On the Benefits and Barriers when adopting Software Modelling and Model Driven Techniques - An external, differentiated replication

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***Abstract*—*Context:* Applying model driven techniques can lead to several benefits, but their adoption entails also numerous issues. *Goal:* We aim at understanding the benefits and barriers on the adoption of the modelling techniques for embedded systems developed in a large German research project. *Method:* We replicate a survey conducted in the Italian industry about relevance, benefits, and problems of software modelling and model driven techniques. *Results:* With respect to the original study, we could confirm design support and quality of software as achieved benefits. On the side of the barriers, too much effort required, lack of competencies and lack of supporting tools were confirmed. Other barriers were confirmed as not having an impact: refusal from management, cost of supporting tool, fear of lock-in. *Conclusions:* We observed that even for the not mature modelling techniques in our context of study, a few benefits and a large number of barriers (or lack of) reported in the original study and in literature were confirmed.**

Keywords*—*Model Driven Engineering, Model Driven Development, Technology Transfer

I. Introduction

Model-based techniques make use of models to describe architecture and design of a system and/or the behaviour of software artefacts, through levels of abstraction [1]. Models are very heterogeneous, can be used in different phases of the development process and in different ways (e.g. to automatically generate code or as communication artefacts). For this reason, following the terminology used in literature (see [2], [3]), we refer to the generic term MD* as an umbrella to indicate Model Driven Engineering (MDE), Model Driven Development (MDD), and Model Driven Architecture (MDA). Evidence in literature shows that, when applied successfully, MD* spans several benefits, among others: better understandability between stakeholders thanks to the rise of abstraction [4], improvements in productivity [5], better enforcement of architecture decisions [6]. On the flip side, the adoption of MD* into existing organisations can encounter several problems: for example studies report lack of traceability between generated artefacts [7], difficulties in maintainability [5] or in finding people with proper level of competencies [8].

We contribute to this body of knowledge with a study on the benefits and barriers of applying MD* in software development for embedded systems. Our investigation was conducted in a German research project, called SPES_XT [1], which was at its final stage, hence mature enough for such kind of evaluation. In SPES_XT and its predecessor SPES 2020 [2], a consortium of more than 20 partners from academia and industry (all the most relevant corporations in Germany in the avionic, automation and automotive sectors participated) developed a system engineering philosophy and a modelling framework to enable a seamless model-based development of embedded systems [9]. The modelling framework constitutes of a large set of modelling techniques, e.g. methods for modular safety requirements, models for parameterized verification of mechatronic systems, method for variability management on different abstraction layers. Case studies already demonstrated the applicability of the SPES methodology and techniques [3] [10]. However, these demonstrations do not automatically imply applicability and transferability into a broad operational industrial practice, as currently the results have been tailored to fit the needs of the SPES industry partners. With this aspect in mind, we investigated the benefits and barriers from the SPES_XT participants. We build our research methodology and design on previous work and we replicate a survey conducted within the Italian industry [3].

The rest of the paper is organised as follows: we present the study design and preparation in Sec. II, we report results in Sec. III (also in comparison with Torchiano et al. [3]) and interpret them in Sec. IV, with links to existing evidence. We briefly report on the limitations (Sec. V) and conclude with reference to future work in Sec. VI.

II. Study definition

According to [11] we classify this replication as external ("Different experimenters -or most of them are different from the original group of experimenters- carry out the replication" [11, p. 3]) and, due to the change of context, differentiated ("Some changes are intentionally made to the original experiment: design, hypothesis, context, measurements " [11, p. 3]).

A. Goal and research questions

The goal of our study corresponds to the goal nr. 3 of the original work of Torchiano et al. [3], i.e. *Understanding the motivations either leading to the adoption (benefits) of MD* or preventing it (problems)*. The related research questions are:

- RQ 1 What are the benefits of using MD* ?
- RQ 2 What issues hinder/prevent the adoption of MD* ?

