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Evaluating Alternatives for Designing Mechatronic Systems in a Systems Engineering Context

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The system analysis process (SEBoK 2012) allows « *developers to objectively carry out quantitative assessments of systems in order to select and/or update the most efficient system architecture and to generate derived engineering data* ». The goal is here to perform trade-off studies. We focus here on the evaluation of costs, risks or effectiveness of Alternative System Design Solutions (ASDS) provided by the technical systems engineering processes (ISO/IEC 2008) considering two main constraints. First, iterative aspect of design approach induces a growing but uncertain maturity level of detail of the proposed solutions. Second, each decision resulting from evaluations must be argued considering stakeholder's requirements. It is particularly crucial to note here that these requirements can be more or less contradictory. They can be also relative to various domains and culture such as mechanics, electronics, or computer science. The proposed work aims at giving a methodological guide with embedded tools and innovative decision making methods to support the effectiveness evaluation of ASDS. It is here applied in the field of mechatronic systems analysis. This guide is the subject of methodological, conceptual and technical contributions summarized in the next sections.

Methodological contribution: a generic set of evaluation activities

The proposed activities are here considered as generic and iterative activities for evaluation purpose in the System Analysis process. They are gathered into four main sets of activities for evaluation focusing respectively on:

- Defining the objectives of the evaluation and selecting the solutions to be evaluated.
- Preparing the job to be performed by defining decision model, selecting applicable multi-criteria analysis methods (Fülöp 2005) and tools and then selecting required data extracted from design models.
- Performing the job including sensibility and traceability analyses.
- Delivering expected results, justifications, recommendations.

Conceptual contribution: a data model for evaluation

The goal is to provide a unified data model (Figure 1) that can be understood and shared by designers whatever may be their origin or business domain. This model formalizes concepts and relations between concepts representing classes of data required during evaluation. It integrates stakeholder, system designer and design evaluator points of view as promoted by (Blanchard and Wolter 2011; INCOSE 2011; Maier and Rechtin 2009). Stakeholders are interested by technical requirements, Measures Of Effectiveness (MOE) and Measures Of Performance (MOP). Designers are interested by ASDS, predictive models as described below, Design Considerations, and Design Dependant Parameters (DDP that can be splited up into input and output DDP namely iDDP and oDDP). Last, evaluators are interested by system architecture, evaluation criteria and associated Technical Indicators.

Conceptual and technical contribution: impact evaluation and evaluation traceability

The goal is to support evaluation activities and systematically trace design choices with a certain level of automation. Relying on the relationships, it is then possible to identify the possible influence of DDPs on the criteria. Then, a decision model is merged with a predictive model (Figure 2) in order to estimate the magnitude of such influences.

