framework – C_DFMA – theories behind the topic
- Business need behind the topic
- PPN Domains
- Domain interface properties
- Analysis and management of PPN model
- Cases
- Validation of the model
- Conclusions

Product Development
Technische Universität München

Study framework – C_DFMA – theories behind the topic

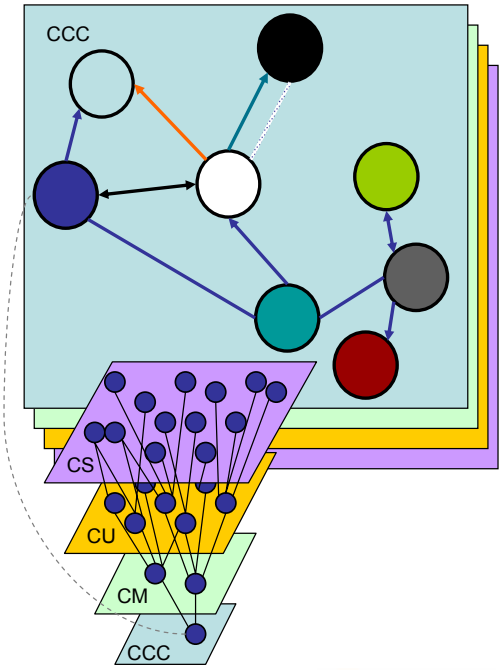
- C_DFMA = Conceptual Design For Manufacturing and Assembly
  - The C_DFMA separated from traditional DFMA method in
  - This study is focusing on C_DFMAs PPN modelling and specifically on requirements modelling the interfaces
- The Domain structure has been studied by several researcher – there is no need to create a new domain layout
  - C. Fine *(taken from the article)*: "This paper discusses a framework for strategic supply chain design that rests on an assortment of conceptual approaches. These approaches include benchmarking fast-evolving industries to posit principles of supply chain dynamics and integrating supply chain design into the concurrent processes of product and manufacturing system design. These approaches yield insights into sourcing strategy as well as implementation of concurrent engineering."
  - A. Takeishi *(taken from the article)*: "Outsourcing has become an important strategy for many firms. Yet, firms need to compete with their competitors who also outsource and may share the same suppliers. This article explores how a firm could outperform others in managing the division of labor with a supplier in product development. Drawing on the empirical data collected from the Japanese auto industry, this paper shows that an automaker needs capabilities to coordinate various activities both externally with a supplier and internally within its own organization, in order to gain better component development performance. Overall, the results imply that outsourcing does not work effectively without extensive internal effort. Copyright 2001 John Wiley & Sons, Ltd."
- The model is based on object oriented way of structuring the data
  - Classification of objects is the major effort to conceptualize the three domains to match
  - The object property data is transmitted into the DSM format and properties are evaluated against the 3 property classes (variation, volume and change), goal values and generalisation into 7 virtues (M.M. Andreasen - DTU)

Business need behind the topic

- Business need behind the topic
  - Growing sales, both in horizontal (volume), vertical (variation) and depth (change) directions require logistical growth and change management excellence from the companies
  - Requirement to manage the complexity and speed is creating needs to change logistically to a new level of process information management
- Rolls-Royce area of interest
  - Need to justify development projects based on lifecycle process management and cost basis on strategic product family and product architecture levels – management of change must be feasible when any domain affects others
  - Grouping product parts based of production technologies and global manufacturing network – product conceptualization in view of process and network to support pre-sales procurement activities among other
  - Standard design families are not managed in the network efficiently. Smaller changes become harder to justify if the logistical purchase process is not aware of the commonality – supporting lifecycle cost indexing in real environment when moving one-off project to serial production

