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Model-Based Enterprise Information System Architectural Design with SysML

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IEEE

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Problem Statement

- Information System Architecture Design: complex task
- Current trend: use of MBSE (INCOSE*)
  - promote **integration** and **interoperability** of methods and tools
- Interest on Non-Functional Requirements Verification

*The International Council on Systems Engineering (INCOSE) is a not-for-profit membership organization

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Enterprise Architectures

- IEEE 1471 (ISO/IEC 42010 Recommended practice for architectural description of software-intensive systems)
- Department of Defense Architecture Framework (DoDAF)
- The Open Group Architecture Framework (TOGAF) (business and organizational concerns)
- Reference Model of Open Distributed Processing (RM-ODP) for the description of information systems which are running on independent heterogeneous nodes
- Zachman framework provides a classification of descriptive system representations in a simple matrix form.

Reichwein, Axel, and Christiaan JJ Paredis. "Overview of architecture frameworks and modeling languages for model-based systems engineering."*ASME 2011 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers, 2011.
Estefan, J. A. (2007). Survey of model-based systems engineering (MBSE) methodologies. *Incose MBSE Focus Group*, *25*, 8.

Current Status

- Design tools emphasize SysML (MagicDraw, Visual Paradigm, Enterprise Architect, Rational Rhapsody Designer, Papyrus UML, Modelio)
- Evaluation is a non-automated process and non-integrated in the MBSE cycle (CASSI[1],ModelicaML[2])
- SysML: NFRs are described in abstract fashion
- Missing: integrated approach based on SysML promoting automation (SLIM[3])

1: Kimura, Daichi, et al. "Evaluation of it systems considering characteristics as system of systems." *System of Systems Engineering (SoSE), 2011 6th International Conference on*. IEEE, 2011.
2: W. Schamai, P. Helle, P. Fritzson, and C. J. J. Paredis, “Virtual verification of system designs against system requirements,” in Proceedings of
the 2010 international conference on Models in software engineering, ser. MODELS’10. Berlin, Heidelberg: Springer-Verlag, 2011, pp. 75–89.
3: Bajaj, Manas, et al. "SLIM: collaborative model-based systems engineering workspace for next-generation complex systems." *IEEE Aerospace Conference*. IEEE, 2011.

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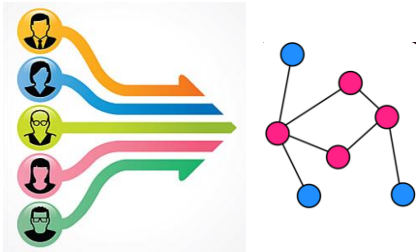
Motivation

When designing Information Systems, software and network infrastructure architecture should be designed in parallel, ensuring system efficiency.

- Many stakeholders - One Central Model (SysML)
- Lack of efficient mechanisms for the verification of quantitative NFRs defined in SysML models



Aim

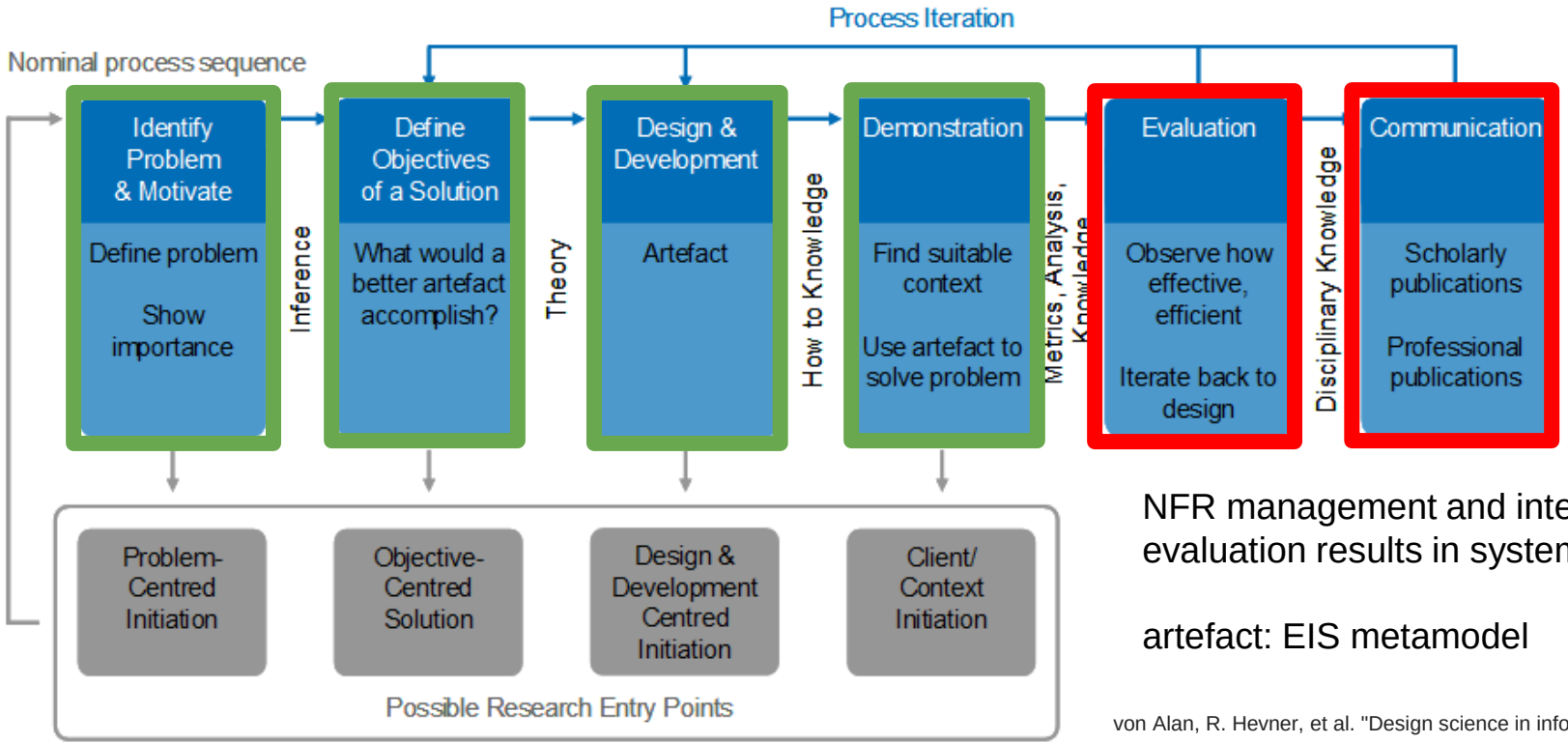
Phd scope: an integrating environment where architectural design and evaluation should be offered based on SysML emphasis: NFRs, verification

facilitate the system designer to explore **alternative design solutions** and **evaluate** the system model before its implementation