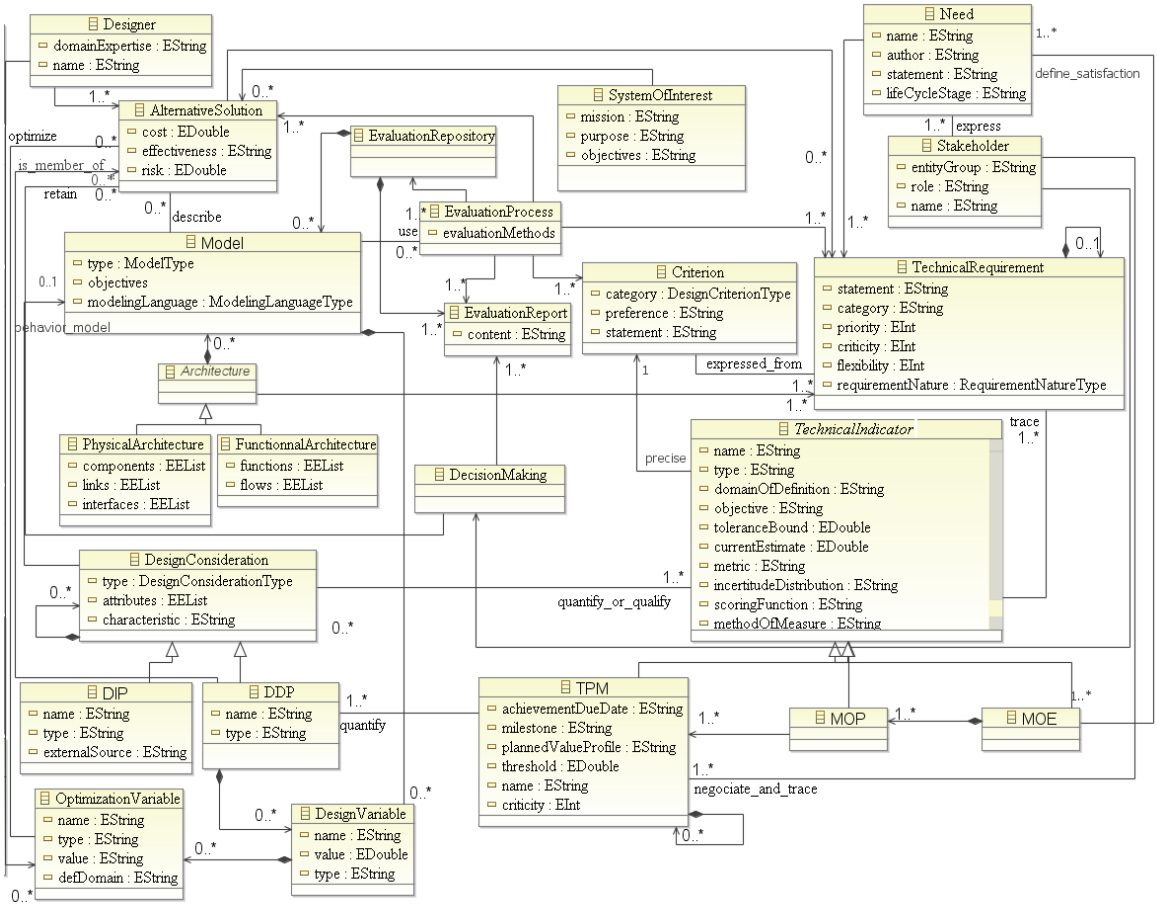

Figure 1: Evaluation data conceptual model (simplified)

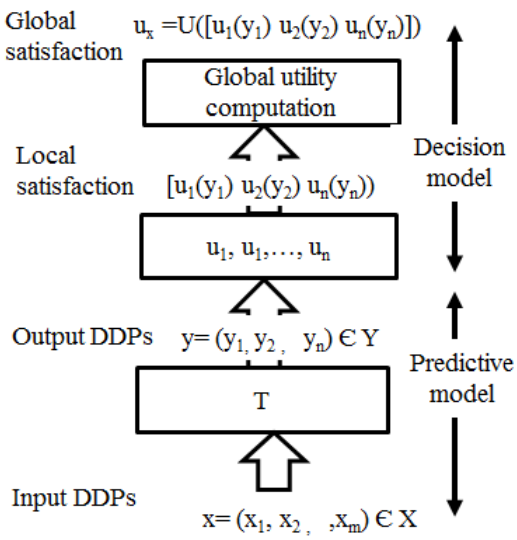

Figure 2: Merging decision model and predictive model

This figure shows how a 'predictive model' is used in order to predict oDDPs values from iDDPs values. The 'decision model' computes the global satisfaction level of each ASDS applying multi-criteria analysis methods, for instance by using utility functions. However, the transformation from iDDPs to oDDPs may be unknown or marred by uncertainty. This mainly arises during the preliminary (or conceptual) design phase. So, an original approach based on qualitative influence analysis is proposed to deal with such an uncertainty issue. This approach consists in asking experts to advise on qualitative influence (improvement or

degradation) of iDDP choices on the value of utility function applied to each oDDP. It becomes then possible to highlight the most promising ASDS since the earliest stage of the design. For this, we adopt aggregation and propagation operators from (Imoussaten *et al.* 2011 – 1030-1037) and (Giorgini *et al.* 2002 - 167-181).

Research and developments perspectives

It should be noticed the lack of interoperability between SE tools and multi-criteria analysis tools. The proposed contributions have been developed in order to be interoperable with classical SE tools. This is achieved by enriching system engineering meta model with the proposed evaluation data conceptual model. The approach has been tested particularly on the CORE V8 tool (Vitech 2011). A software platform supporting the entire guide is under development. The goal is now to enrich contributions by taking into account other *–ilities* evaluation as proposed by (De Weck *et al.* 2012).

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