

Factors affecting developers' use of MDSD in the Healthcare Domain: Evaluation from the MPOWER Project

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Abstract: Model-driven software development (MDSD) is steadily gaining popularity, and new and more advanced tools are being developed. However, the paradigm shift that has been expected has not yet come, despite reliable reports on both quality and productivity improvements using model-driven approaches. This paper investigates which factors are important for developers to use MDSD in their work. In January 2007, a total of 16 developers from one university, two SMEs, one research organization and one large multinational company were introduced to a MDSD toolchain for software service development. After using the toolchain for one year in development of middleware services and end-user applications, the developers evaluated the toolchain and their use of the MDSD process in general. The evaluation was done using proven research methodologies that were adapted to be able to evaluate MDSD. 16 developers from four European countries participated. Although the sample is limited, the findings suggest that perceived usefulness and ease of use are the most important factors for adopting a MDSD development approach. No significant relationships between future use intentions of MDSD and tool performances or subjective norm were found. However, the “traceability” feature of the development approach was found useful. The work was carried out as a part of the MPOWER EU-IST project, and the results will be used for improving the project toolchain and the evaluation processes.

Introduction

Software systems are getting more complex, incorporate more functionality, and users have a higher demand for performance and reliability. One approach to control system complexity is to apply abstraction and reuse of existing well-proven artefacts [1, 2]. This is accordance with the fundamental concepts of model-driven software development (MDSD), that separates business functionality from technological details to hide technical complexity, and applies model transformation and code generation to reuse code and software patterns [3, 4]. Many publications reports from successful adoption of MDSD in IS organizations [5], but very few provide empirical results or

an explanation of the success criteria. In [6], Staron tries to explain the requirements and factors for adopting MDSO in organizations based on a case study in two companies. The study shows that for a company to adopt MDSO, it should make it possible to estimate costs based on models, improve quality and understanding, improve communication between developers, and enable traceability throughout the software artefacts. Staron found that a key factor for determining the adoption is the availability of modelling tools. Tool support was also addressed by MacDonald et al in [7]. They describe the “perfect tool” where platform independence, access to rich libraries and possibility to perform sophisticated analysis (including traceability) are key features in addition to those described by Kleppe [8]. Other recent studies on MDSO adoption includes the book by Guttman and Perodi [5], where six real-life projects, all report positive experiences from using a model-driven software development approach. However, the results and benefits are based on interviews with the CEOs and CTOs in the companies, and do not provide information about the developers’ attitudes and perceptions of MDSO. Despite many reports of successful adoption of MDSO principles in companies around the world, the paradigm shift that MDSO was supposed to make [8, 9] has not happened. At the Future of Software Engineering conference in 2007, France and Rumpe presented the main challenges of MDE (MDSO included)[10]. They identified modelling language, separation of concern and model manipulation and management challenges. All identified challenges are focused on technological concepts and constructs.

The healthcare domain has and continues to be, undergoing a digitization process where all information should be stored and distributed electronically. The demand for healthcare services increases dramatically and soon there will be a shortage of healthcare providers [11]. Healthcare information systems (HIS) are complex, and projects often fail because of the problem of transforming the knowledge of the user domain into knowledge in the domain of those that implements the solutions [10]. But, information technology is considered promising in order to enable care at home, facilitating active ageing at home, and leveraging the informal care given by family and friends. Many stakeholders and legacy systems are involved, and security and reliability requirements are strong. The development costs are compared against the acquisition of more advanced medical equipment, more effective (and expensive) medicine and more healthcare personnel on duty. Developers of HIS need to understand the healthcare work processes, and should have in-depth knowledge about healthcare standards and regulations. Improved traceability between domain and system development artefacts and formal models that can be shared and understood by both healthcare providers and system developers are promised features of model-driven software development. If MDSO were to deliver upon its promise in the healthcare domain, this would be deemed very beneficial for all involved actors.