[1]http://spes2020.informatik.tu-muenchen.de/spes_xt-home.html

[2]http://spes2020.informatik.tu-muenchen.de/

[3]From now on we will refer with the term SPES to both SPES_XT and SPES 2020 projects

B. Study preparation

a) Population and Sampling strategy: The target population of our study is the pool of participants to the project (the list of organisations is available online [4]). The survey was spread to the project partners' contacts and work-package leaders, and subsequently forwarded independently by each partner/leader into their own organisation/work-package. As a consequence we applied mainly non-probabilistic methods (convenience and snowballing sampling) [12]. We collected data through an on-line questionnaire created with Unipark [5].

b) Survey preparation and Execution: We first prepared a preliminary version of the questionnaire. We conducted a pilot to identify potential problems and feedback useful to improve the questionnaire, and we changed a few details (mainly typos and rephrasing). We advertised the questionnaire in two stages: first, we organised a telephone conference with the project coordinators, where we explained the aim and the structure of the questionnaire, and we asked commitment to spread the survey and encourage participation. Second, we sent an official invitation through the mailing lists of the project. After the survey start, the invitation was repeated every week, including updated statistics on participation. In total we sent 4 email invitations plus an additional reminder during another telephone conference with the project coordinators. After data collection was concluded, we performed analyses according to the methodology described in section II-D.

C. Questionnaire design

The replication of the study of Torchiano et al. [3] was a specific section of a larger questionnaire [6] to evaluate several technology transfer aspects of the SPES_XT project. The questions specific to the replication are listed in Table I (we do not report the rest of the survey questions, because specific to projects needs or other aspects). With respect to the original survey, we let participants list additional benefits. We kept the distinction between expected and verified benefit.

D. Analysis methodology

We apply the same methodology used in [3] to analyse the answers to the questionnaire. For RQ1 (expected and verified benefits) and survey question nr. 1 in Table I, we focus -as in the original study- on the actually achieved advantages, computing the benefit achievement ratio, i.e. the proportion of respondents who achieved each specific benefit. We classify the benefits in terms of their likelihood, adopting the same thresholds of [3]: above a 50% frequency a benefit is considered as Very Likely, above 25% as Likely, above 10% as Probable, and below that threshold as Unlikely. To assign the proportion to the corresponding likelihood level, we compute the 95% confidence interval of the proportion using a proportion test and compare the lower limit with the above thresholds. Regarding the survey question nr. 2 in Table I, being an open question, we collect and report the additional benefits signalled by the participants.

For RQ2 (barriers), we have one survey question connected, nr. 3 in Table I, which reports for each participant a list of problems that prevented her/him from adopting modelling. We adopt a similar approach as for RQ1: we report the problem occurrence ratio classifying barriers in terms of relevance. For this purpose we use the following criteria: we assume a proportion larger than 50% implies a High Relevance, larger than 25% Relevance, larger than 10% a Scarce Relevance, and below 10% Irrelevance.

For privacy reason, we could not track information on the participants. Therefore we do not know the distribution of respondents per organisation. However, the large majority of the SPES_XT partners work in very large [7] organisations. Another methodological difference against the original survey is that we do not divide the respondents into two groups, i.e. the adopters of MD* techniques and those who make only basic modelling: given the peculiarity of the research project, we can safely consider all participants as modellers. We take into consideration these two differences when comparing results with the original study by reporting variations in [3] according to company size and type of modellers (MD* vs basic modelling).

III. Results

The questionnaire was online for five weeks. During this time, the total number of people who accessed the survey is 86, from which we got 34 complete and valid answers (completion rate: 39.5%). Because of our sampling strategy and the privacy concerns requested by the partners, we can not provide the respondents ratio, being unaware of the number of people in SPES_XT who got the invitation.

Table II and Table III show, respectively, the benefits achievement ratios and the problems relevance, also in comparison with the original study in Italy and existing evidence in the literature, up to our knowledge [8]. In the first column we report the frequency of selections of the benefits/barriers ("Freq."), in the second the proportion estimated from the test, in the third the confidence interval ("95% CI") that defines the level of likelihood/relevance in fourth column. The middle part of the table reports the likelihood/relevance in the original study and discriminant factors in organisation size or type of modellers (+ for higher values, - for lower values). Last part reports whether we found supporting ("Likely") or contrasting ("Unlikely") evidence in the literature. Finally, Table IV reports the additional benefits and barriers reported (frequency in parenthesis).