Objectives

- propose a **methodology** for EIS Architecture Design based on OMG standards
- **implement** corresponding tools to support the proposed methodology
  - define a SysML profile in order to support the EIS Design
  - **automate** requirements verification process using a specific simulation environment
- **evaluate** the proposed methodology through a complex case study

Science



NFR management and integration of evaluation results in system model

artefact: EIS metamodel

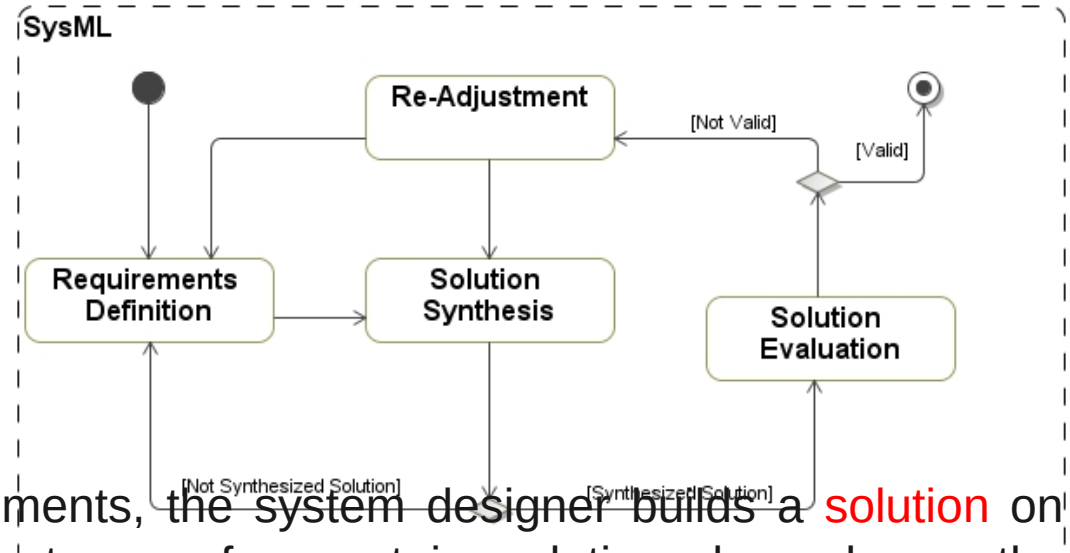
von Alan, R. Hevner, et al. "Design science in information systems research. "*MIS quarterly* 28.1 (2004): 75-105.

source: http://www.anlaufmanagement.rwth-aachen.de/de/2b4f44b90af4b9dcc1257496003d7048_print.html

Design Activity Processes

Design activity processes (INCOSE):

- Requirement definition
- Solution synthesis
- Solution evaluation
- Solution re-adjustment



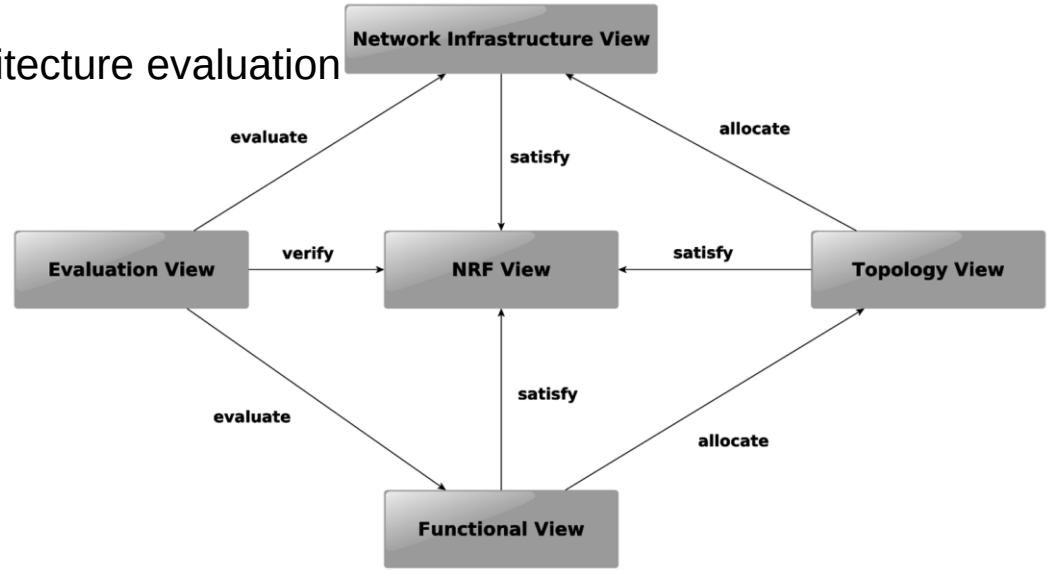
Based on predefined requirements, the system designer builds a solution on system synthesis. The acceptance of a certain solution depends on the evaluation process, which is performed through **requirements verification**.