To investigate the how MDSO can be introduced in healthcare, the MPOWER project [12] has designed and evaluated a MDSO toolchain that supports development of home care services on a SOA platform. The main objective of the evaluation was to document the developers’ current use of MDSO, and their future intentions for using MDSO after having used the MPOWER toolchain in the project. This paper presents the evaluation done in the MPOWER project focusing on developers’ acceptance of the model-based approach to doing system development of healthcare middleware services. A MDSO toolchain was introduced in the project and the users

of the toolchain were asked to fill out an evaluation questionnaire after one year of use. The results suggest that tool usefulness and ease of use are important for the acceptance of MDS. Other factors such as traceability and code generation are found useful.

The remainder of this paper presents the conceptual model along with the hypotheses that will be tested, the research method and the results from the survey. Finally, a discussion with concluding remarks and suggested further research is given.

Conceptual model and hypotheses

MDS should be regarded as a new technology supporting developers, and its use must be evaluated not only on the project outcome level (e.g. delivery on time and on budget), but also on the individual level to discover why or why not MDS works. MDS often represents innovations for the potential adopters, and the evaluation of its acceptance should use methodologies from the diffusion of innovation knowledge base. Two main concerns governed the choice of evaluation methodologies; to address the user's perception of MDS as a tool to support/improve their work, and secondly how the technological features of MDS tools may impact the users' current use and future use intentions. Perceived characteristics of innovating (PCI) is posited to have a significant influence on user acceptance [13]. The technology acceptance model (TAM) [14, 15] and the theory of planned behaviour (TPB) [16] are other models that attempt to explain the user perceptions and use intentions of a certain technology. The conceptual model for the study presented builds upon the factors of TAM, TAM2, PCI and TPB. This study reuses four of five components from the study by Dybå in [17]. In addition, a new component on *tool performance* is introduced. The *tool performance* component is included based on the findings by Staron[6], MacDonald[7], and specifically targets the core MDS features business analysis, traceability and implementation automation[3, 4, 18].

Two dependent variables are measured: the current use of model-driven development techniques, and future use intentions. Figure 1 shows the proposed hypotheses about the factors affecting the use of MDS techniques (+ sign indicates a positive association).

- The Perceived Compatibility (PC) : “the degree to which an innovation is perceived as being consistent with the existing values, needs and past experiences of potential adopters” [13]: *H1: The perceived compatibility is positively associated with current usage and future use intentions of MDD*
- The Perceived Ease of Use (PEU): “the degree to which a person believes that using a particular system would be free of effort” [14]: *H3: The perceived ease of use is positively associated with current usage and future use intentions of MDD*
- The Perceived Usefulness (PU): “the degree to which a person believes that using a particular system would enhance his or her job performance” [14]: *H2: The perceived usefulness is positively associated with the current usage and future use intentions of MDD*

- Tool performance (TP): the degree to which the tools support the development process and the tasks at hand: *H4: The perceived tool performance is positively associated with current usage and future use intentions of MDS*, *H4.1: Business Analysis (BUS)*, *H4.2: Traceability (TR)* and *H4.3: Code Generation (GEN)*
- Subjective Norm (SN): In an extension of the TAM from 2000, Venkatesh and Davis added the subjective norm [15]: “the person’s perception that most people who are important to him think he should or should not perform the behaviour in question” : *H5: The subjective norm is positively associated with current usage and future use intentions of MDD*

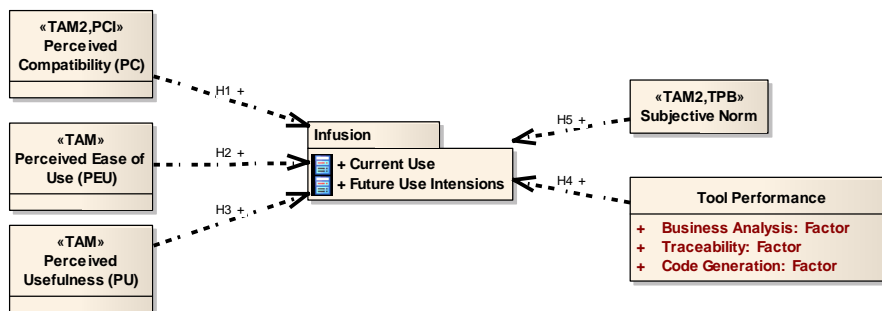


Fig. 1. The conceptual model of the evaluation. Five factors are suggested to affect the current and future usage of MDS

