Applying and Extending FEMMP to Select an Adequate MBSE Methodology

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Abstract: Model-Based Systems Engineering (MBSE) relies on the central concept of model expressed in a well-defined language like SysML. However, efficiently and effectively driving the system design process through its lifecycle requires an adequate methodology. To ease the selection process among several MBSE methodologies, the Framework for the Evaluation of MBSE Methodologies for Practitioners (FEMMP) is worthwhile. This paper reports on the use of FEMMP to help in such a selection process with a focus on recent MBSE methodologies: Arcadia, ASAP and Grid. In addition to providing new and updated evaluations, it also identifies some overlooked criteria and suggests a few improvements. A consolidated comparison with older methodologies is also proposed and discussed.

1 INTRODUCTION

Model-based systems engineering (MBSE) is defined as "the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" (INCOSE, 2007). For the industry, adopting MBSE is an important paradigm shift because the system model becomes the central part for the exchange between engineers rather than documents (Madni and Purohit, 2019). Moving to MBSE does not only mean adopting a system modelling language and a tool supporting it, it is also about the methodology to build and refine the model in various scenarios such as designing a new system or modernizing an existing system.

Especially, SysML is just a language and not an architecture framework nor a methodology and needs to be complemented with guidelines about how to start the model, how to structure it using different views, which artefacts to produce and in which order. Considering Enterprise Architecture frameworks, they provide guidance to drive transformation at enterprise/system level but they tend to focus on the global perspective with many views intertwining different aspects. They lack of simplified perspective addressing only subsets of each view (Morkevicius et al., 2016).

The number of MBSE methodologies have grown considerably over the past decade which more than 20 methodologies identified across various initiatives (OMG, 2018)(Weilkiens and Mao, 2022). This raised the question of selecting an adequate methodology to suit a specific industrial context. In response to this need, the Framework for the Evaluation of MBSE process for Practitioners (FEMMP) provides a set of criteria evaluated using a standard case study which enables the objective comparison of methodologies (Weilkiens et al., 2016)(Di Maio et al., 2021). FEMMP is increasingly used to benchmark specific methodologies such as RePoSyD (Beyerlein, 2020), Viper (Aboushama, 2020) or in a comparative way like Arcadia vs OOSEM (Alai, 2019).

This paper is motivated by a concrete selection process among recent MBSE methodologies, namely Arcadia (Roques, 2016), ASAP (Ferrogalini and Bastard, 2012), and Grid(Morkevicius et al., 2017) in connection with a local industrial ecosystem. In order to drive the selection process, an internal evaluation grid was defined before discovering the availability of FEMMP. Our work was then aligned with FEMMP which allowed us to use comparison information published by others over the past years. It also highlighted some missing criteria in our initial assessment which could be improved. Conversely, we identified some areas where FEMMP can be improved and discussed them.

This paper is structured as follows. Section 2 presents the assessment methodology based on FEMMP with some extensions. Section 3 introduces the three methods of interest. Based on this, Sec-

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tion 4 provides a consolidated evaluation summary of those methods against available evaluation published in other evaluations. Those results are then discussed in Section 5. Finally, Section 6 concludes and identifies some future work.

2 ASSESSMENT METHODOLOGY

This section details our assessment methodology. First, we had a quite systematic look at available methodologies. This enabled us to build a short list the methods of interest that are then investigated using the FEMMP-based assessment. The precise grid used is presented in this section including some enhancements resulting from an independent questionnaire design process.

2.1 Global Overview and Shortlisting

The starting point was to identify MBSE methodologies from cataloguing websites such as (OMG, 2018) and (Weilkiens and Mao, 2022): 13 candidates listed in Table 1 were gathered. In order to quickly identify a short list and to focus the detailed evaluation on a few interesting candidates, the following criteria were considered and related indicators for their evaluation were collected as part of Table 1.

