

# USING THE VODD MATRIX TO BRING DESIGN DEPARTMENT VOICE IN THE CHOICE OF CONCEPTS

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## ABSTRACT

In the context of new product development, highly constraint multi-disciplinary systems are difficult to design and generally lead to a non optimal but acceptable solution (Seepersad et al. 2008). The design of such product implies to collaborate soon in the choice of concepts. Our industrial analysis shows that concept choice is leading to collaborative problems when a design department implies a stronger influence than others. This attitude to favor one design department decreases product performance interest. As concept evaluation is a key point in product designs, this design stage must take into account design department's point-of-views. This article describes our VoDD matrix, based on expert evaluation of component contribution to performances, to bring design department voices soon in the choice of concepts.

*Keywords: Multi-physics, collaborative design, QFD*

## 1 INTRODUCTION

In this article, we propose to semantically enrich conventional representation model of product complexity. We use a Quality Function Deployment (QFD) in a non-conventional way, in order to propagate the designers' aims for performance of the components more than the traditional "voice of the customer". A first contribution is the enrichment of this representation. We adapt the QFD method to capture the voice of the engineering design departments involved in the project; this ontological enrichment of design data makes it easier to envision and manage design challenges for multi-physics systems. This article goes further into Holley et al.'s (2010) publication.

## 2 PROBLEM STATEMENT

This research study is conducted in collaboration with Schlumberger a worldwide leader in petroleum services. The recent developments of onboard electronic cards are an example of this multi-physics problem. Electronic card has to be integrated in a box attached to a main mechanical component. The whole assembly is going in a tube (with a diameter limited by the drill). In order to develop this product the expertise of three design departments is needed (mechanical, electrical and packaging). Every department is optimizing their design to maximize performances, as for example the number of electronic card by product foot length. 18 months after the concept choice, the project failed due to the deterioration of expected product performances by the capacitor size parameter: Capacitor size is a key design parameter control by electronic design department. It has a consequent impact on expected performances and particularly on the number of electronic card by product foot length (main expected performance). More precise analysis shows that the electronic design department voice has not been taken into account as impacting as mechanical one.

Current approach is made through a "verbal around the table" fuzzy evaluation of design department contribution to expected performances. This way to do is too limiting for complex problem because without tools it's difficult to compute all data and to treat them as an entire system.

### 3 LITERATURE REVIEW

The research literature is mainly addressing previous issues with the usage of Quality Function Deployment (QFD). QFD has been well apply to vary applications (Holley et al. 2008) as for instance by Maier et al. (2008) who propose a method to identify opportunity for concept improvement. This method is introducing affordances in a QFD based tool. The called matrix Affordance Based Design (ABD) puts in relation physical structure and requirements. Requirements are interpreted in term of affordances and organized in four categories: Positive Artifact-User Affordances (+AUA), Negative Artifact-User Affordances (-AUA), Positive Artifact-Artifact Affordances (+AUA) and Negative Artifact-Artifact Affordances (-AUA). The interior of the matrix is populated by (+) if the related components is a helpful relationship for each affordance or (-) is it's harmful or ( ) if they are no relationship.

Contrary to Maier et al. work might think, the main lack of the literature is that all approaches are addressing concept evaluation through entire systems. For a large system (several design solutions, several modules and several performances as in our industrial example: 500 evaluations), this approach is limiting in term of concept scoping.

### 4 OUR GLOBAL APPROACH: THE MPDS METHOD

The goal of our global approach is to map design department point-of-views, architecture alternatives, functional needs and expected performances. With this process, our approach aims at helping designers to model their collaborations with other design departments and to assess their impacts on the final product. The proposed MPDS method (Multi-Physics Design Scorecards) matrix based method that is organized in the three steps describes in *Figure 1*.