Research Method

Study context and subjects

The study was carried out in the MPOWER project that started in October 2006 and runs until April 2009. The project uses an agile model-driven development approach [19] for the design, development and evaluation of homecare middleware services. The main objective of the project is to build a middleware platform that enables rapid development of smart homecare services by reusing services in a SOA framework [12]. The services are designed and developed using a set of MDS tools and techniques described in the next section.

Table 1. Summary of study subjects’ characteristics

Work duties	Highest completed education	Years experience with programming /systems engineering

81 % are developers 30% involved in arch 31% are doing research 6 % project management 6 % product support	31% Bachelor's degree 63 % Master's degree 6% Other education	From 1 -20 years Mean: 5,63
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In January 2007, developers from one university (3 participants), two SMEs (7), one research organization (2) and one large multinational company (4) were introduced to a MDS toolchain for software service development. The subjects in the study are the developers of the middleware services and end user applications. They were using the MDS tools from the initial design to final deployment and pilot testing. A total of 16 developers (n=16) from four European countries (Austria, Croatia, Cyprus and Spain) participated.

Model-Driven Tools introduced in the project

The developers in the project were introduced to a model driven methodology with toolchain support in January 2007. The toolchain was configured in the project using both commercial and free open source software. The choice of tools were based on developers' experience, tool maturity, tool footprint and licensing model. Enterprise Architect was evaluated to be the most appropriate MDA tool because of its stability, support solution, low cost and low footprint. NetBeans were chosen for the easy integration with application servers, SOA support (Web Service and BPEL development) and open source model. The methodology for the design and development process followed a waterfall-based approach:

1. In the project, a total of 18 scenarios each with four sub-scenarios were described in Microsoft Word by a total of 137 care providers, patients and patients' relatives.
2. From the scenarios, *use cases* were modelled in Enterprise Architect (EA) [20]. Scenario descriptions were included in the use case UML elements.
3. From the use case models, 170 *features* were extracted and modelled in EA. Each feature was linked to its originating use case(s).
4. From the features, 33 *services* were identified and described with a *service specification* (operations and messages). The IBM Profile for Software Services [21] were imported into EA to specify the services in terms of Service Oriented Architecture (SOA) [22] concepts.
5. Using a tailored model transformation in EA, and standard code generation, *WSDL models* and *WSDL code* were created from the services.
6. The WSDL files generated from EA were imported into NetBeans using WSImport. All message specification classes and operations were generated, leaving only the code for operations' behaviour to be implemented by the developers.
7. Web service descriptors were generated in NetBeans and the web services were deployed to a Glassfish V2 server.

A key methodological issue was the ability to trace the reusable services back to the context and user interactions for which it was designed. This was done using UML

dependency links in EA and periodically exporting the model documentation to a web-server for easy navigation.

The developed web services are being used in web applications that will be evaluated by the care providers, patients and patients' relatives during the spring and summer of 2008.

Data collection procedure

LimeSurvey¹, an open source web survey tool were used for data collection. The requests for participation were sent by email, and all respondents filled in the questionnaire within 3 working days. All 16 developers participated.

The questionnaire had seven groups of questions, each group including a free-text field for comments: 1) candidate information (table 1), 2) current use, 3) future use intentions, 4) perceived usefulness, perceived ease of use, perceived compatibility, 5) subjective norm, 6) tool performance, and 7) MPOWER Toolchain experience. Question group 2 and 3 used a scale ranging from 0-4 (not used at all, used on an experimental basis, used on a regular basis by a few people/project, used on regular basis by most people/projects, used on regular basis by all people/projects)[23] , while group 4, 5 and 6 used a five-point Likert scale [24]. The results from the questionnaire were exported from LimeSurvey to be imported into SPSS 15² for statistical analysis.

