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A Survey Investigating the Influence of Business Analysis Techniques on Software Quality Characteristics

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Abstract Business analysis is recognized as one of the most important areas determining the outcome (success or failure) of a software project. In this paper we explore this subject further by investigating the potential impact of techniques applied in business analysis on essential software quality characteristics. We conducted a literature search for software quality models, analyzed the existing models and selected a subset of commonly recognized quality characteristics. Also, we identified a representative set of recommended state-of-the-art business analysis techniques. These two sets provided the basis for questionnaire survey and interviews. We conducted a survey involving 20 industry professionals, followed up by 2 interviews with experienced business analysts to discuss and interpret survey results. The main outcome are recommendations regarding techniques to be used in software project for a given quality characteristic considered essential.

1 Introduction

The success of a software project is still uncertain, as numerous reviews of past projects indicate that a significant percentage of them ends up as failed or challenged by various problems [7, 29]. Traditionally, project success is defined in terms of time, budget and result, where the result, apart from developed product's scope, also includes product's quality. Alternatively, quality can be distinguished as a separate success criterion (e.g. [22]). However, whether quality is explicitly referenced or not, it is commonly understood that it essential term in software engineering and project management and an important criterion when evaluating project's outcome.

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Causal analyses of project failures and problems reveal that many commonly occurring contributing factors can be mapped to requirements engineering/ business analysis (RE/BA) activities and practices [2, 3, 29]. In our research we tried to explore this subject further, in particular with respect to the influence of RE/BA on the quality of the developed system. As RE/BA is a complex domain in software engineering and includes many components (processes, techniques, competencies, good practices, software supporting tools etc.), we decided to narrow our research down to RE/BA techniques. Such techniques are described in many sources e.g. [12, 23, 31] as tools to be used by business analysts for e.g. requirements elicitation. We defined the following research question: *Which RE/BA techniques applied in a software project have the greatest influence on particular quality characteristics of the resulting software system?*

To answer it, first we conducted a literature search for software quality models, analyzed the existing models and selected a subset of commonly recognized quality characteristics. Also, we identified a representative set of recommended RE/BA techniques. These two sets provided the basis for questionnaire survey and interviews. We conducted a survey involving 20 industry professionals, followed up by 2 interviews with experienced business analysts to discuss and interpret results.

The remainder of this paper is structured as follows. In Section 2 we outline the related work. Section 3 describes the initial steps of our research – identifying RE/BA techniques (3.1) and quality characteristics (3.2). The main steps of conducted survey are described in Section 4, including: questionnaire design, data gathering and processing, interviews to interpret results and final results. We end this paper with validity threats discussion (Section 5) and conclusions (Section 6).

2 Related Work

There is a substantial amount of work published on evaluating techniques used in requirements engineering (RE) or more generally in business analysis (BA). Some researchers focused on techniques for a particular activity e.g. requirement elicitation [30], specification [4] or validation [16], others included a broader spectrum of techniques [15, 17, 18]. RE/BA techniques were evaluated with respect to: their inherent characteristics and potential [4, 15, 17, 30], applicability context (project size, product type etc.) [15, 17] and ability to address RE problems [16, 18].

Several studies exploring the influence of RE/BA process on developed product, project results or even more general outcomes were conducted [6, 10, 26, 27]. Hofmann and Lehner [10] identified a set of best RE practices leading to project's success. Sommerville and Ransom [27] reported that improvements to RE process maturity led to business benefits in all 9 companies participating in the study, however it was not possible to establish a strong causal link. A survey including over 400 companies by Ellis and Berry [6] revealed that higher level of company's maturity in RE and management processes correlates to the better success ratio of

projects developed by such company. Sethia and Pillai [26] provided an analysis (based on a systematic literature review) of the negative impact of requirements elicitation problems on software quality and project's outcome. Also, a need and opportunity for further research providing a better understanding of RE effects and influences is noted [8, 11].

No work directly addressing impact of RE techniques on quality of the developed system could be found, except [24, 25], which uses a completely different research method - data mining for a large set of software projects' data.

3 Literature Search and Analysis

The first part of our research aimed at identifying valid input to be used in the survey. It was based on literature search and analysis of identified sources. We chose to combine information from several sources, instead of relying on a single source. We also had to make decisions to focus on the most essential items and leave out the others (to ensure that the survey is realistic with respect to its scope and number of questions asked). Two main areas of background were important for our research: RE/BA techniques and quality models which translate the generic "quality" term into more detailed characteristics and attributes.