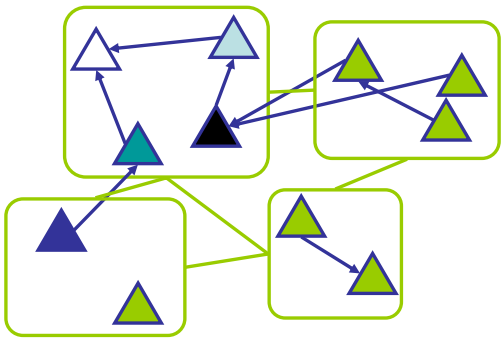
PPN Domains

- Product domain
  - The product domain is modelled in different conceptual levels to meet full portfolio definition
    - Critical Concept Components (CCC; parts, gear)
      - Including critical features
    - Concept Modules (CM; assemblies, gear box)
    - Concept Units (CU; product, engine)
    - Concept Systems (CS; installation, ship)
  - The structure supports all kind of products but is based on modular products and defines the architecture of the family
  - The structure contains sub structuring and internal and external links between the objects
  - The objects main differentiating directions are variation, volume and change
  - The objects include only final state
    - Same part is not needed to describe in several process phases



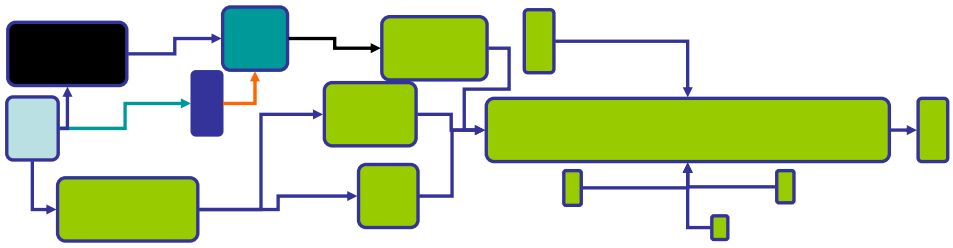
PPN Domains

- Network domain
  - Network is a global map of logistical network
  - The structure contains
    - Borders of logistical network (continents, countries etc.)
    - Suppliers of products and services
    - Logistical chains of supplier network (direct and un-direct)
  - The structure contains sub structuring and internal and external links between the objects
  - The classification of each network object can be used as a filtering mechanics for suitable product domain objects
  - The logistical network is a true ‘fact’ model of the whole PPN model



PPN Domains

- Process domain
  - Contains the process sequences
  - Process structure contains
    - Manufacturing, assembly, supporting and legislative processes
      - Based on Technical Systems definition
    - The structure contains sub structuring and internal and external links between the objects
    - The classification of processes
      - Mandatory to optional processes
      - Differentiating processes (such as casting model; unique for variation and change, but in volume case only for certain steps)
      - Human-machine interaction type (from manual to fully automated)
  - The objects main variation dimension is time



Domain interface properties

- The property values are always actual measurements of existing information – numerical data is most valuable – which means that the information is not constructed to include variation of subjectivity
- However the property values can include the property goal values, set running from +5, +3, +1, 0, -1, -3, -5 *(representing the current value compared to optimal solution, positive values (from +5 to +1) being the way of "to maximize" and negative values (from -5 to –1) as "to minimize". 0 is a set as stabile property).* This is however needed only if the model is used for simulation of data
- The product properties are captured based on process and network properties. The product object requires processes containing certain properties that the network can offer. The classification is main area of the PPN model language generation.
- The network and process domains can offer different variations than the product domain object properties have, which means that the matrix must filter suitable candidates by boolean operators and ranges

Domain interface properties

- External Product domain interface properties
  - The product domain defines the product domain object properties that are mapped against the process and network domain, such as
    - Variation
      - Size (bounding box/cylinder/…)
        - » *Volume (true material volume)*
      - Form (formulation of basic shapes and special form features)
      - Material
      - Component flexibility *(internally designed part without strict functional and fit requirements set as most flexible (1) and externally purchased fully out of design knowledge the most rigid (5); values from 1 to 5)*
      - Other attributes… (special treatments)
    - Volume
      - Number of objects produced against each variant in time
    - Change
      - What are planned activities against each variant in time
        - » *Activities are (module) drivers that can be used to define the activities*

Domain interface properties

- External Process domain interface properties
  - Process domain interface defines the scale of process complexity and total process volumes of products that are produced – this view will show how complex the product portfolio actually is
  - Process objects are all company defined processes – in machinery industry the process structure can be
    - Variation
      - Raw material production properties
        - » *Casting*
        - » *Forging*
        - » *Blanks*
      - Part manufacturing properties
        - » *Cutting and stamping*
        - » *Welding*
        - » *Machining*
        - » *Surface and body treating*
        - » *Inspecting*
      - Assembly properties
        - » *Sub assembling and final assembling*
        - » *Assembly painting*
        - » *Testing*
    - Volume
    - Change
  - These are purely production oriented processes, but the model can include any processes that can be related to product and network – such could be service oriented processes