Views for EIS Architecture Design

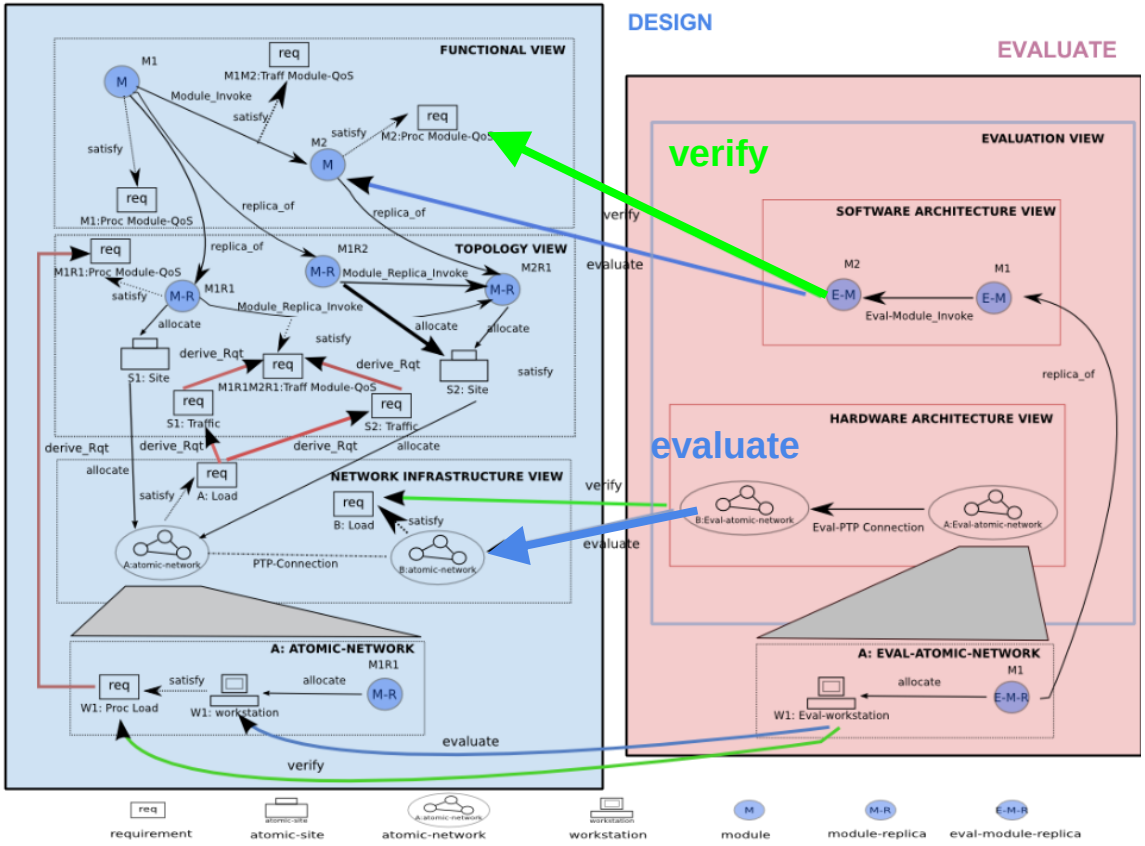
- **Functional View**, consisting of software architecture description
- **Topology View**, consisting of the description of system access points
- **Network Infrastructure View**, consisting of the description of platform-independent distributed infrastructure
- **NFR View** consists of all NFRs that should be satisfied by entities belonging to design views.
- **Evaluation View** serves EIS architecture evaluation

Relations

- **verify**
- **satisfy**
- **evaluate**
- **allocate**



EIS Profile Overview



3 phases

- Design
- Evaluate
- Adjust

until
all requirements
are verified

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Non-Functional Requirements

- SysML supports the requirements definition in an abstract level.
- Requirements definition includes the definition of **functional** and **non-functional** requirements, such as *performance requirements*.
- An extension of SysML requirements is required, where emphasis is given in the definition of non-functional performance requirements.
- Types of Non-Functional Requirements*
    - Response-Time
    - Utilization
    - Availability
    - Behavior
    - QoS (processing, storage, network)

Tsadimas, A.; Nikolaidou, Mara; Anagnostopoulos, D., "Handling Non-functional Requirements in Information System Architecture Design," Fourth ternational Conference on Software Engineering Advances, ICSEA '09. , pp.59-64, 20-25 Sept. 2009

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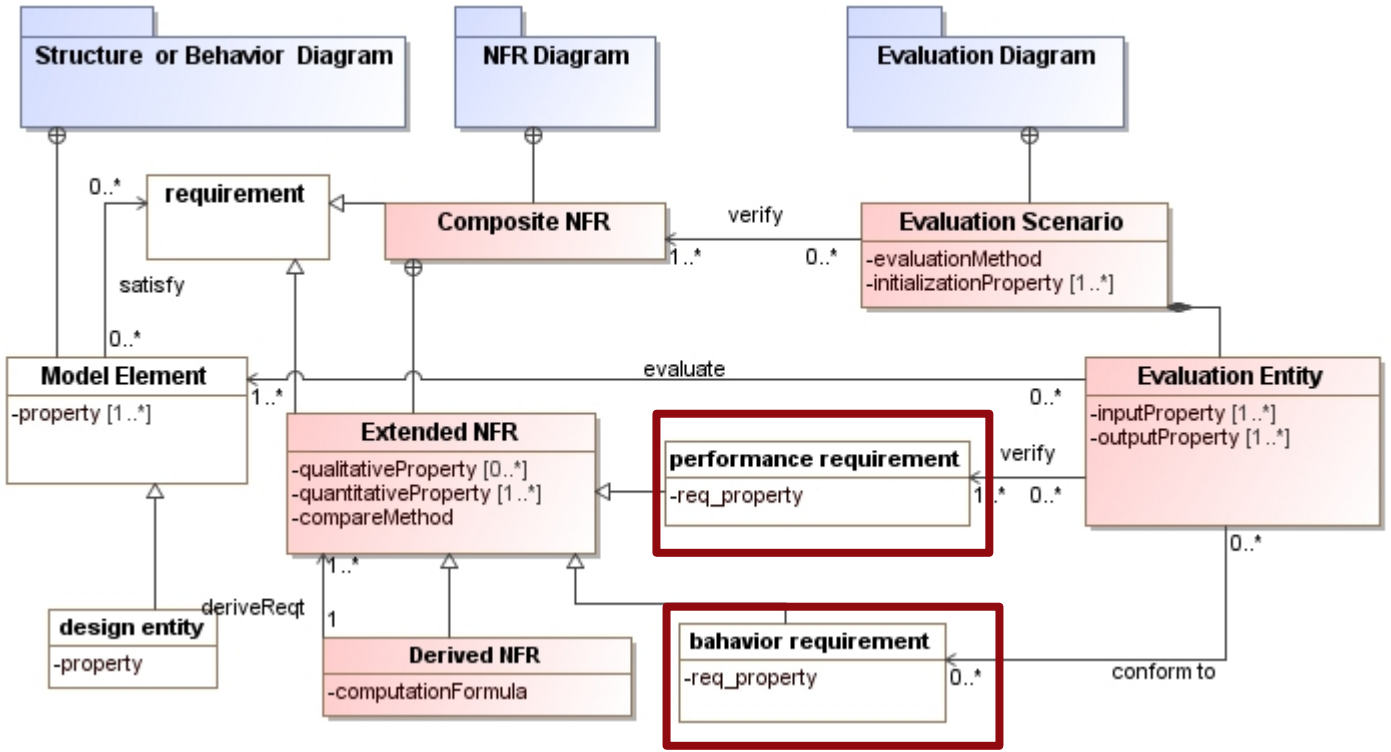
Extending SysML Requirement