3.1 Identification of BA Techniques

We decided to use two main sources to identify and select RE/BA techniques for the planned survey. First of them was an industrial standard: Business Analysis Body of Knowledge (BABOK) version 3 [12]. It is considered a renowned source for business analysts and a basis for CBAP (Certified Business Analysis Professional) certification process. Moreover, this most recent 3rd version had been published only several months before we started this research, so we considered it a state-of-the-art resource. As a second source we selected a book by Wiegers and Beatty [31], a comprehensible guidance covering a broad spectrum of software requirements topics. Its 3rd edition, published in 2013, was expanded with new themes e.g. requirements in agile development.

We analyzed both sources to identify techniques they recommend. As a next step, we selected a subset of them to keep the survey scope realistic. This led us e.g. to reject various kinds of diagrams and notations used to specify and document requirements, as there were too many of them to include them all and we wanted to avoid arbitrary selection. We intended to cover all areas related to RE/BA, not to e.g. restrict the survey to specification techniques only.

Table 1 Selected RE/BA techniques and their sources

Technique	Source(s)
Area: Elicitation	
Scope Modeling	[12] 10.41; [31] Ch.5
Stakeholder List, Map or Personas	[12] 10.43; [31] Ch.6
Focus Groups	[12] 10.21; [31] Ch.7
Brainstorming	[12] 10.5
Event-Response Lists	[31] Ch.12
Interviews	[12] 10.25; [31] Ch.7
Survey / Questionnaire	[12] 10.45; [31] Ch.7
Document Analysis	[12] 10.18; [31] Ch.7
Observation	[12] 10.31; [31] Ch.7
Area: Analysis	
Organizational Modeling	[12] 10.32
Prototyping	[12] 10.36; [31] Ch.15
Prioritization	[12] 10.33; [31] Ch.16
Data Dictionary	[12] 10.12; [31] Ch.13
Business Model Canvas	[12] 10.8
SWOT Analysis	[12] 10.46
Risk Analysis and Management	[12] 10.38; [31] Ch.32
Area: Specification	
SRS Templates	[31] Ch.10
Item Tracking	[12] 10.26
Non-Functional Requirements Analysis	[12] 10.30; [31] Ch.14
Area: Validation	
Reviews	[12] 10.37; [31] Ch.17
Retrospectives	[31] Ch.17
Test Cases and Scenarios	[31] Ch.17
Acceptance and Evaluation Criteria	[12] 10.1; [31] Ch.17
Area: Management	
RE Planning	[31] Ch.7
Estimation	[12] 10.19; [31] Ch.19
Trainings	[31] Ch.4
Glossary	[12] 10.23; [31] Ch.13
Functional Decomposition	[12] 10.22
Roles and Permissions Matrix	[12] 10.39; [31] Ch.2
Lessons Learned	[12] 10.27; [31] Ch.31
Metrics and Key Performance Indicators (KPI)	[12] 10.28

The selected techniques are shown in Table 1, grouped by areas of application. The abovementioned sources introduce different classifications: [31] uses "classical" RE-related areas (Elicitation, Analysis, Specification, Validation, Management), while [12] defines 6 Knowledge Areas (BA Planning and Monitoring, Elicitation and Collaboration, Requirements Life Cycle Management, Strategy Analysis, Requirements Analysis and Design Definition, Solution Evaluation). As these two classifications are not "compatible", we decided to use classification from [31] and do the "mapping" for the remaining techniques.

Techniques in Table 1 are also provided with references to the exact sections/chapters, where a given technique is described in sources(s). Most of these techniques appeared in both sources, however some techniques recommended by a only one of them were also selected because of their potential influence on quality.

3.2 Identification of Quality Characteristics

Since late 70s, several attempts to develop a generic software quality model were made e.g. [1, 5, 9, 13, 14, 19]. Basically, all models have a similar construction – they define a number of main quality characteristics (or attributes, factors etc. as different names are used), which are in turn decomposed into more detailed subcharacteristics. Such decomposition continues (number of its steps also varies between models) until measurements are possible and metrics can be defined.