Domain interface properties

- External Network domain interface properties
  - The process vary in time and technical properties, but cost and other actual virtues are transformed via the network information
  - The network domain interface predefines the scale of logistical diversity of the production system – questions of what processes are done internally by the core company and what is out-sourced and where
  - In machinery industry the network structure is composed of
    - Variation
      - Geographical area entities
        - » *Continents, countries, states, cities*
      - Functional entities (Companies)
        - » *Production site: machine/work cell*
        - » *Ports, railway stations, airfields, …*
      - Linkages
        - » *Roads, railroads, flight routes, ship routes…*
      - State
        - » *Weather types, power availability, …*
    - Each object type contains properties
      - Countries
        - » *Taxes and customs, …*
      - Production site
        - » *Machining; 3 machines, pay rate, …*
      - Road
        - » *Road type, length, …*
    - Volume
    - Change

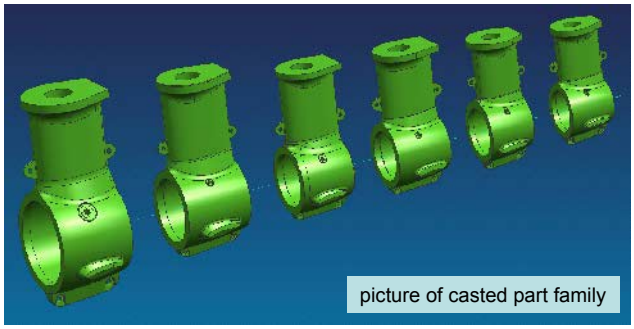
IN COOPERATION WITH BMW GROUP
CAPITALIZE ON COMPLEXITY
Rolls-Royce

Analysis and management of PPN model

- The model is constructed from data of different sources, such as PDM and MRP/ERP systems and by interviews
  - Process steps to generate the model
    - Construct the model architecture
      - Obtain information of the network and process domain
      - Analyse current product port-folio (CCC, CM, CU, CS) to construct the product domain
      - Classify domain objects
      - Map the process and network objects to define common relation properties as part of the classification
    - Migrate the full scope of data
      - Against the model architecture capture all product port-folio data
- Analysis of PPN model require tool(s) that would enable examination of the data either in matrix format by visual or mathematical methods, such as clustering and indexing or viewing the constructed visual model itself

