Using Models in Decision Making Process Under Uncertainty

Philosophy of Models in Engineering Design

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INTRODUCTION

the use of models in the design process in a complex systems design industry, barriers and opportunities

USE OF M&S RESULTS IN DESIGN AND DEVELOPMENT

M&S have gained maturity and use in the design and development:

- *Engineers have made progress in use of M&S in design and development.*
- *Recent research has underlined that resources engaged in modeling and simulation activity can reach up to 50 % of overall development costs [Broy, Kirstan et al. 2013].*

However, industrial observations have brought that:

- Although a considerable amount of resources is spent in M&S, **decision makers often do not trust M&S results**.
- M&S is intended to **support design decisions**, but is sometimes used in the company as a means to off-load responsibilities and workload.

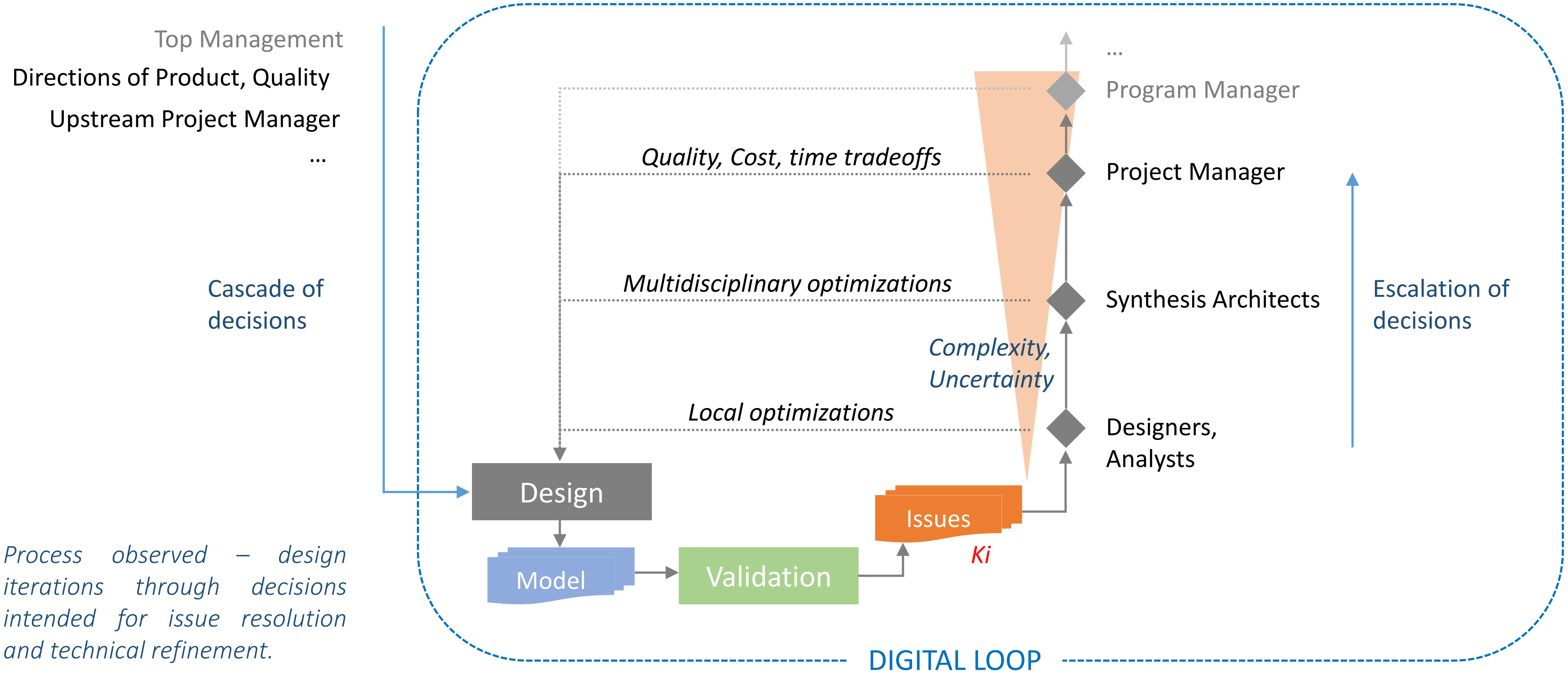
This raises several questions:

- Is this due to the lack of time? Maybe it is due to the timing?
- Why do people not have confidence in M&S results? People issue? Precision? Comprehension?