- Is the method still actively used?
  (indicators: creation date, initiator and activity)
- Is the method SysML-based?
- Is the method well supported by tools?
  (indicator: list of tools)
- Is the method independent of a specific tool (vendor lock)?

The expressed need in our case was to focus on methodologies actively supported by large companies, preferably based on SysML and tool neutral. The process resulted in the preselection of Arcadia (although not purely SysML), ASAP and Grid.

2.2 Detailed Assessment with Extended FEMMP

The Framework for the Evaluation of MBSE Methodologies for Practitioners (FEMMP) aims at gathering all the available MBSE methodologies in a common repository and enable an objective comparison to help practitioners in their selection process (Weilkiens et al., 2016).

The assessment methodology is targeting practitioners and can be performed by practitioner through the following steps and results:

1. Methodology overview producing a short illustrated summary with references.
2. Highlights detailing unique/interesting features.
3. Case Study: short feedback on an application attempt on a standard case (steam engine).
4. Evaluation: evaluation grid driven by questions and using a set of multidimensional criteria, with each dimension reflecting crucial parameters for the evaluation.
5. Discussion summary of the process and results.

This process is quite natural and was actually followed prior to discovering the availability of FEMMP. We also produced methodology descriptions and highlights, investigated a trial application and developed our own evaluation grid. However, in order to enable comparison and check about possible gaps in our assessment, we decided to align with the FEMMP grid which has the following structure:

- six aspects: General (G), Information (I), Language (L), Model (M), Process (P), Tool (T)
- five categories: Adopting (A), Basics (B), Praticality (P), Support (S), User Experience (U)
- three evaluation metrics: Yes/No, list selection and qualitative scale. The latter relies on the following qualitative scale: (A) Fully Compliant: the item is exhaustively covered and addressed, (B) Acceptable Performance: minor constraints or limitations apply, but are well documented, (C) Limited Applicability: major constraints or limitations apply with notable impacts, (G) Generalisation: Compliance claimed, but not supported by evidence, (X) Not Addressed.

Table 2 shows the global list of questions of the last version of FEMMP extended with our own questions based on a comparative analysis with our framework. The column ID-F represent the internal FEMMP identifiers (combining the code of the aspect, the category and a sequence number) while column ID-I represents our own categories from A to E: (A) General, (B) Model, (C) Maturity, (D) Variants, (E) Process. The analysis of Table 2 reveals some interesting points:

- the tool dimension is quite present in the FEMMP and mostly absent in ours beyond the existence of tool support. We decided on purpose to use a separated and more detailed grid for the tool assessment. This avoids introducing confusion between method and tool assessment which can be present with FEMMP. Note also that tool support is present in the previous shortlisting process.
- across other aspects, our evaluation is missing a few questions like tailoring, complexity, capture of process information, redundancy, standard

and frameworks. This confirms FEMMP was designed and validated more carefully than our ad-hoc approach.
- for language related questions, we have a similar coverage but with a finer granularity in ours with separated questions about diagrams and semantics when the language is not SysML.
- FEMMP is missing some questions about method and process related the capture of non-functional requirements, the distinction between problem and solution domain, traceability and support for object-oriented development.
- FEMMP seems to overlook some general questions about maturity and industrial adoption (C2-C3). The reason behind this is that FEMMP seems to assume that criterion to be fulfilled as prerequisite. The benefit in our case lies more in the additional evidence which can be used to refine some comparison.
- FEMMP similar coverage is achieved for documentation, training, support activities.

In the detailed evaluation presented in this paper, we will use FEMMP with our additional questions. This enables the comparison with published FEMMP evaluations while covering our additional needs. It could also be proposed as part of a future evolution of the method as discussed later. To integrate them in a distinctive way, we used an additional extension category (X), e.g. C2 about maturity will be identified as G-X-01.