We compared a number of generic quality models to identify the most common quality characteristics and establish their definitions. This task may appear unnecessary, as software quality models have already been analyzed, improved and compared (e.g. according to inclusion of particular characteristics [28] or deficiencies [20]). Our purpose was however different – instead of identifying the most complete or suitable model, we intended to identify a small number of most common quality characteristics included in established quality models and to define them by compiling proposals from several models. To achieve it, we conducted the analysis of 5 quality models, independent from existing published comparisons. The following models were analyzed: McCall model [19], Boehm model [1], Dromey model [5], FURPS model [9] and ISO 9126 model [13].

A comparison of quality characteristics included in those models is presented in Table 2. As different names and hierarchical decompositions are used in analyzed models, contents of Table 2 are the result of several decisions e.g.:

- The characteristics are on the same level of abstraction (e.g. Resource utilization is a part of Efficiency), but nevertheless we included them to provide a more comprehensive comparison.
- When alternative names to the same characteristic were given in various models, we tried to choose the one more consistent with current terminology (e.g.

used in ISO 25010, which was not part of this comparison, but an additional reference in case of such conflicts).

- Only a more general Usability characteristic was included with assumption that it covers characteristics like As-Is-Utility and Human Engineering from Boehm model, as well as Usability sub-attributes from ISO 9126.

Table 2 Comparison of characteristics in software quality models

		Inclusion in quality models				
	Characteristic / Attribute / Factor	McCall	Boehm	Dromey	FURPS	ISO 9126
1.	Accessibility		**x**			
2.	Adaptability					**x**
3.	Analysability					**x**
4.	Co-existence					**x**
5.	Completeness	**x**	**x**			
6.	Correctness	**x**		**x**		
7.	Efficiency	**x**	**x**	**x**		**x**
8.	Flexibility	**x**				
9.	Functionality			**x**	**x**	**x**
10.	Installability					**x**
11.	Integrity	**x**	**x**			
12.	Interoperability	**x**				**x**
13.	Learnability					**x**
14.	Maintainability	**x**	**x**	**x**	**x**	**x**
15.	Modifiability		**x**			**x**
16.	Operability	**x**				**x**
17.	Performance				**x**	
18.	Portability	**x**	**x**	**x**		**x**
19.	Reliability	**x**	**x**	**x**	**x**	**x**
20.	Replaceability					**x**
21.	Resource utilization					**x**
22.	Reusability	**x**		**x**		
23.	Suitability					**x**
24.	Supportability				**x**	
25.	Testability	**x**	**x**			**x**
26.	Understandability		**x**			**x**
27.	Usability	**x**	**x**	**x**	**x**	**x**

The comparison provided the basis for selection of quality characteristics to be used in the planned survey. We intended to use a small number of more general,

but well-defined characteristics. Table 2 reveals that 3 characteristics (Maintainability, Reliability and Usability) are explicitly addressed in all of analyzed models. Functionality is not included in older models (McCall, Boehm), but its importance is obvious. Therefore, we finally selected 4 characteristics, and (combining proposals from various models) defined them. The model we mostly relied on turned out to be ISO 9126, but the resulting characteristics differ from the ones in ISO 9126, because of influences from other models:

- Functionality – suitability to provide an appropriate set of functions, resulting with the needed degree of precision, ability to interact with specified external systems, assurance to prevent unauthorized users/systems access.
- Usability – capability to be understood, learned and operated by users, as well as being recognized by them as attractive.
- Reliability – capability to tolerate faults, to avoid failures and to recover in case of failure.
- Maintainability – capability to be modified and to be adopted to another environment with adequate performance.

4 Questionnaire Survey

In this section we describe the key elements related to the survey and its results.