OBSERVED DESIGN PROCESS

Vehicle design process can be seen as series of decisions largely supported by modeling and simulation.

A decision is a choice between two or more alternatives that involves an irrevocable allocation of resources. [Howard and Abbas, 2015]



Process observed – design iterations through decisions intended for issue resolution and technical refinement.

BACKGROUND

Uncertainty has been broadly studied and explored

Hassanzadeh proposed two approaches to define uncertainty [Hassanzadeh, 2013]:

- **Object-based** [Thiry, 2002; Galbraith,1973; Klir, 2005; Zadeh, 2006; Knight, 1921]
- **Subject-based** [Head, 1967; Lipshitz et al., 1997; Milliken, 1987; Thompson, 1967]

Several classifications have been proposed and are discussed:

- **Objective** (ambiguity) or **Subjective** (vagueness), [Ayyub and Chao, 1997; Klir and Yuan, 1995].
- **Aleatory** (irreducible, variability) or **Epistemic** (reducible), or error, [Oberkampf et al., 1999; Haukass, 2003; Isukapalli et al., 1998; Der Kiureghian, 1989]

Several **uncertainty-based design methods** intended for both experimental and computational uncertainties (model form or parameter uncertainties), are available [Zang et al., 2002]:

- **Probabilistic methods**
- **Non-probabilistic methods**

In our context, what are the uncertainties in the process?

How to best manage them?

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Credibility of M&S results

- Credibility: The quality to elicit belief or trust in M&S results [NASA, 2016].
- Recently a standard has been proposed to ensure that the decision maker is made aware of the key information regarding M&S results that is needed to infer their credibility [NASA, 2016 ; Hartway et al., 2009].

Could such prescriptions reinforce the trust into M&S results in the company?

Decision making in the automotive industry

Although designers prefer tested procedures and experience based approaches [Earl, Johnson and Eckert, 2005], decision-making methods are largely used an tested:

- **P**roblem **S**tructuring **M**ethods,
- **M**ulti-**C**riteria **D**ecision-**M**aking Methods,
- **D**ecision-making **P**roblem **S**olving Methods.

Some work has been done related to the classification of the decision_making methods with regard to design phases, e.g. Renzi et al. [Renzi et al., 2017].

In the context of our process, what methods are used in the company?

METHOD

an observational study to identify the difficulties in existing decision making with regard to M&S activities