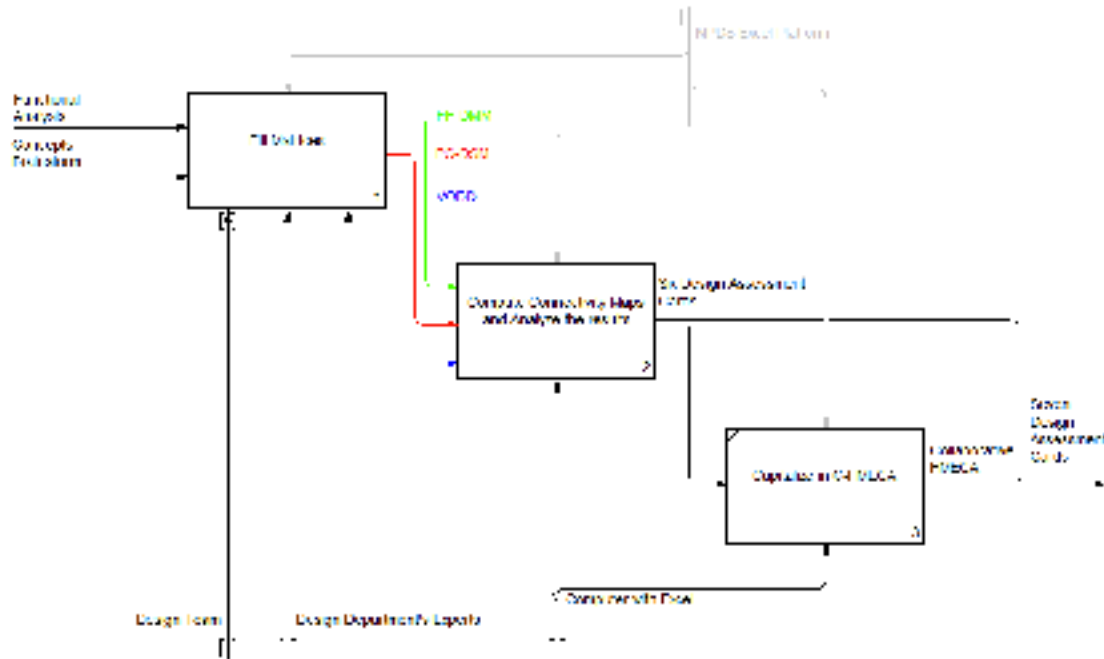


Figure 1. AI SADT of the MPDS method

The “fill matrices” step objective is to gather project data based on “functional analysis” and “concepts brainstorming” into three matrices: Functional Flow – Domain Mapping Matrix (FF-DMM), Physical Connection – Design Structure Matrix (PC-DSM), and Voice of Design Department (VoDD), which will be used to generate six design assessment cards based on connectivity maps. The capitalization of MPDS results in the Collaborative-FMEA has for objective to quickly highly collaborative design risk about the project. Therefore, the six design assessment cards extracted from connectivity maps are used as an input.

This article will focus on the analysis of design department contribution to product performances through the use of VoDD matrix. We aim at detect possible conflicts of interests on technical performances, at understand the potential contribution of design departments to the overall product

technical performances and at understand how to compute overall product technical performances based on local evaluations.

## 5 VODD'S ONTOLOGY

A multi-physics design process requires the ability to identify potential design conflicts and find compromises. In order to achieve this, the Voice of Design Department (VoDD) matrix gathers data concerning design constraints and correlations between technical performances. These data are the following:

- *Design Department* represents the department in charge of the design of a module of the system. A design department is identified by its name and the names of its engineers.
- *Evaluation* represents evaluations of technical performance criteria based on value scales. An evaluation is identified by a technical performance criterion name and a technical solution name.
- *Expert* refers to the person who evaluates technical performance. An expert has a name and is associated with knowledge.
- *Module* designates a part of the system that must exist in order to perform a function. A module has a name.
- *Technical Performance* refers to technical performance criteria expected to be fulfilled in the evaluation of a function. Technical performance is specific to a given function: independent technical performance values are listed for each function. Technical performance has a name.
- *Technical Solution* represents a design solution for a module. A technical solution has a name.
- *Value Scale* contains the value scales for the evaluation of technical performance criteria. A value scale is specific to the technical performance of a given function: the technical performance of each function has its own value scale for its evaluation. A value scale is attached to a technical performance criterion name, numerical values, and a value description.