Requirements Derivation

- Simple and derived requirements
- SysML provide the means to define and interrelate requirements but no way to define their derivation
- A derivation formula is defined (formal method or heuristic algorithm)
- e.g., Load req for a network is derived from network reqts for all software components allocated in this specific network

Requirements Derivation: example

Estimating the network load (recursive):

- internal traffic
- total traffic

let **STEP 5:**

STI let T be the set of all network-connections

cre $\forall t, t \in T$, let n_1, n_2 be the two connected networks and S_1, S_2 the sets of sites allocated to n_1, n_2 respectively

$\forall t, t \in T$:

$\mathbf{traffic}_t = \sum \Lambda[y, 2], \{y : \Lambda[y, 0] \wedge \Lambda[y, 1] \in S_1 \cup S_2\}$

$\mathbf{totalTraffic}_r = \sum_{q=1}^{n} \mathbf{totalTraffic}_q - \mathbf{inTraffic}_q, q \in Q_r - \mathbf{inTraffic}_r$

$\mathbf{inTraffic}_r = \sum \Lambda[y, 2], \{y : \Lambda[y, 0] \wedge \Lambda[y, 1] \in S_r\}$

$\mathbf{remove}(\Lambda[y, *]\{y : \Lambda[y, 0] \wedge \Lambda[y, 1] \in S_r\})$

repeat step 4 until $R' = \emptyset$

where $s_k, s_l \in S$,

$\mathbf{traffic}_{s_k \to s_l}$ is the aggregated traffic between sites S_k and S_l

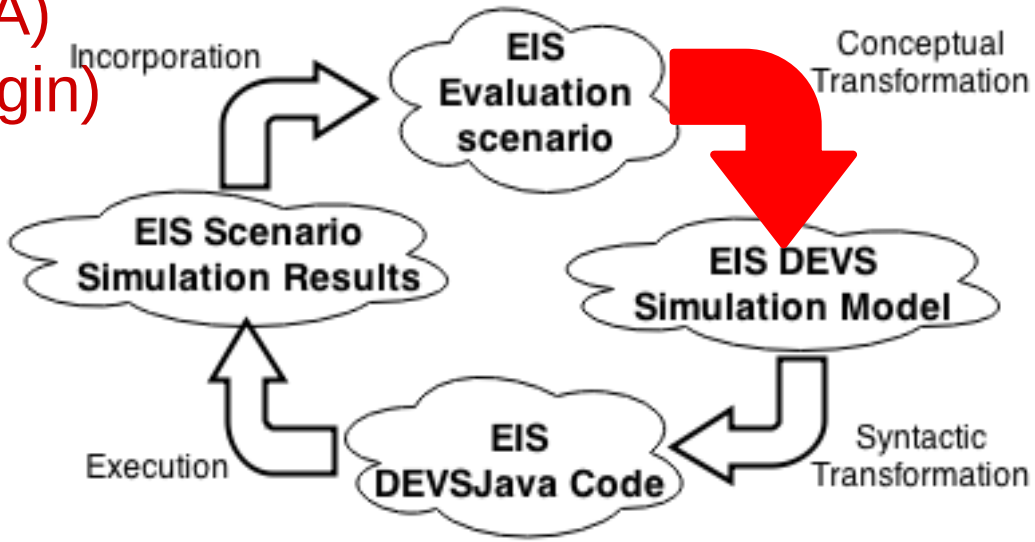
Evaluation

- Obtain quantitative estimation of the model behavior
- Comparison of simulation output with defined requirements for a model element
- The significance of the unverified requirements determines the extent of the necessary solution re-adjustments
- Simulation is a common evaluation method for the performance of EIS architectures[1]
- SysML ➡ test case, our approach ➡ Evaluation Scenario

1: A. Law, Simulation modeling and analysis, 4th ed., ser. McGraw-Hill series in industrial engineering and management science. McGraw-Hill, 2006.

EIS Simulation Lifecycle

- Conceptual Transformation (QVT)
- Syntactic Transformation (XSLT)
- Execution (DEVSJAVA)
- Incorporation (EIS plugin)