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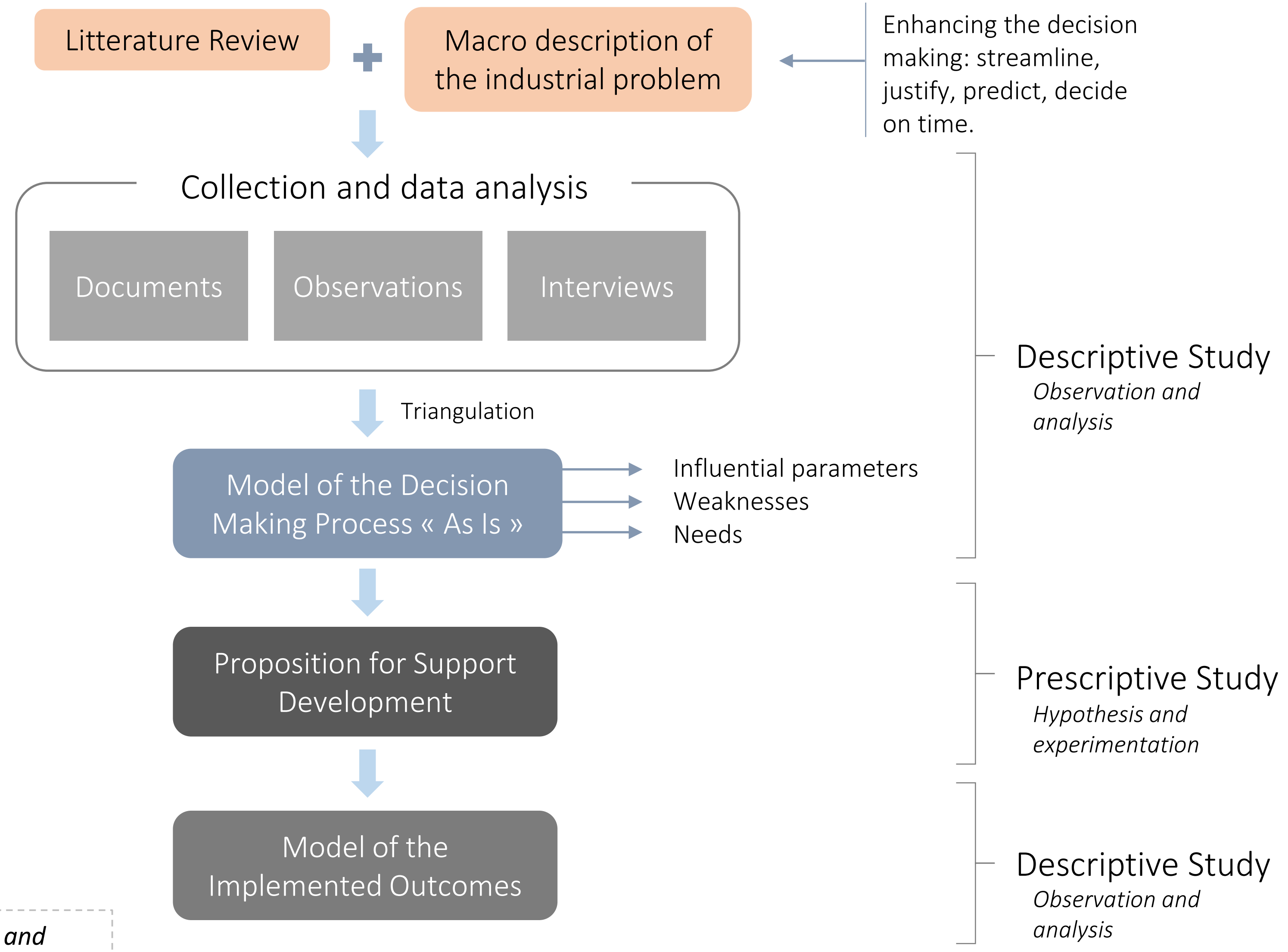

[Inspired by Blessing and Chakrabarti, 1998; 2002]

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DATA COLLECTION AND ANALYSIS

The study aimed to **map out the decision-making process** occurring during the solution proposal stage in the company.

Analyzing internal documents, attending to decision meetings, interviewing stakeholders such as the targeted decision makers (Project Managers) and their influencers. Collecting data that enabled us to build a model of the decision process "as is".

Documents

- Organization of Computer Aided Engineering Process.
- Logic of development reference.
- Minutes of the decision meetings of various level.
- Project organization – Project management team.
- Project feedback.
- Simulation process.

Observations

- Decision meetings concerning a plateform project.
- Project manager and stakeholders written information exchange.

Interviews

- Program Managers.
- Project Managers.
- Synthesis Architecs.
- Modeling & Simulation practitioners.

OBSERVATIONS

need and difficulties related to uncertainties in M&S processes in support of vehicle design