## 6 VODD: AN EXPERIMENTAL EXAMPLE

This approach has been experimented on an industrial application who aims to develop onboard electronic cards under the scope of a project. The previous card developments were not able to achieve environmental constrains: high pressure, high temperature under shock and vibrations as required for our sub-project.

Design team members and design department expert collaborate to populate the VoDD matrix with data extracted from the functional analysis. The results used from functional analysis are defined functions with identified technical performance criteria and value scales. We propose the following process in order to fill in the VoDD matrix represented in Figure 2 (an example, extracted from Holley et al., 2010, is given in Figure 3):

0. Modules, technical solutions (“0a”), and their physical connections (“0b”) are automatically filled in based on the MPDS platform (not presented in this paper).
1. List technical performance criteria (“1”) that permit evaluation of functions as well as differentiation of technical solutions.
2. Define value scales for the technical performance criteria of each function.
3. Fill in the body of the matrix (“2”) with experts’ evaluation of technical solutions’ contribution to technical performance. In order to capitalize on the experts’ discussions, we recommend documenting the workshop via audio and video recordings.
4. Fill in the correlation between the technical performance criteria (“3”).
5. Define function {Min, Max, Avera, or Sum} (“4”) for technical performance of the concept.

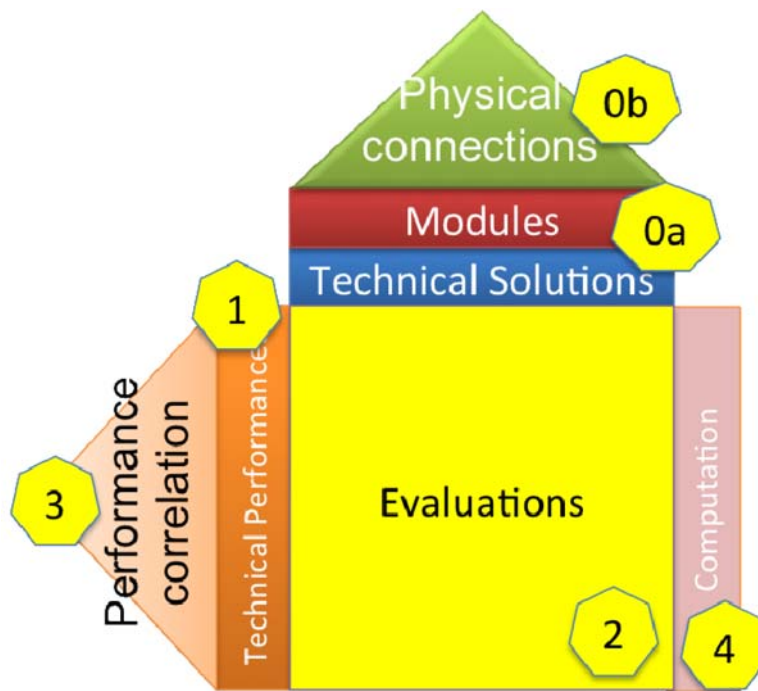


Figure 2. VoDD matrix

Columns correspond to modules and their technical solutions (“0a” in Figure 2). Rows list the technical performance expected in order to evaluate functions as well as to differentiate each technical solution (“1”). The contribution of technical solutions to the fulfilment of technical performance criteria represents the body of the matrix in the form of scale-based evaluations (“2”). Evaluation scales are defined and adapted for the technical performance criteria associated with each function. In general these value scales are set so that the highest value of the scale corresponds to the target set by the project. The left side of the VoDD matrix (“3”) defines the correlation between technical performance criteria, either positive or negative:

- “+1” describes a positive correlation between the two technical performance criteria,
- “0” means that technical performance criteria are not influencing each other,
- “-1” corresponds to a negative correlation.

The right side of the matrix (“4”) specifies the manner of evaluating a function, based on evaluation of the technical performance of the associated concepts. Each technical performance is associated with one of the following:

- “Min” indicates that the technical performance of the given concept is defined by the minimum value of the contribution of its technical solutions.
- “Max” indicates the maximum value of its contribution to technical solutions.
- “Avera” indicates the average value of its contribution to technical solutions.
- “Sum” indicates the sum of its contribution to technical solutions.