3 OVERVIEW OF MBSE METHODOLOGIES

Due to space constraint, this section only gives a summary of the three MBSE evaluated methodologies we shortlisted: ARCADIA, ASAP and Grid. We use the presentation canvas proposed by FEMMP. Other methodologies are described in a similar way in other references like (Weilkiens et al., 2016), (Alai, 2019), (Javid, 2020), (Di Maio et al., 2021).

3.1 ARCADIA

ARCADIA (ARChitecture Analysis and Design Integrated Approach) is an MBSE for complex technical systems, developed by Thales.

Methodology. ARCADIA provides a method but also a language which is not a SysML profile nor a domain-specific modelling language. It is a metamodel strongly inspired by SysML and providing very similar diagrams but simplified for some behavioural aspects and enriched for the architecture framework (Bonnet et al., 2016). Figure 1 depicts the five engineering levels of ARCADIA which first cover the problem domain with *operational analysis* (user perspective) and *system needs* (both functional and non-functional) and then the solution domain with the *logical architecture*, *physical architecture* and *end-product breakdown structure/integration contracts* (not shown on the Figure).

Highlights. ARCADIA is implemented by the CAPELLA tool which is Open Source with a strong community although some commercial components are definitely required for an industrial context, e.g. for collaborative work and toolchain integration. The

Table 1: Global overview of MBSE methodologies.

Acronym	Meaning	Since	Initiator	Active?	SysML?	ToolNeutral	Know tool(s)	Reference	Sel.
Arcadia	ARChitecture Analysis and Design Integrated Approach	2015	Thalès	Yes	No (close)	No	Capella	(Voirin et al., 2015)	X
ASAP	Advanced System Architect Program	2012	Alstom	Yes	Yes	Yes	Artisan (PTC)	(Ferrogalini and Bastard, 2012)	X
FAS	Functional Architecture for Systems Method	2010	Lamm Weilkiens	?	Yes	Yes	Artisan (PTC)	(Lamm and Weilkiens, 2010)	
GRID	–	2016	Morkevicius	Yes	Yes	Yes	MagicDraw	(Morkevicius et al., 2017)	X
Harmony	–	2006	IBM	No	Yes	Yes	IBM/Telelogic	(Hoffmann, 2006)	
JPL SA	State Analysis	2006	NASA	No	No	No	State Database	(Ingham et al., 2006)	
OOSEM	Object-Oriented Systems Engineering Method	2000	INCOSE	?	Yes	Yes	–	(Lykins et al., 2000)	
OPM	Object-Process Methodology	2002	Dori	?	No	No	OPCAT	(Dori et al., 2003)	
PPOOA	Process Pipelines in OO Architectures	2002	Fernandez	No	No	Yes	Visio add-on	(Fernández-Sánchez and Mason, 2002)	
PBSE	Pattern-Based Systems Engineering	2010	Schindel	?	Possibly	Yes	Sparx EA, Rhapsody	(Schindel and Peterson, 2013)	
RePoSyD	Req. Eng. Project Management and System Design	2020	Hoppe	Yes	No	Yes	RePoSyD	(Hoppe, 2020)	
SYSMOD	SYStem MODelling	2008	Weilkiens	Yes	Yes	Yes	MagicDraw (plugin)	(Weilkiens, 2020)	
STRATA	–	2004	Vitech	Yes	No	No	Core, Genesys	(Vitech, 2016)	

Table 2: Detailed MBSE assessment grid.