IV. Discussion and Relation to Existing Evidence

Our survey participants reported less verified benefits than in the Italian industry: we believe this is due to the low maturity level of the SPES techniques: SPES_XT is a research project in which new modelling techniques are developed, hence their proper validation require time. This explanation is corroborated by the frequencies of the expected benefits: we observed values at least twice as those for the verified benefits. The probable

[4] http://spes2020.informatik.tu-muenchen.de/partner_xt.html

[5] http://www.unipark.com/en/

[6] All questions are listed from page 4 to 8 of the technical report at http://goo.gl/qVLaor

[7] European Union recommendation 2003/361/EC: http://goo.gl/eNNVE5

[8] Being a systematic comparison with literature not the focus of our study, this comparison was partially built upon the search in [3] and relied only our knowledge of additional sources and interpretation of their findings

TABLE I. QUESTIONS OF THE SURVEY

ID	Question	Type	RQs
1	What are the expected benefits as consequence of using SPES_XT modelling techniques ? Which of them were also verified ? Valid answers:Design Support,Improved development flexibility, Improved Quality, Quality of the software, Maintenance support, Platform independence, Standartisation, Shortened reaction time to changes, Others, None	Nominal	RQ1
2	Which others benefits did you expect ?	Open	RQ1
3	What are the problems hindering or preventing modelling with SPES_XT techniques ? Valid answers: Too much effort required, Not useful enough, Lack of competencies, Lack of supporting tools, Refusal from management, Cost of supporting tools, Refusal from developers, Fear of lock in, Not flexible enough, Inadequacy of supporting tools, Other	Nominal	RQ2

TABLE II. BENEFITS ACHIEVED IN ADOPTING MODELLING TECHNIQUES

	SPES_XT				Torchiano et al [3]		Evidence in literature	
Benefit	**Freq.**	**Estimate**	**95% CI**	**Likelihood**	**Likelihood**	**Notes**	**Likely**	**Unlikely**
Design Support	15	40%	25% .. 58%	Likely	Very Likely		[13]	
Quality of the software	9	24%	12% .. 42%	Probable	Likely		[14] [4]	
Platform independence	6	16%	7% .. 33%	Unlikely	Unlikely	+ in MD*	[15]	
Standartisation	6	16%	7% .. 33%	Unlikely	Likely	+ in MD*		
Shortened reaction time to changes	6	16%	7% .. 33%	Unlikely	Possible			
Improved documentation	6	16%	7% .. 33%	Unlikely	Very Likely		[16] [17]	
Improvement development flexibility	5	14%	5% .. 30%	Unlikely	Possible			
Maintenance support	1	3%	0% .. 16%	Unlikely	Likely		[15]	[18]
Productivity	n/a	n/a	n/a	n/a	Possible	+ for MD*	[15] [13] [14]	

TABLE III. POSSIBLE PROBLEMS PREVENTING ADOPTION OF MODELLING TECHNIQUES

	SPES_XT				Torchiano et al [3]		Evidence in literature	
Barrier	**Freq.**	**Estimate**	**95% CI**	**Relevance**	**Relevance**	**Notes**	**Likely**	**Unlikely**
Lack of supporting tools	17	57%	38% .. 74%	Relevant	Relevant			
Too much effort required	16	53%	35% .. 71%	Relevant	Relevant		[14]	
Lack of competencies	14	47%	29% .. 65%	Relevant	Relevant	+ in large org.	[15] [17] [19] [4]	
Refusal from developers	13	43%	26% .. 62%	Relevant	Scar. Relevant	- in large org.	[5]	
Inadequacy of supporting tools	7	23%	11% .. 42%	Mod. Relevant	Scar. Relevant		[16] [18] [13] [17] [4]	
Cost of supporting tools	3	10%	3% .. 28%	Scar. Relevant	Scar. Relevant		[18] [15]	
Fear of lock in	3	10 %	3% .. 28%	Scar. Relevant	Scar. Relevant	+ in MD*	[17]	
Not useful enough	2	7%	1% .. 24%	Scar. Relevant	Relevant			
Refusal from management	2	7%	1% .. 24%	Scar. Relevant	Scar. Relevant		[5]	
Not flexible enough	2	7%	1% .. 24 %	Scar. Relevant	Scar. Relevant			