The top of the matrix (“0b”) contains data regarding the assembly of technical solutions extracted from the PC-DSM matrix. This automated extraction leads to a choice among {0, 1, void} for any matrix intersection:

- “0” represents no physical connection possible between two technical solutions,
- “1” corresponds to a possible assembly between them, whatever the typology of the connection,
- A void entry corresponds to technical solutions that are not connected.

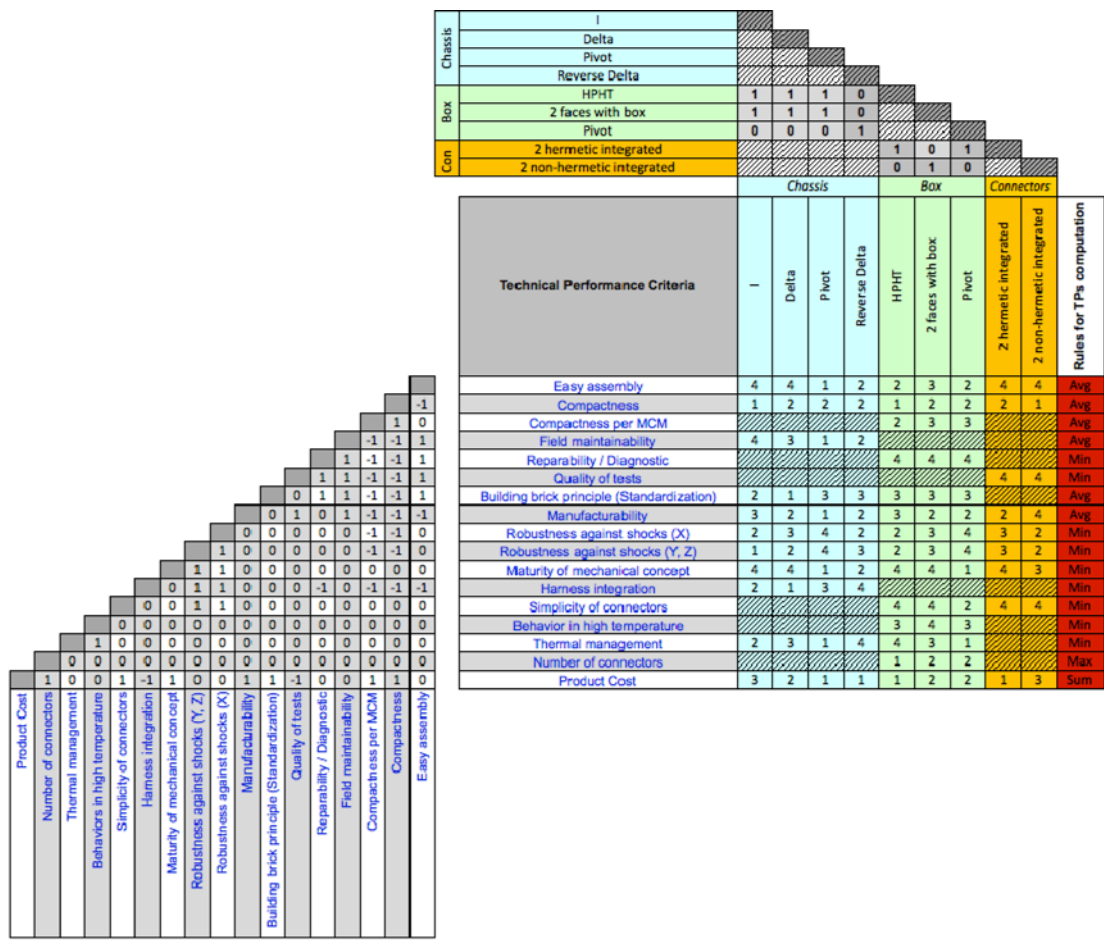


Figure 3. On board electronic card case study VoDD

The presented on board electronic card case study is a regulator board composed of a chassis, a box and a connector (called modules). Each of these modules can be achieved by the design of technical solutions as for instance, “I”, “Delta”, “Pivot” or “Reverse Delta” for the chassis module (see Figure 3).