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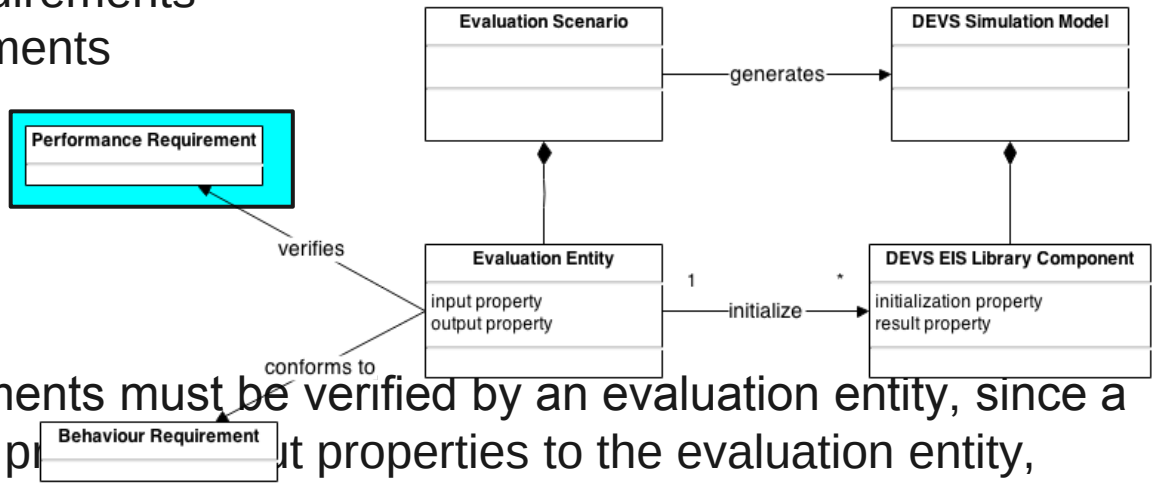
Simulation Model Generation

A design entity may satisfy two kinds of NFRs:

- performance requirements
- behavior requirements

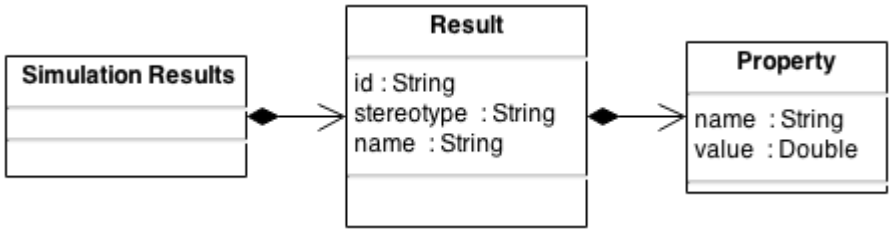


Performance requirements must be verified by an evaluation entity, since a behavior requirement pr ut properties to the evaluation entity, indicating the conditions (constraints) under which the evaluation (simulation) should be done (run)

Evaluation Entities

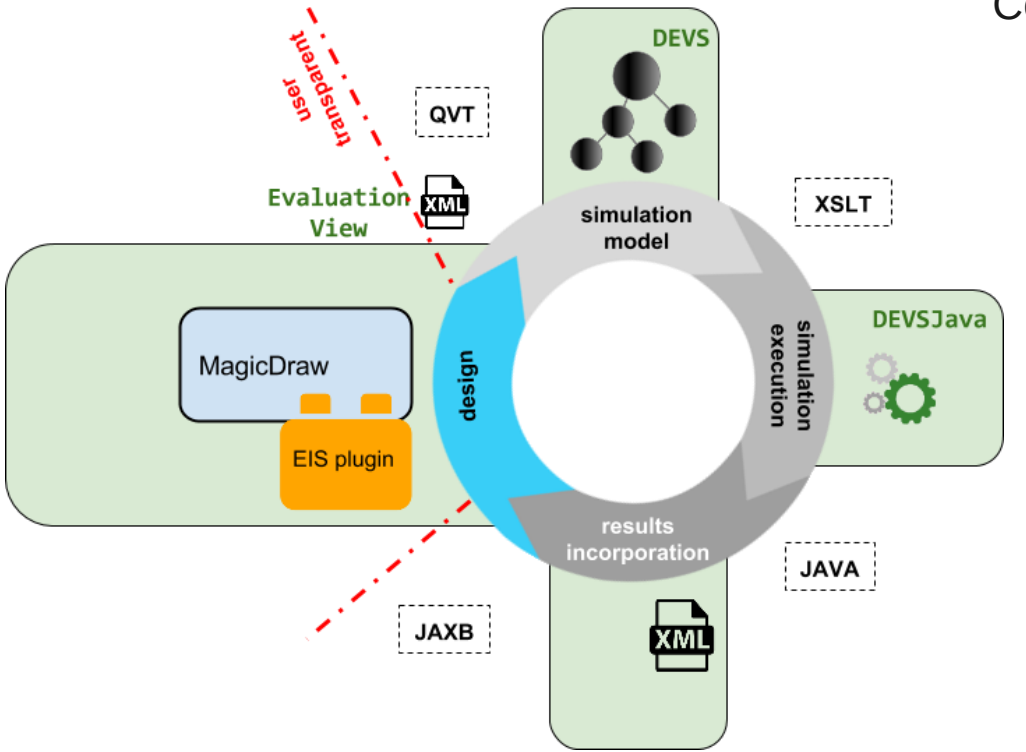
Input & **Output** Properties

- Input Properties → Simulation Inputs
- Output Properties ← Simulation Results : Verify Requirements



An evaluation scenario facilitates both a) the definition of the conditions under which the system will be evaluated (probably using simulation) and b) the depiction of the evaluation results, so that the system engineer may be directly informed of requirement verification.

An Integrated Framework for EIS Architecture Design



Commitment to standards:

- UML: profile definition
- SysML: system design
- XMI: (meta)data interchange
- MOF: meta modeling
- QVT: model transformations
- XSLT: syntactic transformations