Criterion	Description	ID-F	ID-I
Learning Curve	How steep does the learning curve feel?	G-A-01	C4
Suitability for Beginners	How easy to understand is the methodology for (MB)SE novices?	G-A-02	C4
Training Effort for SEs	How much training does it take for experienced SEs to implement the methodology correctly?	G-A-03	C4
Industry Domains	Which industry domains does the methodology support particularly well/ has it been developed for?	G-B-01	C1
Creativity Support	How does the methodology foster a creative environment for the systems engineering team ?	G-B-02	E2
Support of Standards	Does the methodology also support other standards or norms? If so, how well?	G-B-03	
Scope	For what engineering purpose is the methodology suited (innovation, improved products, refactoring, etc.)?	G-P-01	
Tailoring	How easy is it to tailor the methodology (add/delete/change processes/process steps, or toggle tool features on/off)?	G-P-02	
Complexity	How often is the methodology interrupted by external processes and/or non-integrated tools, e.g. 'paper-review'?	G-P-03	
Simulation	How well does the methodology provide for an integrated simulation of the various model abstractions?	G-P-04	
Documentation	How well is the methodology supported (books, manuals, case studies, on-line help, community, user feedback etc.)?	G-S-01	C4
Training	How well is training supported (availability, consultants, coaches, e-training, background knowledge required)?	G-S-02	C4
Maturity	Is the method mature, maintained and supported by an active community ?		C2
Industry adoption	Is the method already successfully adopted by major companies ? Are there reported experience reports ?		C3
Process Info Capture	How well does the tool capture the information generated throughout the process?	I-B-01	
MBSE-SE Exchange	How well does the tool facilitate the exchange of the information between the MBSE and the non-MBSE domains	I-B-02	
Philosophy	Are Model Elements clearly distinguished from Diagram Elements (separation of content from representation)?	L-B-01	
Language	What Modelling Language is used (If NOT SysML: How well does it define the real-world semantics, are elements strictly typed, is their meaning unambiguous do they have a defined purpose etc.)?	L-P-01	A4,A5 B3
Integration	How well can the model be integrated with specialty engineering models ? (Does it support coengineering?)	L-P-02	B6
Modelling Features	What modelling features and approaches are included from the reference framework ISO 42010 (Architecture)	M-B-01	
Modelling ISO 15288	How well does the MBSE methodology support modelling of the ISO 15288 processes?	M-B-02	
Abstraction	How well does the model support keeping it abstract through multiple levels?	M-B-03	B1
Meta-Model	Does the methodology provide a (semantic) meta-model, ontology or similar?	M-B-04	
Scalability	How well does the model scale to large projects, 'grows' with time without becoming cumbersome?	M-P-01	
Variants	How well does the methodology support the variant management?	M-P-02	D1
Indep. View Generation	How well does the methodology support the generation of views that can be read in another MBSE language?	M-P-03	
Redundancy	How well does the methodology prevent duplication (of work, model elements, artefacts, communications, etc.)?	M-P-04	
NFR	Does the method allow the capture of non-functional requirements?		B7
Pb vs Solution	Does the method clearly separate the problem and solution domains?		B2
Traceability	Does the method provide strong traceability support between requirements, functions, (sub)systems/components?		B4,B5
ISO Standard	What process steps of ISO 15288 are covered?	P-B-01	
Framework	What views from the reference framework are used (MODAF, DODAF...)?	P-B-02	
Consistency	Is the process self-contained (are in-/outputs to all steps connected)?	P-P-01	B5
OO Support	Does the method provide support for OO development?		B8
Precision	How precisely is the process implemented in terms of semantics and sequence, do workarounds impacting quality?	T-B-01	E1
Information Security	How secure is the data/information exchange between parties	T-B-02	
Perspectives	To what level is the creation of experts' perspectives automated	T-E-01	
Reporting	How quickly are standard/custom reports, is design documentation created	T-E-02	
Admin	How well does the tool help to minimise work that isn't creating any value	T-E-03	
Checking	Does the tool support consistency checking of the model? (e.g. automated detection of wrong content/formats)	T-E-04	
Navigation	How easy is it to find a specific model element (following links, using queries, a traceability model) ?	T-E-05	
Connectivity	How easily can the information be exchanged with other tools (standard (open) API, import/export, wizard, etc.)?	T-P-01	
Reuseablity	Does the tool allow to reuse any type of Modelling Element across projects	T-P-02	
Support	How well is the tool supported (vendor response times, 24/7 helpline etc.)?	T-S-01	C4
Intuitition	How intuitive is the tool to work with (e.g. compliance with UX conventions)?	T-U-01	
View	How easy is it to configure the UX dynamically (define a matrix with sorting/filtering, extend with annotations)?	T-U-02	
UI	How readable is the UI (screen layout, zoom, can fonts and sizes be changed, is information well presented)?	T-U-03	
Multi-User Env.	How well does the tool support the distribution of the work among different parties.	T-U-04	
Known tools	Can you identify tools providing good support to the methodology?		A6