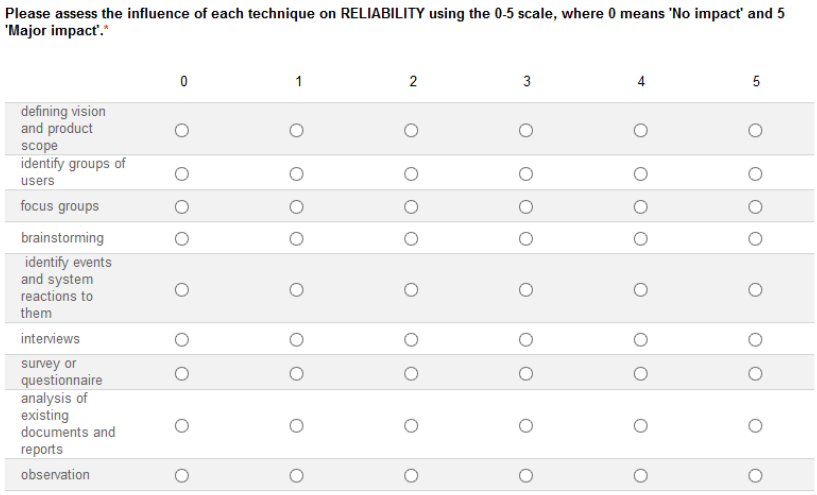
4.1 Questionnaire Design

We planned to answer question about RE/BA techniques' impact on quality by conducting a questionnaire-based survey published in the Internet. A number of online survey software tools (SurveyMonkey, Google Forms, Interankiety, SurveyGizmo) were considered. The final choice was Google Forms - this tool lacked questionnaire design flexibility and user interface configurability, but provided the best functionality for reviewing and processing answers and was freely available without any restrictions.

As any survey can be compromised by incomprehensible or ambiguous questions, we paid attention to the proper questionnaire design. The following actions were taken to ensure the questionnaire is well-formed and understandable:

- It was divided into 3 separate parts: (1) context information about survey participant's background, (2) assessments of RE/BA techniques' influence on quality characteristics, (3) feedback on questionnaire's understandability and completeness (including open questions about additional RE/BA techniques considered by the participant as crucial for quality characteristics).

- Terms used in the questionnaire were explained and used in a consistent manner. Definitions of quality characteristics and short explanations of RE/BA techniques were associated with each question in which they appeared, to be easily accessible to survey participants.
- A pilot survey involving persons representative for the target group was conducted to verify questionnaire design before the full scale survey started.



Please assess the influence of each technique on RELIABILITY using the 0-5 scale, where 0 means 'No impact' and 5 'Major impact'.*

	0	1	2	3	4	5
defining vision and product scope	○	○	○	○	○	○
identify groups of users	○	○	○	○	○	○
focus groups	○	○	○	○	○	○
brainstorming	○	○	○	○	○	○
identify events and system reactions to them	○	○	○	○	○	○
interviews	○	○	○	○	○	○
survey or questionnaire	○	○	○	○	○	○
analysis of existing documents and reports	○	○	○	○	○	○
observation	○	○	○	○	○	○

Fig. 1 Example question – influence of Elicitation techniques on Reliability

The main task of survey participants (included in part 2 of the questionnaire) was to evaluate the impact of particular BA techniques on particular quality characteristics using 0-5 Likert scale (0 – No impact, 5 – Major impact). A partial screenshot from Google Forms demonstrating example of such question is shown in Fig. 1. Each such question focused on techniques from a single area (Elicitation, Validation etc.) and one quality characteristic. Survey participants were supposed to answer 20 questions similar to the one presented in Fig. 1, including in total 124 evaluations (technique/characteristic).

4.2 Survey Data Gathering and Processing

The questionnaire was prepared in two language versions (Polish and English) and published online. The survey participants were involved using personal contacts, mailing and publishing invitations on websites dedicated to business analysts and others interested in BA topics. Only the responses with answers addressing all mandatory questions from part 2 were considered. In total 20 such responses were gathered (17 to Polish and 3 to English version). Because of the small number of

responses to the English version, we decided not to analyze them separately, but to process all responses together. After a closer look, one response was removed from further consideration (all evaluations were identical starting from some point). The remaining 19 responses were further processed. Context questions from part 1 of the questionnaire provided background information about survey participants, including the following:

- All of them (19) were employed in the IT industry;
- History of professional experience: 1-5 years (9), 6-10 years (6), >10 years (4);
- Current company's number of the employees: 30-120 (10), over 120 (9);
- Current job position: manager/lead (7), designer/developer (5), business analyst (4), architect (1), tester (1), system engineer (1);
- The age demographics: 27-34 years old (11), 18-26 (5), 35-40 (3);