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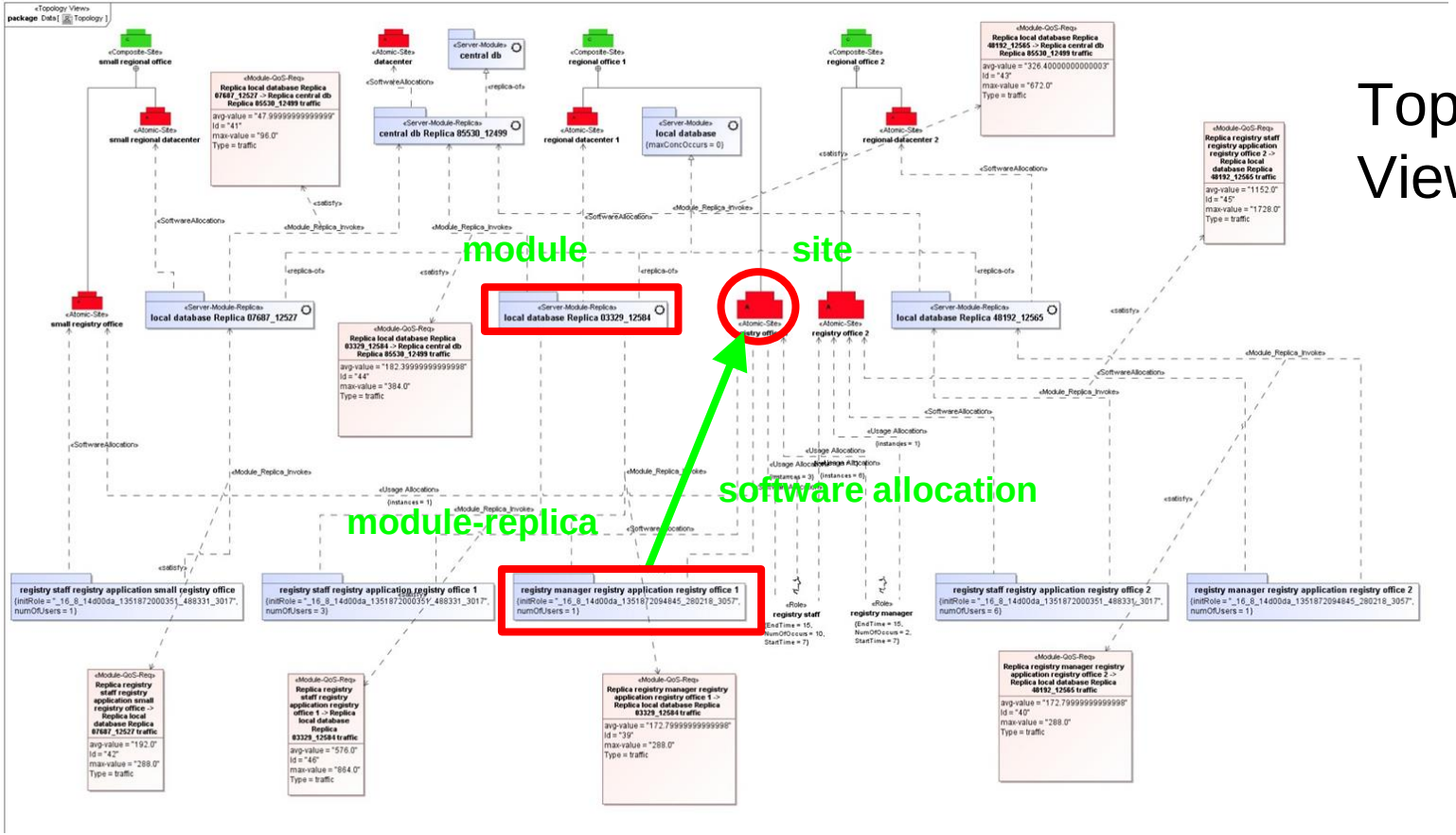
Depict Design Decisions



Topology View

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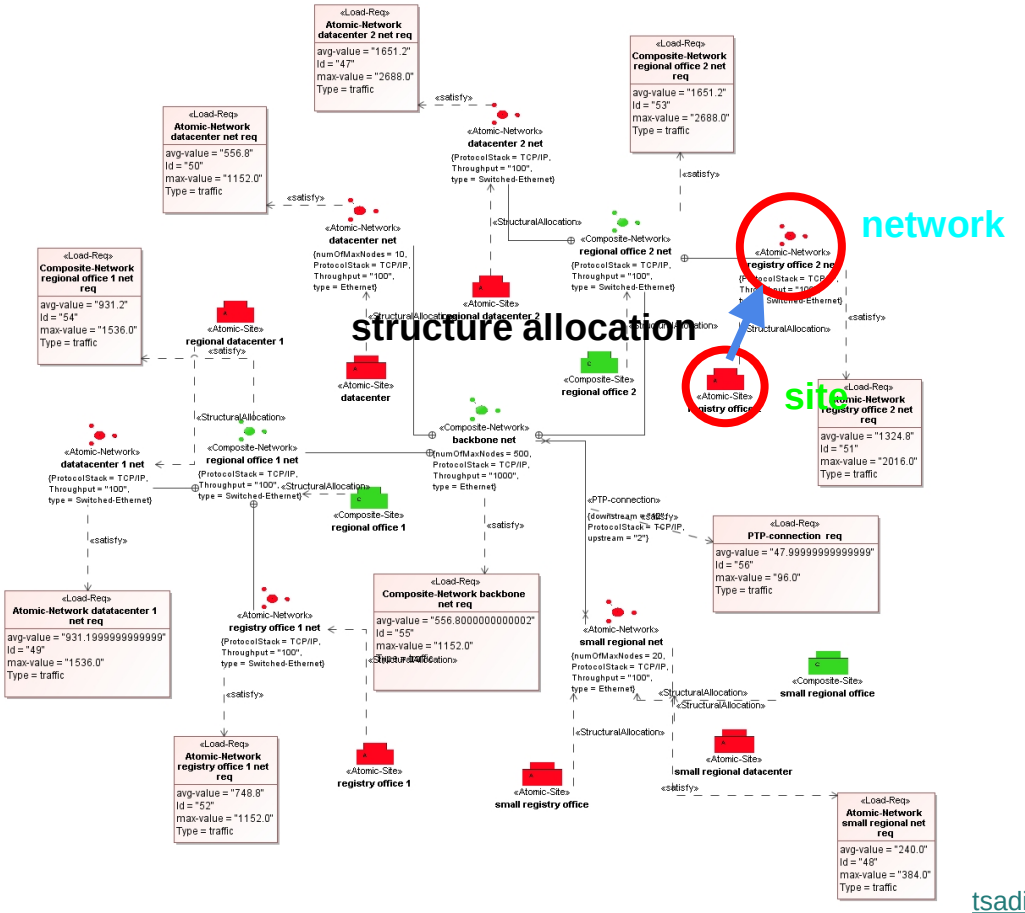
Depict Design Decisions