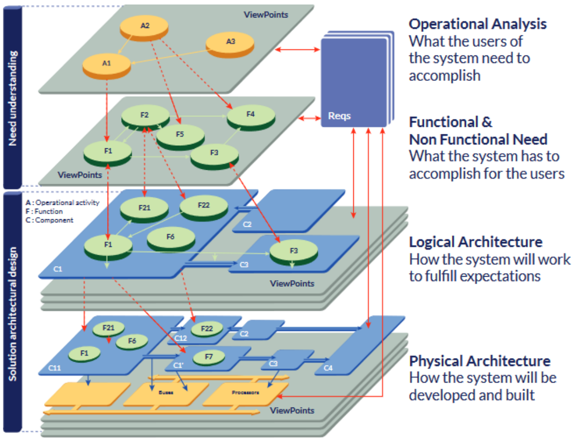

Figure 1: ARCADIA methodology.

tooling enforces consistency, supports the methodology, ensures traceability and has a globally good user experience.

Case Study. The steam engine case study has been modelled in Capella. It is highlighted in (Di Maio et al., 2021) and explained in more details in (Javid, 2020). Figure 6 depicts an Operational Architecture Blank (OAB) diagram capturing the allocation of Operational Activities to Operational Entities. The tool provides good methodological guidance for Arcadia through a process wizard.

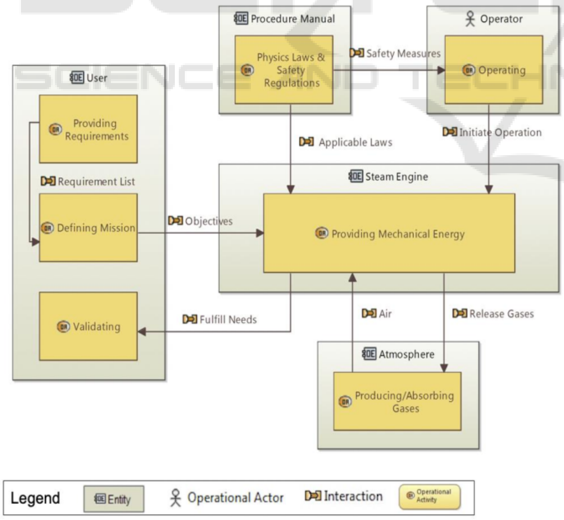

Figure 2: ARCADIA OAB Diagram for the case study.

3.2 ASAP

ASAP (Advanced System Architecture Program) is an efficient top-down MBSE approach developed by Alstom for its internal use.

Methodology. ASAP is organised in 3 main layers depicted in Figure 3. First, the *operational* level copes with the point of view of external users to identify their needs and the external interfaces (WHY). Second, the *functional* level focuses on WHAT the system does to fulfill its mission and the identification of functional flows. The third layer is *constructional* to structure into interconnected subsystems and their expected behaviour to achieve the system functionalities (HOW). The expression of each layer relies on specific diagrams of SysML, only a subset of SysML is used.

Highlights. The method can be extended to deal with the software engineering and also relies on UML in this case. It does not require a specific tooling but a SysML compliant tool able to cope with industrial requirements (scalability, efficiency, collaboration). A training program is available covering different profiles like managers, readers, designers and architects.