There are two types of technical performance: one that gives a basis for evaluation of a function and one that highlight particular advantages of a given technical solution; both types can be either qualitative or quantitative.

“Robustness against shocks (x-direction)” is a technical performance criterion evaluating the function “resist shock”, broken into a four-point qualitative scale:

- “1” means that shocks over 1G are not tolerated,
- “2” means that shocks over 5G are not tolerated,
- “3” means that shocks over 10G are not tolerated,
- “4” means that shocks over 15G are not tolerated.

In contrast, the technical performance criterion “number of connectors” is used to point out an advantage of a technical solution based on a quantitative scale:

- “1” indicates the need for 4 connectors,
- “2” indicates that the need for 2 connectors,
- “3” that only one connector is needed and
- “4” indicates that the box has no connector.

## 5 CONCLUSION

This paper presents our defined Voice of Design Department (VoDD) matrix based on ontology, process for their filling by design team member and taxonomy for their completion. QFD rearrangement joint to ontology and taxonomy represent our principal contribution of the literature

review about Quality Function Deployment. Our aim by introducing Design Departments voice into QFD so called VoDD concerns the ability to catch engineer's contribution to the overall product technical performances.

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## Oil Market

- Extreme conditions
  - High pressures
  - High temperatures
  - High shock and vibration
- Naturally constrained
  - Mud, oil, gas and acid
  - Within a small diameter (typically 5 to 15 cm)



- Schlumberger projects
  - 5 designers
  - 7 to 15 years projects
  - 5 to 10 million \$/year
- Issues
  - Duration lengthened about 40% to 150%
  - Cost may be x2
  - Reliability need 2 to 3 years of re-engineering



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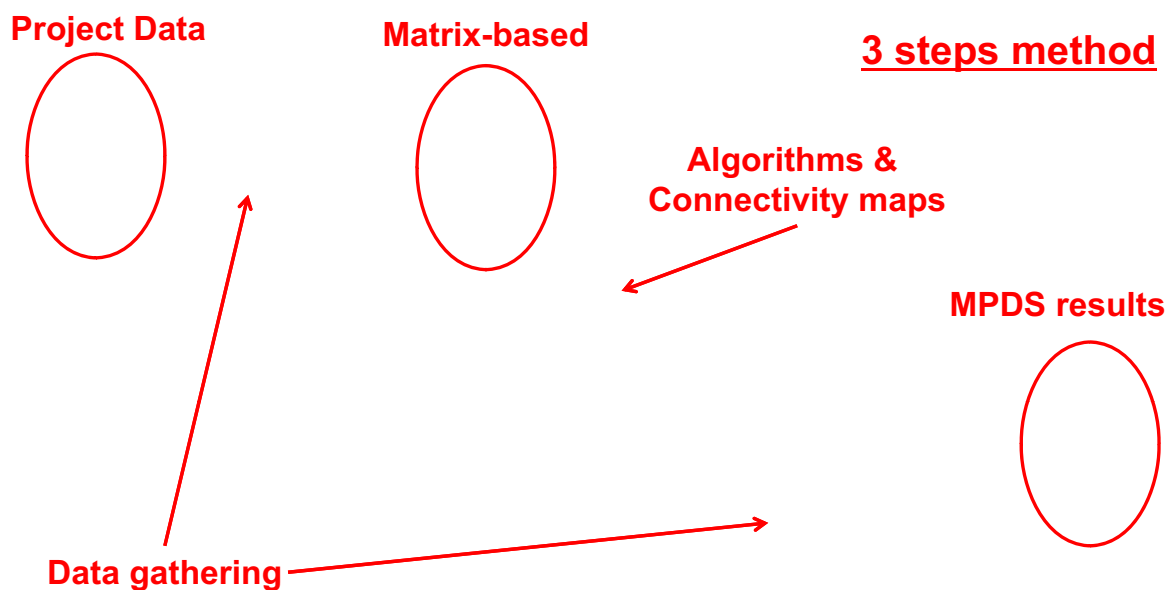
## Audit and Diagnosis of Design Project Management