Assessment of reliability and validity

The reliability of the independent and dependent factors in the conceptual model is presented in table 2. Factors in *italic* are subfactors of "Tool Performance (TP)".* Question "given a choice, I would prefer not to use model-driven development in any future" was misinterpreted by some respondents. Reliability was strongly improved when this question was removed from the factor. The MPOWER specific questions were not subject for factor analysis.

Table 2. The reliability of the independent and dependent factors measured.

Factor	#items	Cronbach's alpha
Perceived Usefulness (PU)	5	0,872
Perceived Ease of Use (PEU)	6	0,917
Perceived Compatibility (PC)	4	0,937
Subjective Norm (SN)	3	0,966
Tool Performance (TP)	13	0,878
- <i>Business Analysis (BUS)</i>	4	0,573
- <i>Traceability (TR)</i>	3	0,944
- <i>Code Generation (GEN)</i>	4	0,836
Current use (CU)	6	0,947
Future use intentions (FUI)	3 (4*)	0,970 (0,675*)

¹ Limesurvey website: <http://www.limesurvey.org/>

² Statistical Package for the Social Sciences (SPSS) website: <http://www.spss.com/>

The content validity, as defined by Dybå[25], has to do with the appropriateness of the scale items in the domain under study. For this study, this is ensured through the reuse of validated scales from TAM, TPB and PCI – all with questions adapted to the MDS domain. The criterion-related validity from Dybå is concerned with the degree to which the scales under study are related to an independent measure of the relevant criterion. This was evaluated by computing the multiple correlations between the independent variables and the dependent variables. The results are shown in table 3.

For the dependent variables, only “Current Use (CU)” has a significant correlation with the independent variables “Perceived Usefulness (PU)” and “Perceived Ease of Use (PEU)”. The results also show correlations between “Perceived Usefulness (PU)”, “Perceived Ease of Use (PEU)” and “Perceived Compatibility (PC)”.

Table 3. Intercorrelations between independent and dependent variables

Variable	PU	PEU	PC	SN	TP	BUS	TR	Gen
PU	1							
PEU	,783(**)	1						
PC	,557(*)	,776(**)	1					
TR	ns	ns	ns	ns	-	,599(*)	1	
GEN	ns	ns	ns	ns	-	,618(*)	ns	1
CU	,596(*)	,596(*)	ns	ns	ns	ns	ns	ns
FUI	ns	ns	ns	ns	ns	ns	ns	ns

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed), ns = not significant

Results

To further investigate to which degree the factors correlate, regression analysis were conducted on the significant correlations. The partial regression analysis, checking each of the independent variables (PU and PEU) with the dependent variable CU is shown in table 4. The results show that both PU and PEU can explain 30,9% of the variance in current use. Both models are significant on the 5% level.

Table 4. Partial regression analysis of CU with PU and PEU

Regression equation	Adjusted R Square	Beta	t-value	Significance
CU = PU	,309	0,596	2,775*	,015
CU = PEU	,309	0,596	2,774*	,015

Table 5 shows the results for the regression between the dependent variable CU and the two independent variables that had a significant correlation with CU, namely PU

and PEU. The analysis shows that the complete model is significant on the 5% level and 30,5% of the variance of CU can be explained using the two independent variables PU and PEU. However, the coefficients are not statistically significant; hence an equation for expressing the value of CU from PU and PEU cannot be created.