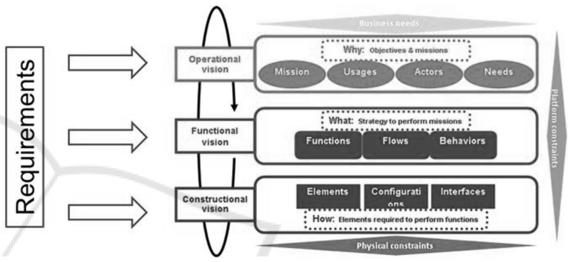

Figure 3: ASAP methodology.

Case Study. We modelled the steam engine using a SysML tool (PTC Windchill Integrity Modeller). The tool does not enforce the methodology but is quite strict about SysML syntax. Figure 4 depicts a small requirements diagram. In complement, we also studied a simple ASAP case study, a bathroom scale, that provided more insight on the use the proposed modelling levels.

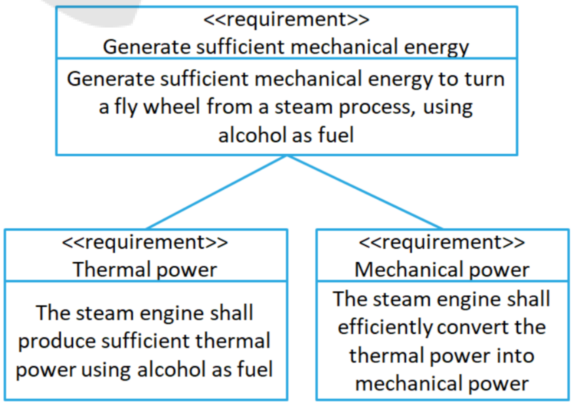

Figure 4: ASAP requirements diagram for the case study.

3.3 Grid

The Grid approach is influenced by Bombardier and Kongsberd Defense & Aerospace. It was built in reaction to previous industrial failure to adopt to MBSE. It is designed with a strong focus on guiding the system engineers through the modeling process (Morkevicius et al., 2016).

Layer of Abstraction		Pillar: Requirements	Pillar: Behavior	Pillar: Structure	Pillar: Parametrics
Problem	Black box	**Stakeholder Needs:** • Requirements diagram • Requirements table	**Use Cases:** 1. Use Case diagram 2. Activity diagram	**System Context:** • Internal block diagram	**Measurements of Effectiveness:** • Block definition diagram
Problem	White box	**System Requirements:** • Requirements diagram • Requirements table	**Functional Analysis:** • Activity diagram	**Logical Subsystems Communication:** 1. Block definition diagram 2. Internal block diagram	**MoEs for Subsystems:** • Block definition diagram
Solution		**Component Requirements:** • Requirements diagram • Requirements table	**Component Behavior:** • State machine diagram • Activity diagram • Sequence diagram	**Component Structure:** 1. Block definition diagram 2. Internal block diagram	**Component Parameters:** • Parametric diagram

Figure 5: Grid methodology.

The methodology is systematically structured using a bi-dimensional grid depicted in figure 5 where columns are aspects also known as four pillars of SysML (requirements, structure, behaviours and parametrics) and rows are viewpoints reflecting the problem domain (using the "black-box" user perspective and "white box" system functionalities) and the solution domain (at the component level). Each cell can described through specific SysML diagrams. The global structure is also inspired by Enterprise Architecture frameworks such as Zachman (Zachman, 1987). Like ASAP, it is vendor neutral for the tool support but with known implementation using MagicDraw (No Magic, 2016).

Highlights Grid provides a rich traceability across its cells which ease the model maintenance, change management and impact analysis. For example, a state machine at solution level must enforce some requirements at problem level or a use case can be traced to a functional analysis which is allocated to a subsystems implemented in a solution level component. Another strength of Grid is to provide a foundation for product line engineering based on the parametric pillar. This dimension is generally not well supported in MBSE methodologies.