### Action Research approach

- **Audit** concerns about **14 projects** and **25 jobs**
  - **Model** design tasks including **job interactions**
- Our diagnosis
  - Design process very loosely: **Extreme variability**
  - **No** prescribed **design tools**: No FMECA
  - **No collaborative platform**: No multi-disciplinary management
  - **Engineers are experts** in their **area of expertise**
- This article takes part of a Ph.D. work look for the improvement of design process by a simple user-friendly method to manage design collaboration: highlight highly **constrained architectural zones**



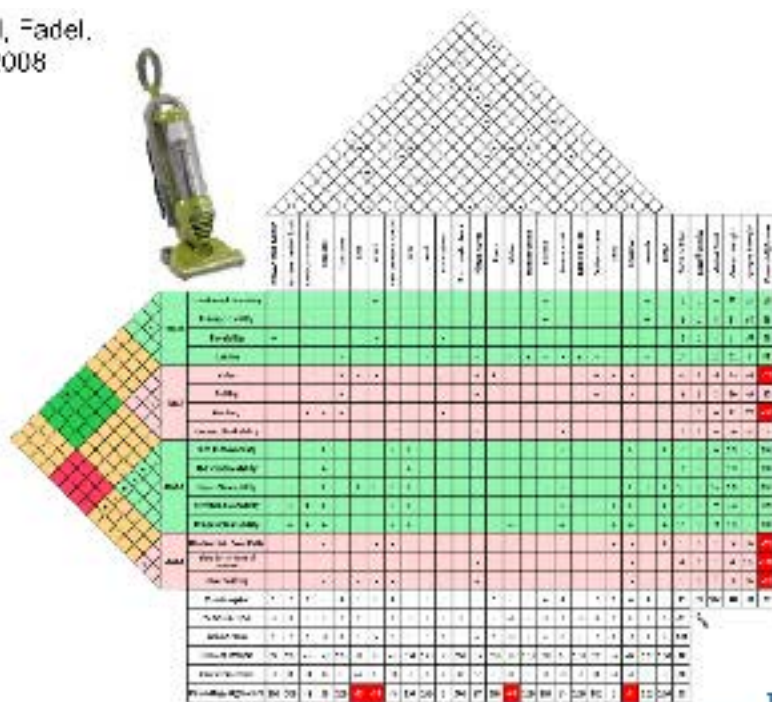
## Our Global Approach: Multi-Physics Design Scorecards method





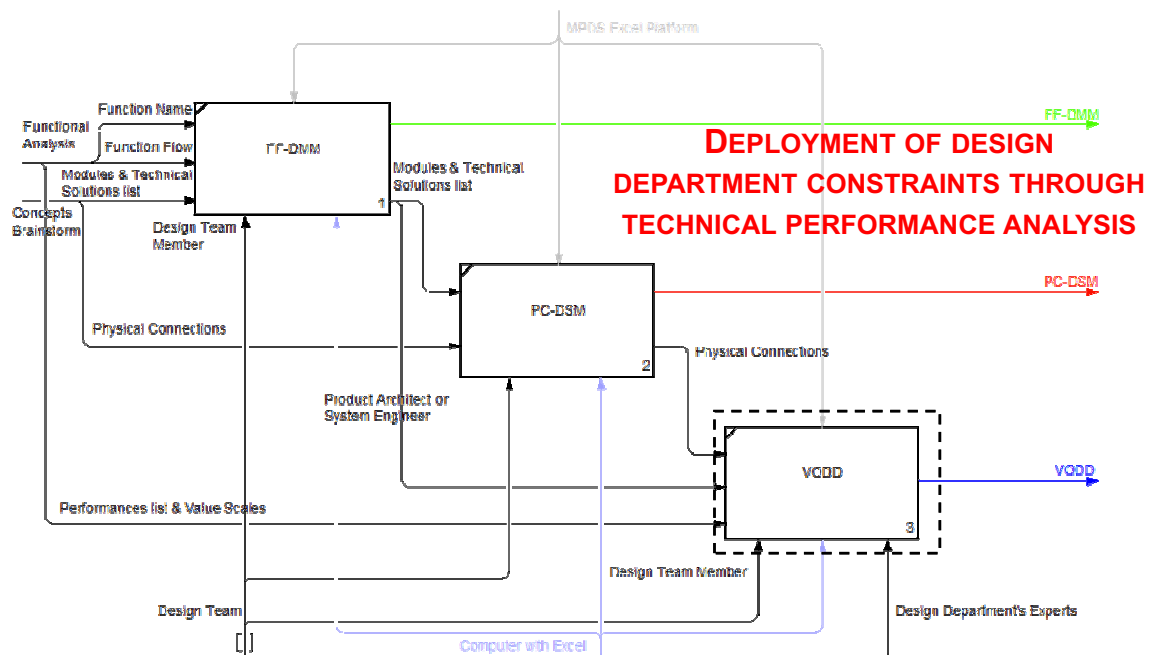
### Literature Review: The Affordance Matrix