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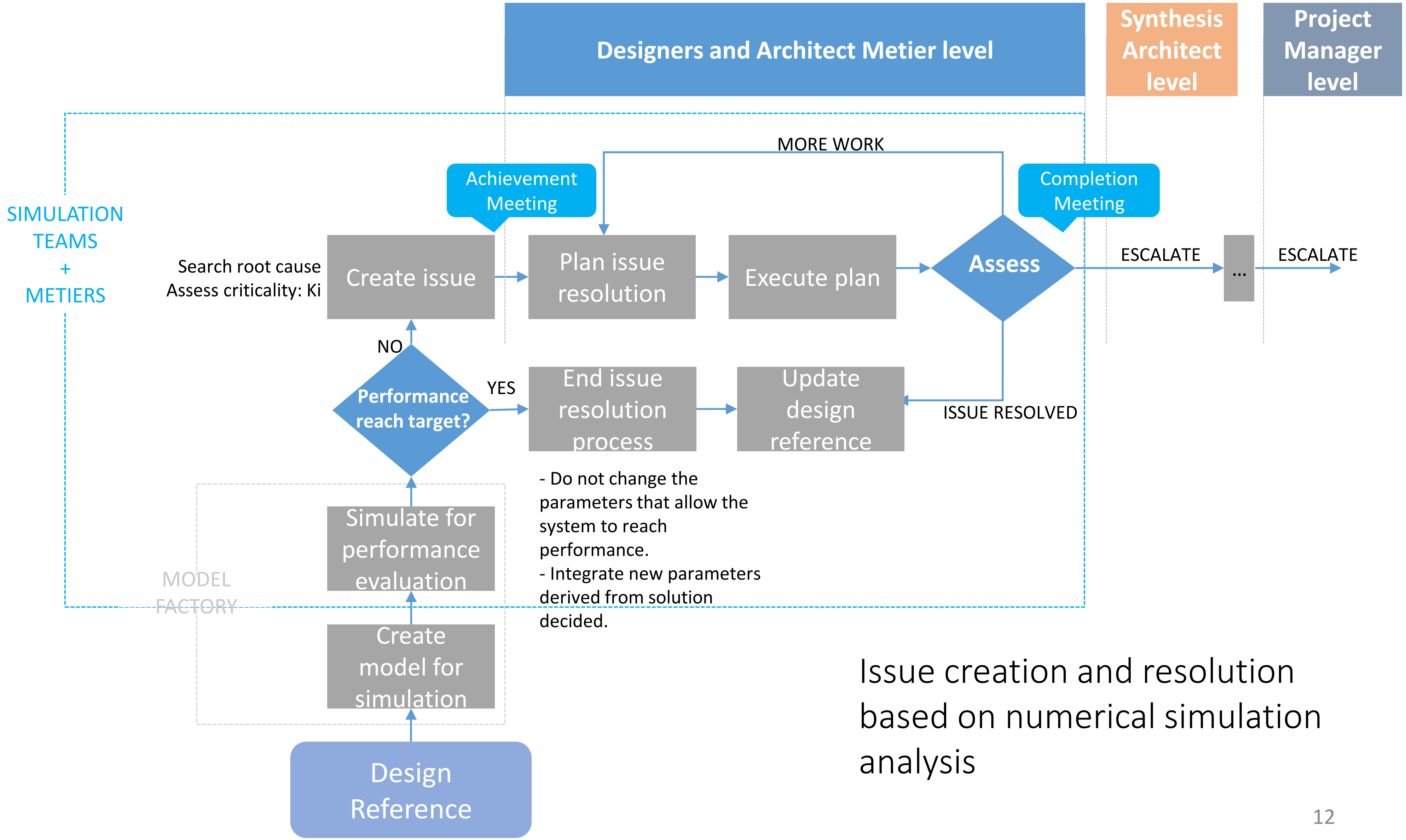
SIMULATION BASED ISSUE RESOLUTION PROCESS



Issue creation and resolution based on numerical simulation analysis

DECISION MAKING DIFFICULTIES

4/6	→ Decisions come up **too late / too early / unknown time** to decide.
3/6	→ **Lack of documentation** / maturity of decision dossiers (QCD).
2/6	→ Wrong /unreachable performance target.
2/6	→ **No risk estimation**.
2/6	→ Solutions too much focused on cost savings.
2/6	→ Lack of **synthesis / too much information**.
1/6	→ Unclear **problem statement** (what needs to be decided).
1/6	→ **Simulation results not good** / representative.
1/6	→ Stakeholders do not attend to meetings.

DIFFICULTIES WITH MODEL-BASED DECISION MAKING IDENTIFIED IN THE COMPANY

Consistency of the data

Whether the results are based on the latest technical definition, and take into consideration the last countermeasures (the previous decisions).