Case Study. The steam case study was modelled using Enterprise Architect as tool. The collection of diagrams is close to those of ASAP given the SysML adoption which however the additional support for parametric diagrams enabling to capture variability points (not present in the case). Figure 6 shows an Internal Block Diagram (IBD) for the logical subsystem communications. In addition, another case study, a climate control unit, was also analysed for the use of parametric diagrams (Morkevicius et al., 2016).

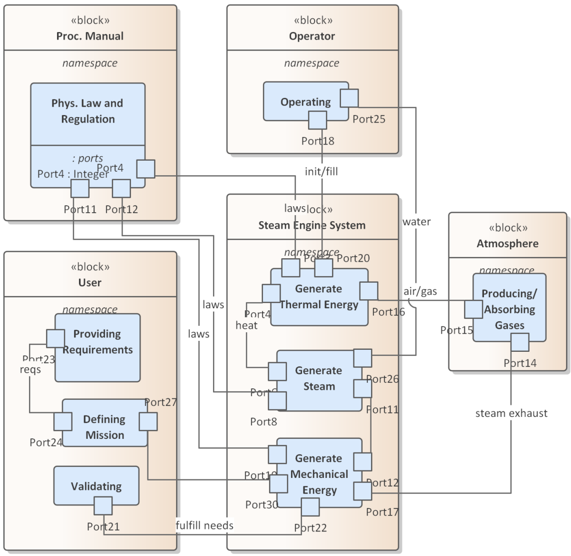

Figure 6: Grid IBD diagram for the case study.

4 MBSE METHODOLOGIES COMPARISON

Our primary purpose was to compare our three shortlisted methodologies detailed in the previous section. However, to enable a larger comparison, we also integrated information published by others, namely OOSEM vs Arcadia (Alai, 2019), Vitech STRATA (Aboushama, 2020) and RePoSyD (Beyerlein, 2020). Table 3 presents a consolidated comparison of those 6 methodologies across 19 criteria. The information resulting from our own evaluation is presented between brackets. Additional columns remind about the criteria, identifiers, aspect, category and response type.

We carried out this consolidation using the following process:

- we only focused on the scale and yes/no types.
- we ruled out questions relating to tool support for reason identified earlier and discussed in more details in the next section.
- we included our extensions but did not attempt to recover answers for external reviews. This also yields for criteria left empty in such reviews.
- the contributed evaluations were initially performed in our own grid and then transposed in FEMMP using detailed evaluation information and not only the resulting score. Each evaluation was performed by a team of experts with a single expert in charge of a specific evaluation. Review meetings were organised to discuss each criterion comparatively, first before the evaluation to make sure of the understanding of the criteria, and then

Table 3: Detailed MBSE assessment grid.

Criterion	ID-F	ID-I	Aspect	Category	Response Type	OOSEM	STRATA	RePoSyD	Arcadia	ASAP	Grid
Tailoring	G-P-02		General	Practicality	Scale	A	A	C	B	(B)	(A)
Complexity	G-P-03		General	Practicality	Scale	B	A	B	A	(A)	(A)
Documentation	G-S-01	C4	General	Support	Scale	B	C	C	A/B	B	(C)
Training	G-S-02	C4	General	Support	Scale				A	A	(C)
Maturity	G-X-01	C2	General	Support	Scale	(Yes)	(Yes)	?	(Yes)	(Yes)	?
Industry adoption	G-X-02	C3	General	Adopting	Scale	(Yes)	(Yes)	?	(Yes)	(Yes)	(Yes)
Philosophy	L-B-01		Language	Basics	Yes / No	Yes	Yes	Yes	Yes	(Yes)	(Yes)
Language	L-P-01	A4,A5,B3	Language	Practicality	List	SysML	SDL	RML	SysML like	SysML	SysML
Integration	L-P-02		Language	Practicality	Scale	C	B	A	C	(B)	(B)
Abstraction	M-B-03	B1	Model	Basics	Scale	(B)	(A)	(B)	(A)	(A)	(A)
Meta-Model	M-B-04		Model	Basics	Yes / No	(SysML)	Yes	Yes	Yes	(SysML)	(SysML)
Scalability	M-P-01		Model	Practicality	Scale	A	B	A	A	(A)	(A)
Variants	M-P-02	D1	Model	Practicality	Scale	B	B	B	B	(B)	(A)
Independent View Generation	M-P-03		Model	Practicality	Scale				(C)	(A)	(A)
Redundancy	M-P-04		Model	Practicality	Statement	B	A	C	A	(B)	(B)
NFR	M-X-01	B7	Model	Basics	Scale				(B)	(B)	(A)
Pb vs Solution	M-X-02	B2	Model	Basics	Scale				(A)	(B)	(A)
Traceability	M-X-03	B4,B5	Model	Basics	Scale				(A)	(A)	(A)
Consistency	P-P-01	B5	Process	Practicality	Yes / No	Yes	Yes	Yes	Yes	Yes	Yes