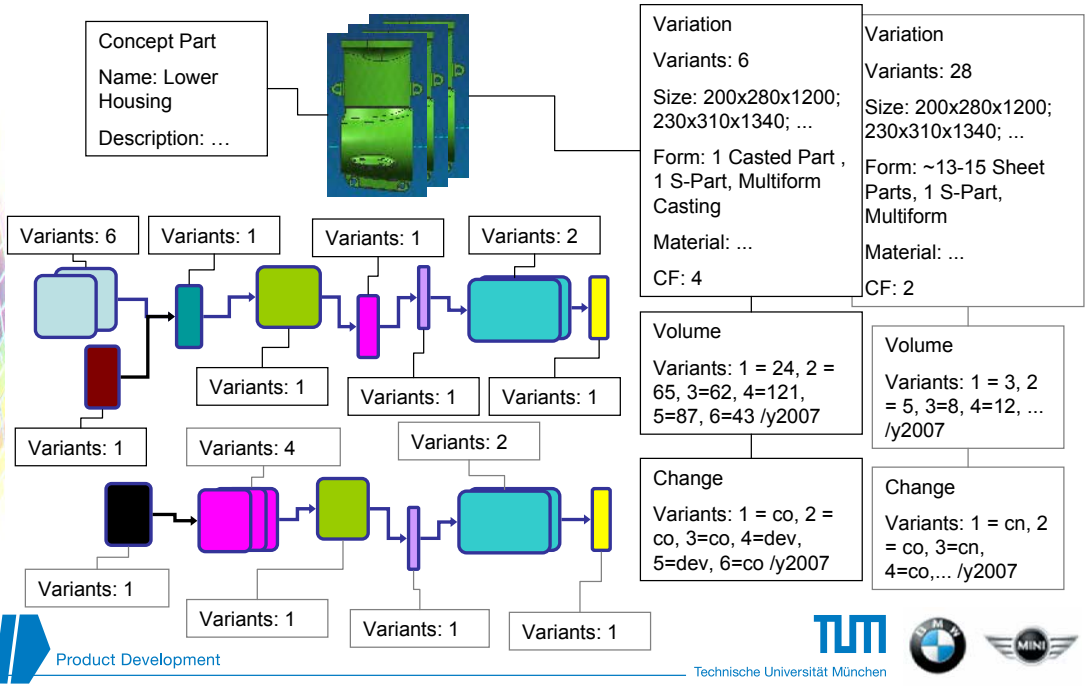
Case

- Case 1: Steel Casting Family versus Welded Steel Family
  - Large steel structures are produced globally in different countries
  - The network differs in size limits, volume and required delivery time in both architectures
  - The major difference is the process itself – logistical network is entirely different
  - Modelling the product concept domain based on network and process domain properties the situation can be visually seen and the enables the study the product concept against the 7 virtues



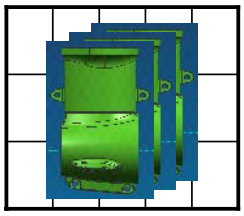
Case

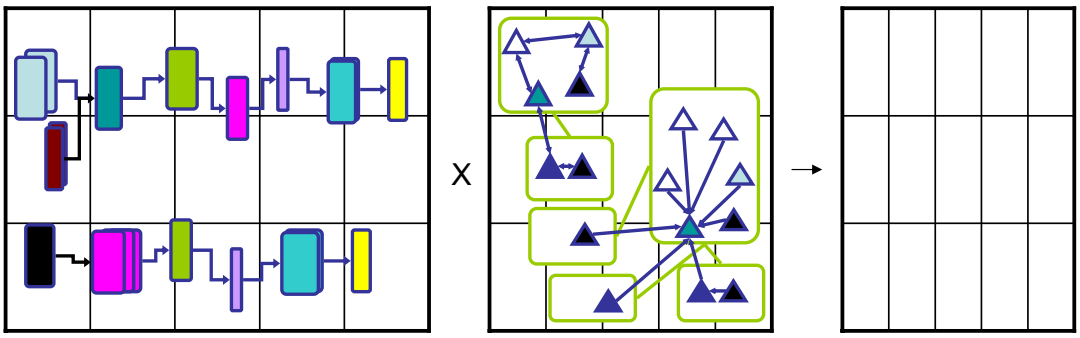
- Case 1: Steel Casting Family versus Welded Steel Family



Case

- Case 1: Steel Casting Family versus Welded Steel Family
  - The goal is to generate a matrix transformation model where the process objects and the properties can be mapped (x) to network objects and their properties obtaining a coherent matrix formulation to meet the product domain matrix
  - Currently the study is still in state of defining the interface entities as part of the PPN language
    - Each property must have defined order of property values to justify the matrix property comparison





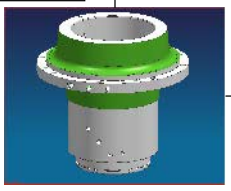
Case

- Case 2: Laser Coating versus High Resistant Material
  - The family of parts need functionally a surface area of wear resistant and low friction
  - The part has originally been manufactured from wear resistant material of high quality
  - The second option is based on laser coating process technology, which enables to produce the base part from normal steel alloy and by laser coating only the functionally required surface
  - The whole lifecycle process requires to manage the parts in sales variation and volume. Change to new design also affects to change property

Concept Part

Name: Bearing Housing

Description: …



Variation

Variants: 4

Size: 345x680; 372x710; ...

Form: 2 Tube Parts , 1 Sheet Part, ...

Material: ...