Feasibility of alternatives

Some alternatives presented are not analyzed enough in a product-process perspective. The project manager need to rely on experts that, despite the rules of core competences [règles métiers] and experience, might not have certain answers.

Validity of simulation assumptions

Whether the results of simulation are based on assumptions that reflect the reality, despite the history, knowledge, and rules about tests. Calculations made with nominal values, whereas there is a variability within the physical prototypes.

DIFFICULTIES WITH MODEL-BASED DECISION MAKING IDENTIFIED IN THE COMPANY

The framing of the decision problem

Some presenters come up without a well framed problem. The project manager asks what they expect him to decide. No QOC (question, options, criteria).

The Quality Cost Delay impact

For a specific alternative one or multiple dimensions of the QCD can be unknown.

The “right time” to decide

Decision has to be made before given moment. That moment is not certain and depends on several factors (milestones, other design specifications, availability of information, etc.)

The data consistency *(from the modelers perspective)*

Whether the technical definition and data necessary to build models are the latest.

M&S CREDIBILITY

According to decision makers, there is a need for:

4/6 → Knowledge about the **limitations**, the **predictability** of simulation, the **precision**.

3/6 → **Robustness** estimation.

3/6 → Understanding the **assumptions** / the method of calculation. Need that explanations of results to be available.

2/6 → Expression of **uncertainty** about results / confidence interval.

2/6 → References / comparison to history (phys. tests) /analogies.

M&S CREDIBILITY

Credibility : physical is considered more credible than numerical

- Auditors tend to minimize the relevance of M&S before the physical tests (mostly for acoustics/thermo).
- People often do not question the protocol, the technical definition, and the relevance of phys. tests whereas in M&S, the update of the tech. def., the accuracy, the simulation assumptions are questioned.
- Good news/ Bad News : Assumptions, data consistency, etc. mostly questioned when M&S Results are unsatisfcatory : when they do not confirm the alternative the most preferred (cost increase…).
- Unclear data pedigree: data sometimes presented without explicit origins, lack of explanation.
- Solutions that increase the cost are really sensitive => ask for « recalculation », for optimisation => postponed decisions.

USE OF M&S

M&S and selection of alternatives

- M&S can help to **streamline** the alternatives that are considered below the performance required but does not often allow to make conclusions between alternatives that are similar, or does **not provide all the info sufficient** to decide (cost, time, feasibility,…).

- Considered as not predictive enough for domains such as acoustics, ground links, etc. when the simulation need to be made out of entire vehicle synthesis model.

- When the alternatives either related or represent technical solutions that are not entirely satisfaying but worth considering, the **decision is a choice of investigation**.

- Alternatives, presented as « Hypothèses », are, in terms of decision, the **paths of investigation** of different solution proposals (directly or undirectly allocating ressources of time, money, and workforce).

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USE OF M&S

Rationale of M&S use

- **Is there a real need for M&S for each subject?** It seems that M&S is sometimes used as a proof that a work has been done (results not credible/conclusive at the time of the decision).
- Neglecting the estimation of resource allocating.

People involvement

- In some cases, for some reasons (risk, resources) **people are not willing to rework** their design solutions and **question simulation results**, ask for recalculations, or advise the project manager to choose an option that does not impact their work (when several subsystems involved, cf architecture).
- Claimed inaccuracy of simulation can used as an argument to postpone decisions when they involve people overinvestment.

DISCUSSION

emerging questions from the study related to the use of models as a support for decision-making

MORE QUESTIONS THAN ANSWERS

How to support people in characterizing and understanding uncertainties in M&S process?

- How to reduce uncertainties in the design process?
- …

How to convey information related to the M&S process to decision makers?

- Use credibility assessment of M&S results?
- …

How to support communication related to models between design and simulation people?

Thank you.

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ANNEX

ANNEX

Whatever modeling and simulation activity is increasingly performing, **decision-making is a human activity influenced by beliefs and biases**.

Hence, the **trust** of decision makers into their models need to be considered and enhanced in a decision support development perspective.

Uncertainty is the hard core of model-based decision-making, and its characterization and management could help to improve confidence into information, and allow clarity of actions.