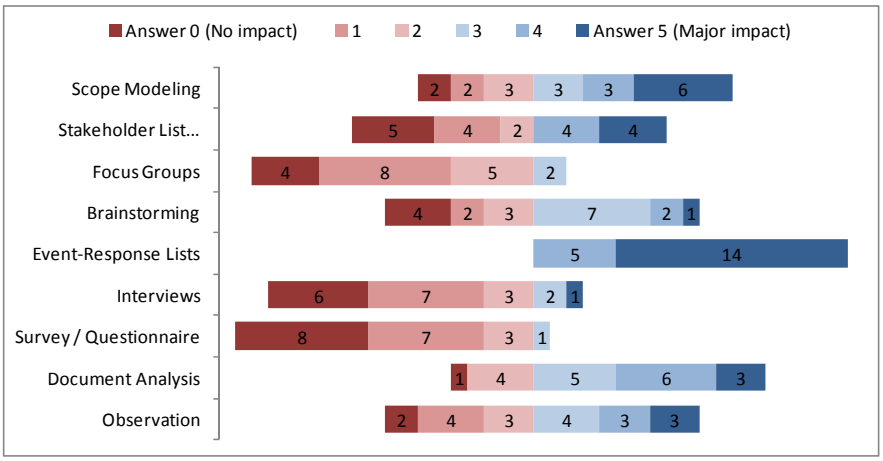


Fig. 2 Example distribution of answers – impact of Elicitation techniques on Reliability

The most important were the answers to part 2 questions – evaluations of RE/BA techniques impact on quality characteristics as perceived by surveyed professionals. We processed these answers, summarized them and visualized as graphs. An example regarding evaluation of Elicitation techniques on Reliability characteristic is shown in Fig. 2 as a diverging stacked bar chart, centered to show how answers about none/weak influence (0-2) and strong (3-5) are distributed. As it is not possible to include full results in the paper, it only shows examples, but the raw data collected in the survey (translated to English) is available at [21].

Table 3 contains the same answers as Fig. 2., but the scale is divided into 2 parts: "positive" 3-5 answers indicating strong influence and "negative 0-2 answers interpreted as weak influence (or none at all).

Table 3 Impact of Elicitation techniques on Reliability – answers divided into 2 main categories

Technique	Influence evaluations (% of answers)	
	0-2 values range ("negative")	3-5 values range ("positive")
Scope Modeling	36,9	63,1
Stakeholder List, Map or Personas	57,9	42,1
Focus Groups	89,5	10,5
Brainstorming	47,4	52,6
Event-Response Lists	0	100
Interviews	84,2	15,8
Survey / Questionnaire	94,7	5,3
Document Analysis	26,3	73,7
Observation	47,4	52,6

Distribution of answers for a single assessment was checked to locate its local maximum. As result, a technique could be considered to: have a substantial impact when a local maximum could be found within 3-5 range of values; have a negligible impact if such maximum was in 0-2 range; or remain unclassified if data was inconclusive and neither of two previous conditions were met. There were two such cases for the example presented in Table 3: brainstorming and observation. Such cases were a subject of further analysis and discussion during the interviews conducted later and described in Section 4.3.

4.3 Interviews

Interviews with two experienced business analysts were arranged to discuss and interpret survey results. We intended to receive general feedback about survey validity and perceived value of its results. We also wished to discuss more thoroughly the cases of inconclusive survey results, hoping to identify the causes of such outcome and additional factors determining the impact we tried to investigate. The interviews with each of 2 analysts were conducted separately. Before the meeting, each one received and reviewed introductory materials. The materials included survey results and the outcome of the analysis we conducted. Our interviewees were:

- Analyst 1 – employed as technical lead by a software house which specializes in dedicated systems supporting business processes, responsible for the contact with customers and requirements engineering process, 9 years of experience.
- Analyst 2 – employed as business analysts in a company developing systems and services for airlines, several certificates in BA and project management, 6 years of industrial experience as business analyst in 3 software companies.

Both interviewees confirmed that they generally consider the survey and its results to be useful and consistent with their opinions about applicability of RE/BA techniques, however in several particular cases there were differences between the opinion of one or both analysts and survey results. Such cases and inconclusive survey results were subjects of detailed discussion. Additional factors which can possibly decide whether a technique has impact on quality (and thus explain differences in survey answers) were identified for particular cases. For example, as mentioned before, survey participants had varied opinions whether applying Observation technique has impact on Reliability of developed system. Interpretation of interviewed analysts was that this technique can lead to Reliability improvement by identifying user-caused faults, but only when a detailed prototype or pilot deployment is planned in software project. Such comments were noted as additional guidance for RE/BA technique selection.