after the evaluation, to align some evaluation details, share the results and produce a summary.

5 DISCUSSION

In this section, we provide some extra discussion beyond the FEMMP extension already discussed in Section 2.

Methodology Selection is of course the first logical question. Among our three selected methods, there is clearly no winner nor looser. Due to its qualitative nature, FEMMP does also not claim to be able to rank the methodologies objectively and the suggested weights are more to help in prioritisation. Moreover, we believe the balance is specific to each case as there might also be mandatory criteria and more optional ones given each specific context. For example, variant management might be very important in systems deployed in many variants compared to system known to be unique. The transition management from document to model-based must also be considered and existing workflow must also be preserved, e.g. for certification.

The Generic Informal Criteria might be tuned in more quantitative and directed scale enabling more precision and homogeneity in the ranking. However, this would require a substantial work to specify, to understand and to rank. A danger could be to use some specific solution as reference point. An example is the variability in the number and nature of the structuring in the various methods although they share similarities, they are all different.

About the Tool Support, as pointed earlier, tool related criteria must be carefully formulated within in the scope of the methodology selection as there must not be any confusion between them. A key criterion is probably to be vendor neutral which is favored by the generalisation of SysML as language. The evaluation of tool criteria might become quite fuzzy because the response could vary with the tool considered. Consequently, it seems better to limit the tool related questions to some questions about a few key features (like collaboration, generation, integration) and to rely on a separate assessment for the tool support. This is the process that was followed in our case without detailing it here because the tool evaluation is in itself a huge work. Actually it can be more precise and thus requires a larger set of finer-grained criteria.

About the Case Study: the proposed case study about the steam engine was used as a starting point. It provides an interesting common background for comparing the methodologies and understanding the various diagrams types used to support the global design process. However, in complement, we also analysed other case studies, including more complex ones when available. We believe this complementary viewpoint is useful in order to understand the way diagrams are used by others, especially for more specialised notations, e.g. parametric diagrams for dealing with variability. It also helps to make sure the evaluators are not misinterpreting specific parts of the methodology.

6 CONCLUSION & NEXT STEPS

This paper performed a comparative evaluation of MBSE methodologies based on the existing FEMMP approach with two main extensions. First, we added a shortlisting step based on a few guiding criteria. Second, we introduced some extra criteria based on an independently designed evaluation methodology. Then, we applied the extended evaluation grid to three MBSE methodologies, two of them not yet ranked. The evaluation summary was consolidated with other published evaluations to reach an total of 6 methodologies across 19 criteria.

Our work is limited by the facts that not all criteria were ranked and by some subjectivity due to qualitative nature of the evaluation. However, we believe this work is of interest for the consolidated results but also for the proposed extensions and discussion. We hope our feedback can add to other reports and help driving the evolution of FEMMP, providing better guidance in selecting an adequate MBSE methodology and fostering the adoption of MBSE.

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