Network Infrastructure View

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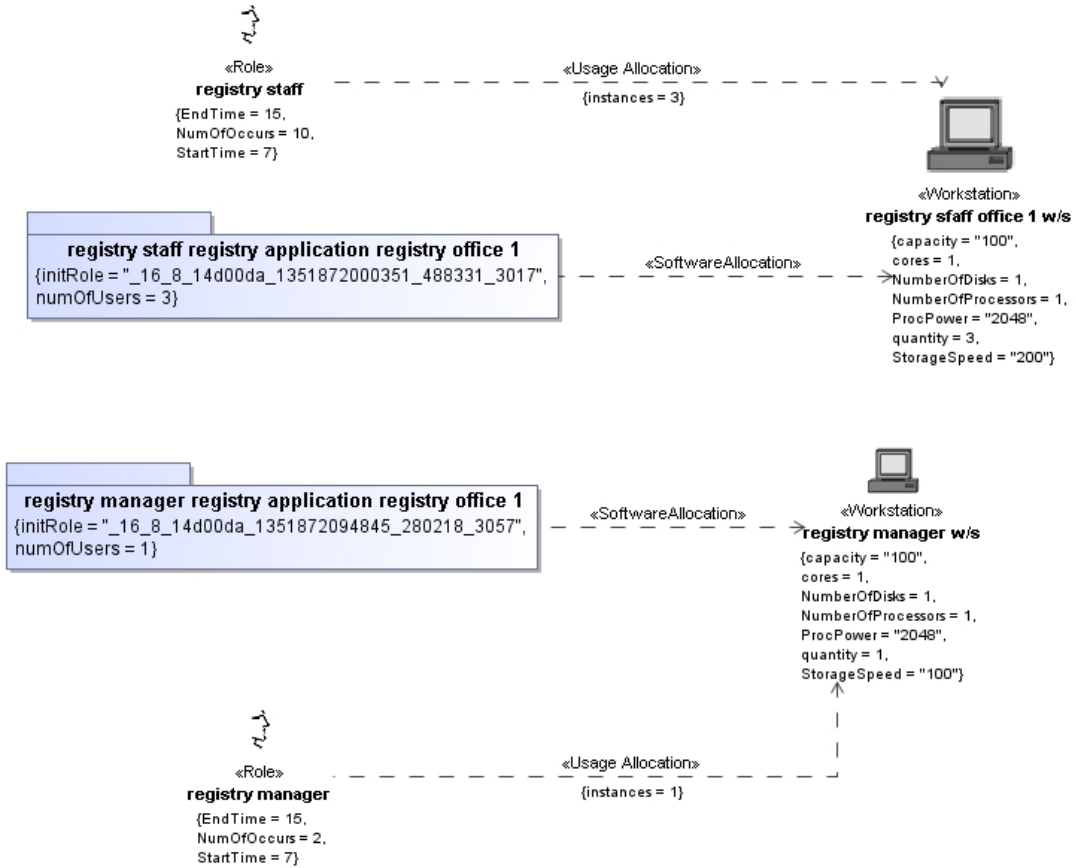
Depict Design Decisions



Network Infrastructure View: Atomic-Network

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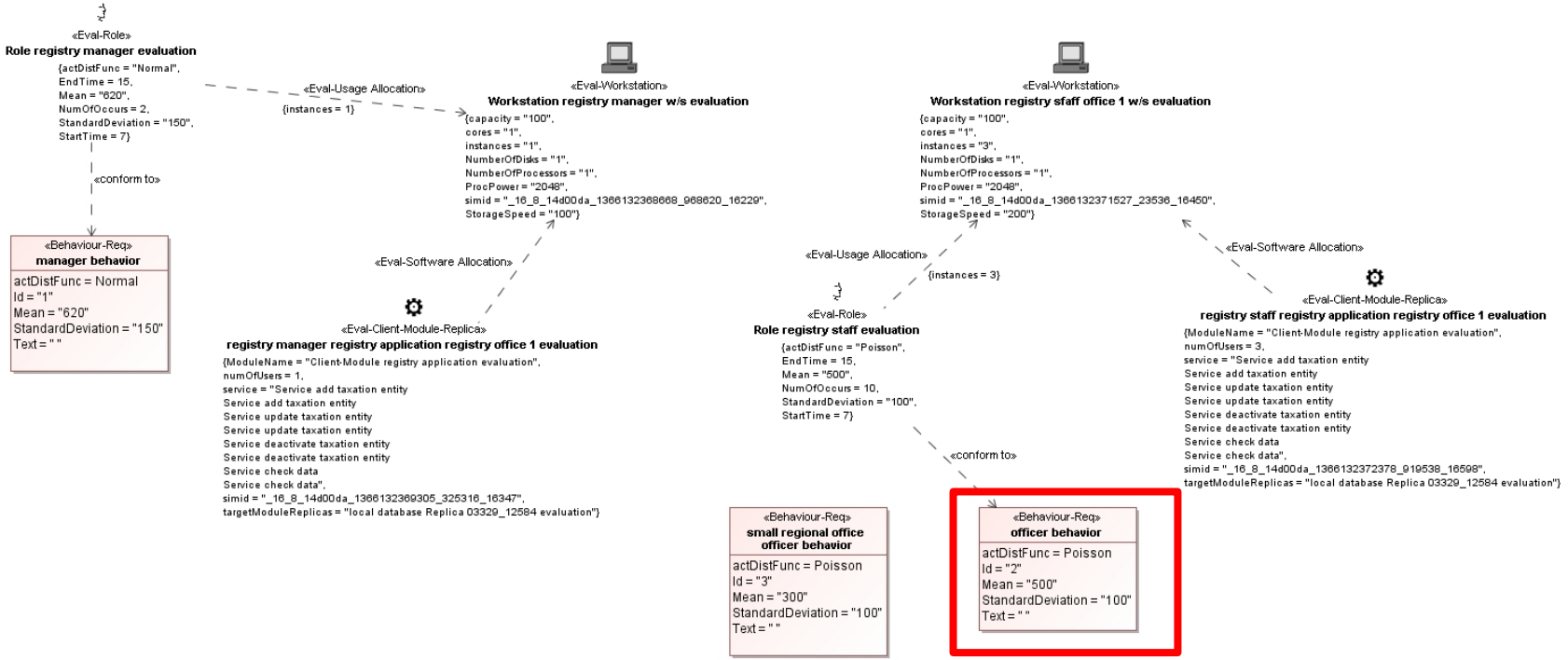
Evaluation EIS Architectural Solutions