Table 5. Regression analysis for CU = PU + PEU(*p<0,05)

Regression equation	Adjusted R Square	Beta	t-value	Significance
CU = PU		,334	,967	,351
+ PEU	,305*	,334	,965	,352

The three subfactors of Tool Performance (TP) were measured, namely Business analysis (BUS), Traceability (TR) and Code Generation (GEN). None of these correlated with CU or FUI. However, descriptive statistics in table 6 shows that traceability was a feature that the developers found useful. The variance in code generation was high.

Table 6. Descriptive Statistics of Tool Performance Subfactors

	Minimum	Maximum	Mean	Std. Deviation	Variance
Code Generation	1,25	4,25	3,0000	,83166	,692
Business analysis	2,67	4,00	3,5111	,48578	,236
Traceability in toolchain	3,00	5,00	3,7500	,67220	,452

A separate group of questions targeted the concrete experience from using the MPOWER MDSD toolchain and methodology proposed in the MPOWER project. The questions and the statistics are presented in table 7. 13 out of 16 respondents (n=13) developers had used the complete toolchain and qualified to answer this group of questions. The scale is 1-5 (Strongly disagree – Strongly agree).

Table 7. Descriptive statistics for MPOWER specific features

Question	Min	Max	Mean	St.d
Using Model-driven development in MPOWER is useful	3	4	3,77	,439
Using Model-driven development in MPOWER improves the collaboration between the partners	2	5	3,77	,832
Using Model-driven development in MPOWER requires much coordination	2	5	4,00	,913
Using Model-driven development in MPOWER decreases my performance as a developer	2	5	2,85	,899
UML is easy to understand	3	5	4,00	,707
UML provides all the functions/mechanisms I need	2	4	3,38	,768
The tools (i.e. Enterprise Architect and NetBeans) were easy to use / learn	1	5	3,46	1,198
The tools limited my performance as a software developer	2	5	2,92	,954

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Using models just adds more work to the development process	2	4	2,85	,801
Models are important to the development process	3	4	3,77	,439
Models can be used in programming	3	4	3,62	,506
UML is useful for Service Oriented Architectures	3	5	3,92	,494
Traceability between model elements (components, features, actors) is important for the development process	3	5	3,85	,801
Traceability is for system documentation only	2	3	2,46	,519
Traceability improves my understanding of the system	3	5	3,69	,751

Comments from the respondents

To capture qualitative comments from the subjects, free-text fields were included on each group of questions. One developer made a comment in the group with questions on PU, PEU and PC:

- “Using Model-Driven development improves my job performance and productivity, only if everything works well with the transformation of models... Otherwise you can find yourself spending too much time trying to make things work (and doing the required changes manually). If this is the case then using Model-Driven development takes too much time from my normal duties. “

Three developers made comments on the MPOWER Toolchain:

- “By my opinion, the problem in MPOWER was the selected tool. EA is a powerful tool but 1) not fix very well with NetBeans and 2) unknowledging of the tool by the involved team, did that the project development was difficult, sometimes losing a lot of time instead of reducing (that’s the idea of the use of the tool).”
- “Maybe we could select more stable tools (instead of NetBeans) or tools that work well together”
- “The idea of using EA + NetBeans is good, but I found a lot of problems in the use of these tools (more to integrate the work done in the first one to the second one), modifying the code by hand sometimes. Somehow, I thought that people hadn't tested the tools before deciding to use it.”

Discussion

A survey was performed in a MPOWER project to investigate factors affecting developers' acceptance and utilization of MDSD. After using a MDSD toolchain for designing and developing healthcare middleware services, 16 developers from five different organizations in four European countries participated. Although the statistical power of the evaluation is low, the results can be used as a starting point for further evaluation or tailoring of MDSD tools and processes. The evaluation results show that perceived usefulness and perceived ease of use have an impact on the developers' current use of MDSD. This finding is confirmed by the statistics from the tool performance factor and the free-text comments made by some respondents. They

find models useful in development, and MDS is useful to improve collaboration, traceability and generate code. This is fully in accordance with the results from the study presented by Staron in 2006 [6], where improving quality by increasing understanding, improving communication within development and improved traceability are identified as key requirements for MDS. On the other hand, the results in table 7 indicate that MDS requires much coordination in the development team. Coordination should be supported by tools, requiring flexible management systems, as identified as a key MDS challenge for the future[10].