TABLE IV. ADDITIONAL BENEFITS AND BARRIERS REPORTED BY PARTICIPANTS

Benefits	Barriers
Support for (Software) Product Lines (3)	Project pressure (4)
Reusability (2)	Incompatibility to existent tool chains (1)
Improved automation in software development due to model based development (1)	High ramp-up (1)
Improved validation/simulation (1)	Methods not stable enough, need more validation (1)
More effective communication between stakeholders by a common terminology (1, also verified)	Methods not applied to realistic cases (1)
Integration of separated development activities and models (e.g., safety) (1, also verified)	High effort for integration of new processes and tools (1)
Seamless Development Processes (1)	Willing and money for going beyond the prototyping step (1)
Modularity (1)	Proof of scalability in huge distributed development organisation (1)
Safety (1)	Not invented here syndrome (1)
Variability (1)	Methods lack in integration (1)
Consistency (1)	Current infrastructure not optimal (1)
Development, implementation and support of dedicated methods and tools for computer architecture analysis, assessment and optimization (1)	Effort for introduction (1)

or likely benefits reported by SPES_XT participants are design support and quality of the software, both in agreement with the original study. Improved quality of software is also reported by Burden et al. [4] in the automotive sector (which is one of the three application fields of SPES_XT): the authors report that one of the factors for better quality in the software product is that using MDE allows domain experts to be directly involved in the development process and closer to developers. Increase in quality is also confirmed by Heijstek [14] both by team members in a large scale industrial MDD project and by comparing the average number of defects in similarly sized projects which did not make use of MD*. Regarding design support, we found supporting evidence in one study in literature with 80 professional engineers using UML [13]. We report also agreement in platform independence, as not verified benefit: this is in contrast with what was found in [15]. Among the additional benefits from the open question, many respondents reported better reusability and support for product lines, as variant management was one specific engineering challenge in SPES_XT: also for these aspects we did not find further evidence in our search. We observe more agreement on the barriers. Several were mentioned as not having an impact by both studies: refusal from management, cost of supporting tools (in contrast with [15]), fear of lock-in (in contrast with [17]). The relevant barriers in common are: too much effort required (confirmed in [18]), lack of competencies (also reported in [15]), lack of supporting tools (also reported in [20]). We interpret the high effort required as a direct consequence of the other two relevant barriers, i.e. lack of competencies and supporting tools. An analysis of the correlations among the barriers (Spearman) revealed a significant correlation (pval ≤ 0.05) only between the latter two. Opinions in contrast with the survey in Italian industry were the refusal from developers, which was surprisingly scarcely relevant in the original study (and even lower for large companies): from our experience we expect such a barrier to adoption of new techniques especially in large companies. Another contrast regards the barrier "Not useful enough", which was scarcely relevant in our context: we believe that this is due to the fact that, since respondents were the same people developing the techniques, they will use those techniques, which are hence considered as useful. We interpreted the other barriers elicited from the open questions as a manifestation of those we derived from [3]: for example "high ramp-up" and "project pressure" is related to the high effort and lack of competencies, "incompatibility to existent tool chains" to the inadequacy of supporting tools, the "not invented here syndrom" as a symptom of refusal from developers. Barriers like "not stable enough", "need more validation", "proof of scalability", "methods not applied in realistic cases", support our hypothesis that the immaturity of the techniques caused low frequencies of verified benefits.

V. Threats to Validity

We are aware that opinion surveys entail the risk that perception from people might be misaligned from reality. In addition, some of the results we obtained might not hold with a broader diffusion and validation of the SPES techniques, or if we had a higher participation to the survey (response rate is unknown though, in addition our sample is relatively small). Also, we cannot generalise our findings out of the scope of our project, and we can not attribute all variation of results to the variation of context.

VI. Conclusion and Future Work

Despite the variation in the target population and application fields from the investigation in the Italian industry [3], our study confirmed a few verified benefits and a large set of barriers (or lack of). In light of these results, we will start in the next months a specific transfer project to address the barriers revealed with the development of a modelling tool chain and a tutorial program: in our expectation this will decrease the effort for introduction. In this project we will also continue our evaluations, with two goals: i) better identify the influence factors, ii) deeper understand the effects -and barriers- of applying the SPES techniques into the project's partner company. The bridge between these two goals is a knowledge base where to store our evaluation results with the contextualisation schema developed. This will result in a contribution to the scientific community in form of further evidence and a contextualisation framework.

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