Hardware Architecture: Atomic Network



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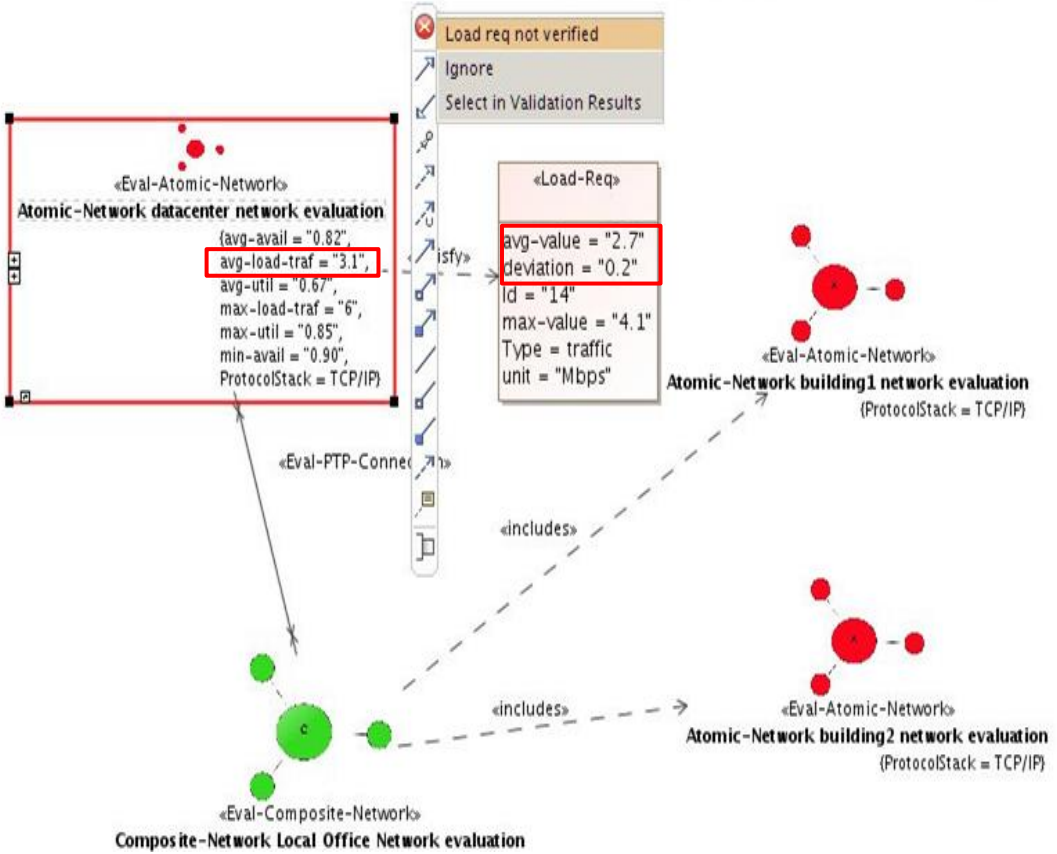
NFR Verification -Designer Notification

Notification of a non-verified requirement

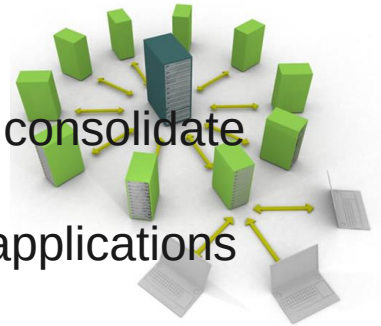


Case Study

Renovation of the legacy system of a public organization
objective: enhance application performance without major rewriting the applications themselves.
Two scenarios to be explored:

I. to support existing distributed database architecture and try to consolidate hardware
II. to establish a central database architecture resulting in minor applications code modifications.

350 interconnected regional offices technologically supported by a central IT Center responsible for IT diffusion and management.



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Contribution

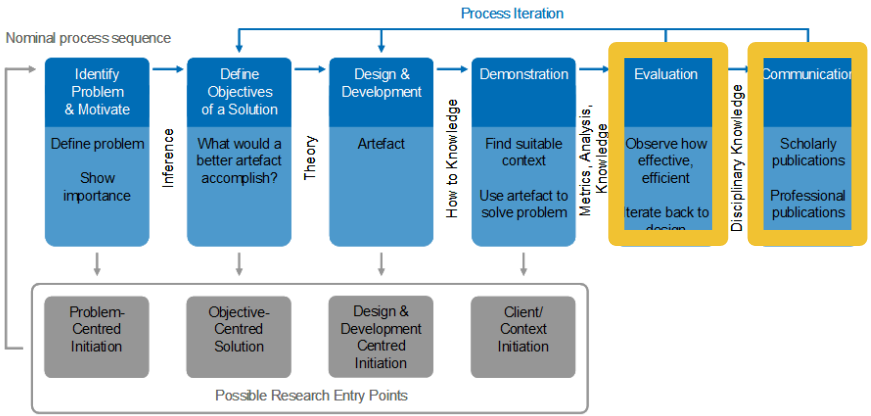
- The proposition of a Model-based Systems Engineering approach using SysML and formal languages based on OMG's standards.
- Enease system designer to effectively design an Information System, providing feedback about the performance of the system.
- integration of evaluation results with the system model and the visualization of the comparison between evaluation results and corresponding requirements
- *Prove the feasibility of the proposal by a case study*

Future Work

Next Steps

- evaluate through a large scale case study

- explore more NFR types (e.g. Security)
- applicability in other domains Transportation)
- Technoeconomic analysis



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THANK YOU

Questions?

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