4.4 Final Results

The main result of our research is included in Table 4, which lists the most influential techniques with respect to each of quality characteristics. The table summarizes the results of the survey, confirmed by interviews. The techniques are grouped by RE/BA areas (defined in Section 3.1). The ordering within each area (single table row) is meaningful – the most influential technique is listed first.

5 Validity Threats

This section discusses the different types of threats potentially affecting internal and external validity of our research.

Internal validity concerns the design of research study and potential additional factors that could affect the outcome. In our case, research design could be flawed by wrong selection of RE/BA techniques and/or quality characteristics. Although more techniques are available, described in literature, the systematic approach applied and reliance on renowned sources constitute the argument for including the most important ones. Quality characteristics were derived on the basis of a number of quality models, however the choice of models can be questioned, especially

considering that we relied on older sources. More recent models, which reflect the scope of current knowledge on software quality are available e.g. ISO/IEC 25000 series. However, our purpose was to identify a small number of most common characteristics included in established quality models, not to use a complete quality model covering all aspects of e.g. system quality or data quality. Another potential threat is that survey participants lacked sufficient information to answer the questions. We made effort to prevent this by providing them with definitions of all terms used (techniques, characteristics), but nevertheless we asked them (part 3 of the questionnaire) about feedback. The average answer about values on understandability of questions was 3.27 (1-4 Likert scale). Typical threats like history, selection, rivalry or mortality are not applicable due to the method of research (no groups compared, single task of answering questionnaire). Maturation (in particular fatigue) could be an issue – to address this we reviewed data and excluded answers of one participant because of fatigue symptoms.

As for external validity, we made an effort to involve people with an appropriate background (industry practitioners not e.g. undergraduate students as survey respondents, experienced BA as interviewees). However it is difficult to generalize the results because of small size of our sample (19 respondents, 2 interviewees) and the fact that vast majority of them were from a single country.

6 Conclusions

In this paper we explored one aspect of RE/BA influence on project outcome by investigating a potential impact of RE/BA techniques on a set of software quality characteristics. For this purpose we conducted a literature search for software quality models, analyzed them and selected a subset of commonly recognized quality characteristics. Also, we identified a representative set of RE/BA techniques recommended by reliable sources. These two sets provided the basis for questionnaire survey and interviews. We conducted a survey, gathered valid responses from 19 industry professionals and conducted 2 interviews with experienced business analysts to discuss and interpret survey results. The main outcome addressing our research question are recommendations regarding techniques to be used in a software project in case a given quality characteristic is considered essential, summarized in Table 4.

A further research is possible by focusing on other RE/BA techniques and/or quality characteristics, by considering more detailed sub-characteristics (e.g. learnability or attractiveness instead of usability) and by identifying additional factors determining whether a given technique is applicable in a given context.

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Table 4 Most influential RE/BA techniques according to survey results

Characteristic	Area	Most influential techniques
Functionality	E	Scope Modeling; Event-Response Lists; Observation
	A	Business Model Canvas; Organizational Modeling; Prototyping
	S	SRS Templates
	V	Test Cases and Scenarios; Acceptance and Evaluation Criteria
	M	Functional Decomposition; Lessons Learned
Usability	E	Observation; Focus Groups
	A	Prototyping; Organizational Modeling
	S	Non-Functional Requirements Analysis
	V	Test Cases and Scenarios; Acceptance and Evaluation Criteria
	M	Lessons Learned
Reliability	E	Event-Response Lists
	A	Risk Analysis and Mngmt; Business Model Canvas; Prototyping
	S	Non-Functional Requirements Analysis
	V	Test Cases and Scenarios; Reviews
	M	Lessons Learned; Metrics and KPIs; Functional Decomposition
Maintainability	E	Scope Modeling
	A	Business Model Canvas; Data Dictionary
	S	Non-Functional Requirements Analysis; Item Tracking
	V	Retrospectives; Reviews
	M	Lessons Learned; Functional Decomposition

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