CF: 2

Volume

Variants: 1 = 31, 2 = 55, 3=65, 4=34 /y2007

Change

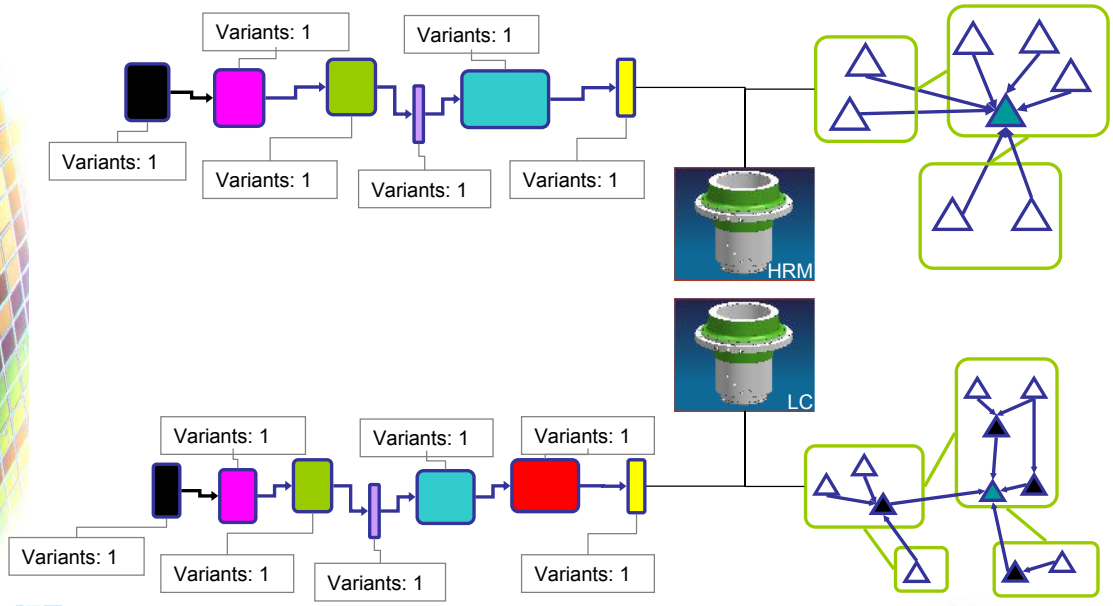
Variants: 1 = co, 2 = co, 3=co, 4=co, /y2007

Change

Variants: 1 = dev, 2 = dev, 3=dev, 4=dev, /y2007

Case

- Case 2: Laser Coating versus High Resistant Material



Validation of the model

- Validating the model on the basis of the cases give indication that
  - Creating the model structure itself is a useful task
    - Different functional organisations can see that “when change happens in any domain structure the immediate result can be a complex external domain interface change, that change other domains dramatically”
      - The scale and type of change compared to scale of effect is an important factor of change management and decision making
  - Classifying the product domain objects based on requirements that other functions need is a useful task also
    - Question to “what really matters in the network” is answered
      - Lot of the data exist all ready in different systems, but today it is not constructed and mapped in a standard way so that the data would be turned into information and knowledge
  - Comparing the variations in the external domain interfaces can not be handled in reasonable resources and time. The output is too complex when the 4 levels of product domain matrixes are generated with relations and then matched to relations in other domains.
    - The validation would require a software tool to do the hard processing work and report to users even in the cases of two parallel critical component families
  - The model is not yet validated against theoretical facts – but in business vice the model looks promising

Rolls-Royce

Conclusions

- Results
  - Modelling the three domains all ready give visual feedback and defining the common interface properties have given immediate results by indicating the scope and complexity of change
  - Domains internal matrixes give results expected from as general DSM method does
- Limitations
  - It seems defining the domain external matrixes and combined entities correctly takes more time than originally planned
    - So far there is large number of different matrixes can be build, but are not easily combined to meaningful combinations and the amount of relation data even simple cases is enormous
    - Theoretical justification for the combination of matrix results are not yet found
- Next
  - The model requires more cases and testing to show scalability from parts to installations
  - The model requires more theoretical studies to be proven as high quality
  - PPN model language generation continues to evolve
  - Possible software tool development to support strategic PPN model management
    - Basic modelling software of the PPN model
    - Simulation software package for the PPN model
    - Web interface software for collaborative environment for the PPN model
  - The final purpose is to develop a “Strategic Operational PPN Business Room” for company management as can be found today in
    - ‘Air Traffic Control Rooms’
    - ‘Strategic Defence and Battle Planning Rooms’
    - ‘Civil/Defence Aerospace Engine Control Rooms’