Maier, Sandel, Fadel,  
DSMC - 2008



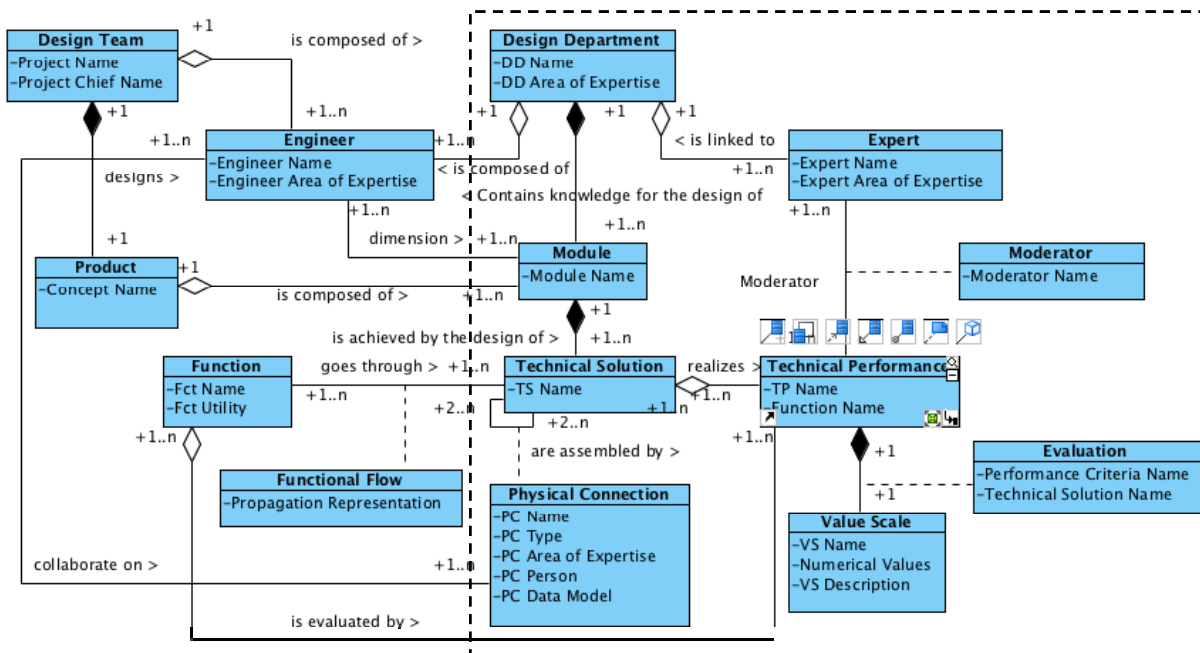
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### Analysis of Multi-Physics Concepts: Data Gathering



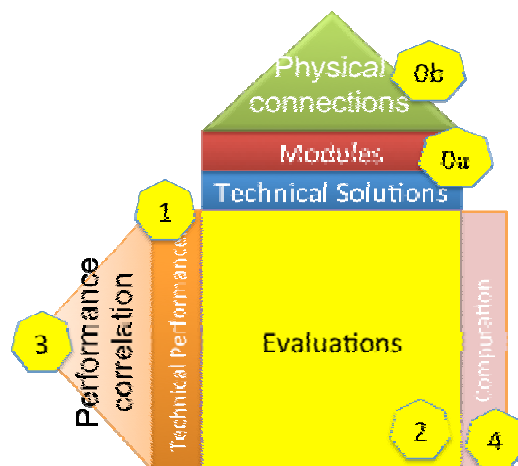
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### Data Gathering Ontology