Furthermore, the analysis shows that none of the proposed factors have an influence on the developers' future use intentions of MDS. This is a neutral result that can be explained by a general positive attitude to MDS in the development process (table 7, first item: mean 3.77), and mixed experience with tool stability and functionality (table 7, neutral mean values for items on developer's performance, and free-text comments).

Subjective norm was not found to affect the current or future use of MDS. One explanation could be that the number of participants in the survey should be higher to ensure a normal distribution for performing statistical analysis. In most software engineering projects, getting sufficient evaluation results is a hard goal to achieve, and a combination of quantitative and qualitative approaches should be used as suggested by Miller in [26]. The free text comments provided in the survey made it possible to explain findings from the statistical analysis and thus increase the validity of the survey as a whole.

The results from the evaluation may indicate that the factors chosen in the evaluation were not appropriate. For most of the factors, correlations were not significant. Based on the textual comments from the developers, factors addressing perceived ease of use, compatibility and usefulness are appropriate. Similarly, tool performance is relevant, whereas subjective norm may have been left out.

To summarize, two out of five proposed hypotheses are supported by the findings in the survey: perceived usefulness and ease of use are positively affected with current use of MDS. Traceability between artefacts is also found useful.

Clearly, the performance of the MDS tools introduced in this study was not good enough. The tools chosen are all popular design and development tools (EA, NetBeans, Glassfish V2), but required some minor adjustments to work together. The developers did not agree on the effectiveness and usefulness of MDS. A specific case is code generation functions that got a mean score on 3.00 (neither agree nor disagree), but with a range from 1.25 to 4.25 (table 6). The comments given explain this high variance with the fact that the generated code was not 100% correct and that a time-consuming process of manually changing the generated code was required.

As presented in the introduction, there are both positive and negative experience reports from adopting MDS in industry. This fact emphasizes the need to investigate the factors that affect the developers' adoption and use of MDS. The study presented herein use developers that have some experience with UML, but not with MDS as a whole. This group of developers are important to take into consideration to improve the diffusion of MDS in the software development community.

In healthcare systems development, with its special characteristics, MDS could and should play an important role. Traceability will be a key concern, and bridging the gap between healthcare processes and IT support tools is essential to defend the

investments in IT systems for healthcare. In accordance with trends in MDS literature [7, 10], the use of domain specific languages / domain specific application development environments should be investigated. The MDS concepts along with a domain specific language extension such as a UML profile for HomeCare could improve the developed systems' adherence to domain information standards through reuse of conceptual models and transformation templates, and at the same time improve quality and development cost [27]. The process of adopting MDS should use experience from other domains and organizations[28, 29].

Future work

The study presented in this paper will be followed up by a new evaluation in the MPOWER project's next phase. In addition, controlled experiments using students at Norwegian universities will be conducted in 2008 using an improved MPOWER Toolchain as intervention.

Concluding remarks

The results from statistical analyses and subjective comments from the respondents indicate that MDS tools must be perceived useful and should be easy to use (indicated with bold associations in Fig 2). Tool performance does not have a direct effect on MDS use, although business analysis, traceability and code generation were found useful. It is especially important that MDS tools are stable and provide complete and correct artefacts.