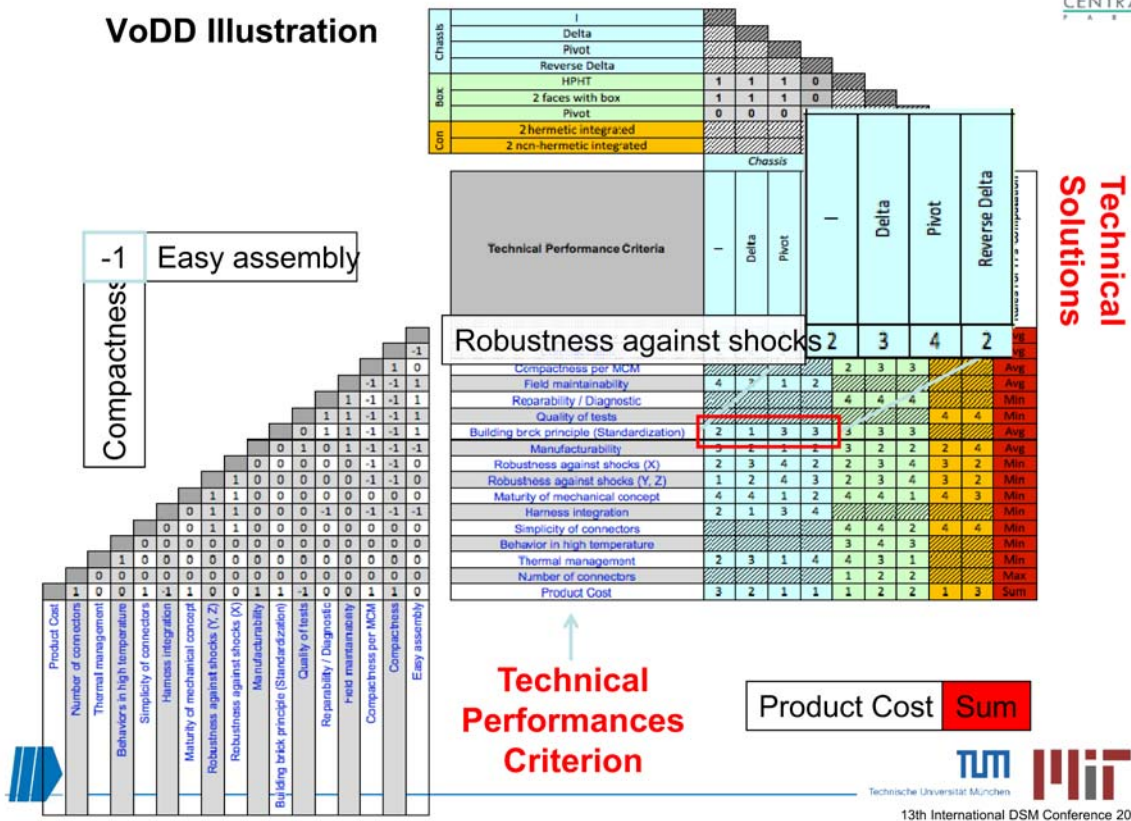


### VoDD Protocol

- The process to fill in the VoDD matrix:
- 0. **Modules, technical solutions, and their physical connections** are filled in based on previous matrices.
- 1. **List technical performance criteria. Define value scales** for the technical performance criteria.
- 2. **Fill in the body** of the matrix with **experts' evaluation** of technical solutions' contribution to technical performance.
- 3. **Fill in the correlation** between the technical performance criteria.
- 4. **Define function for technical performance criteria computation** of concept.



VoDD Illustration



Technical Performances Criterion

Product Cost Sum

Technical Solutions

Conclusion

- Defined Voice of Design Department (VoDD)
  - Ontology,
  - Filling process,
  - Taxonomy.
- Contribution of the literature review
  - Ontology,
  - Taxonomy.
- VoDD ability
  - To catch engineer's contribution to the overall product technical performances.