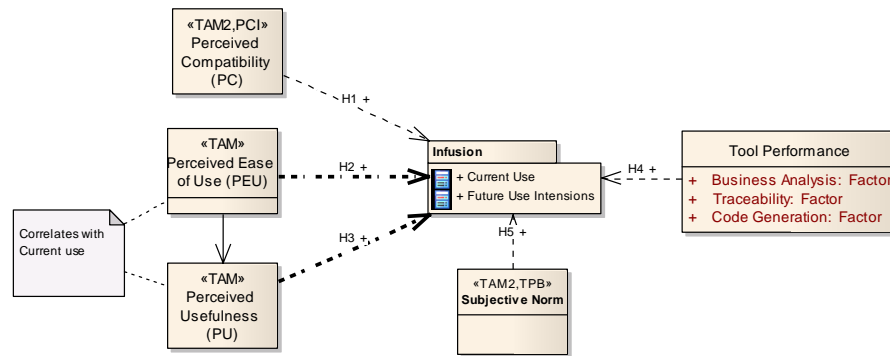


Fig. 2. Conceptual model where supported hypothesis are shown as bold associations

Despite the low statistical power of the survey, the results give an indication of what developers with limited knowledge of MDS expect when trying to adopt an MDS approach. The findings should be investigated in a larger study. Using a

survey based on established models for technology acceptance should be extended with qualitative approaches including free text feedback and possibly also interviews.

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Appendix A: Questionnaire

Currently, how would you assess your use of Model-Driven Development techniques in your activities / projects?

1. CU In the analysis phase (business processes that need IT enablement)?
2. CU In the requirements phase
3. CU In the software / system design phase
4. CU In the implementation phase
5. CU In the deployment phase
6. CU In the evaluation / maintenance phase

Model-driven development experience

This group of question is on your experience using Model-driven development techniques.

1. PEU I think Model-Driven development is clear and understandable
2. PEU Using Model-Driven development does not require a lot of mental effort

3. PEU I find Model-Driven development easy to use
 4. PEU Model-Driven development is not cumbersome to use
 5. PEU Using Model-Driven development does not take too much time from my normal duties
-
1. PU I find Model-Driven development useful in my job
 2. PU Using Model-Driven development improves my job performance
 3. PU Using Model-Driven development increases my productivity
 4. PU Using Model-Driven development enhances the quality of my job
 5. PU Using Model-Driven development makes it easier to do my job
 6. PU Learning to use Model-Driven development was easy for me
-
1. PC Model-Driven development is compatible with the way I develop Software
 2. PC Using Model-Driven development is compatible with all aspects of my work
 3. PC Using Model-Driven development fits well with the way I work
 4. PC Model-Driven development is compatible with the way we organize our work

Intended future use of Model-driven development techniques

What are your plans for the future with respect to Model-driven development?

1. FUT I intend do increase my use of Model-driven development for work in the future
2. FUT I intend to use Model-driven development in the future for my work
3. FUT Given a choice, I would prefer not to use Model-driven development in any future work
4. FUT I would like to use Model-driven development in the future

Subjective norm

These questions are related to your organization/projects. With respect to model-driven development

1. SN Please choose the appropriate response for each item:
2. SN People who influence my behavior think I should use Model-driven development
3. SN People who are important to me think I should use Model-driven development
4. SN Co-workers think I should use Model-driven development

Tool Performance

This section addresses technological characteristics of model-driven development.

What do you think about tools used in the MPOWER Toolchain

1. BUS The UML tools for business analysis (scenario, usecase , feature) are easy to use
2. BUS The UML tools for business analysis (scenario, usecase , feature) provide the required functionality
3. BUS The UML tools for business analysis (scenario, usecase , feature) improves the analysis process
4. BUS The advantages of using the UML tool for business analysis outweighs the disadvantages

1. GEN The UML tools for service development (service design and WSDL generation) are easy to use
 2. GEN The UML tools for service development (service design and WSDL generation) provide the required functionality
 3. GEN The UML tools for service development (service design and WSDL generation) improves the development process
 4. GEN The advantages of using the UML tool for service development (service design and WSDL generation) outweighs the disadvantages
-
1. Using the MPOWER toolchain improved the development process
 2. The advantages of using the MPOWER Toolchain outweighs the disadvantages
-
1. TR The possibility to trace from scenario to service design (traceability) is important
 2. TR Traceability improves the development process
 3. TR The advantages of adding traceability information outweighs the disadvantages