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An Approach for Constructing Evaluation Model of Suitability Assessment of Agile Methods using Analytic Hierarchy Process

G. Mikulėnas, R. Butleris
Department of Information Systems, Kaunas University of Technology,
Studentu str. 50, Kaunas, Lithuania, phone: +37060032182, e-mail: gytenis.mikulenas@ktu.lt

Introduction

According to the latest CHAOS Report published by Standish Group, still only about 32 % of software projects can be called successful, i.e. they reach their goals within a planned budget and on time. In the mid 90's people started creating new methods because industrial requirements and technologies were moving too fast and customers were unable to determine their needs in the early stages of the projects. 2001 saw the rise of the agile software development concept. Agile methods utilized existing ideas, practices and methods that were considered incompatible with the traditional plan-driven approaches. Today, there are a lot of so called agile methods that are still evolving, e.g. Extreme Programming (XP), Scrum, Dynamic Systems Development Method (DSDM), Crystal, Open Unified Process (OpenUP), Agile Modeling (AM) Feature Driven Development (FDD), Adaptive Software Development (ASD), Iconix, and etc.

Although statistics show that the usage of agile practices at IT companies is increasing, IT companies tend not to take drastic risks instantly switching from their methodological know-how to agile methods. Moreover, researches reveal the facts that agile methods are not suitable everywhere due to some organizational and project environmental restrictions. The problem is that majority of researchers in this field concentrate on presenting success stories or lessons-learned by organizations that have adopted agile methods for specific projects. Therefore, there is a lack of researches of suitability evaluations of agile methods considering various environmental characteristics at IT companies.

The aim of this paper is to present an approach for constructing such evaluation models that will utilize factors and characteristics from existing approaches and from our previous researches. Also, widely used analytic hierarchy process (AHP) method is used for prioritizing the characteristics. The purpose of such approach is to improve the usage of agile methods. There are several problems related with this improvement. First, agile methods should not be used when they are not suitable. Second, agile methods should be used when they are suitable. Third, there is intermediate suitability that must be considered with caution when applying agile methods partly. Only by applying the process of suitability evaluation it becomes possible to increase the benefit, minimize the risk of misuse of agile methods and to affect on overall success rate of software development projects. The paper consists of seven parts. A general overview of the research is presented in introduction. Existing supplementary approaches and our previous researches are covered in section “Related work”. Nomenclature of our approach is defined in section “Definitions of proposed terms”. The details of our approach are presented in section “Proposed process for constructing evaluation model of suitability of agile methods”. The case study consists of two parts. First part “Case study of the construction of the evaluation model” presents an example of the creation evaluation model. Second part presents an example of the usage of that model. The section “Conclusion” presents summarized results of the research.

Related work

It is noticeable that there is a lack of comprehensive evaluation models for the assessments of agile methods suitability at IT companies. However, some attempts are made. Alistair Cockburn proposes the use of two criteria such as system criticality and team size in his selection grid approach [2]. The more system is critical and team is bigger the more rigorous methods should be used instead of lightweight agile methods. However, these two criteria do not cover the overall both IT company and project environment. Kroll proposed the use of process map by indicating two dimensional axes between agile and traditional software development methods [4]. The more risk, low ceremony of the process, the need of continuous integration and testing exist the more iterative agile methods should be used. However, this proposal is more educational and superficial lacking discrete evaluation. The same problems exist in the proposal of Dave Cohen’s agile factors where author gives some insights of the criteria of the suitability of agile methods [3]. Authors Beck and Boehm emphasize cultural differences as the main criterion between the IT companies that use agile methods more than other companies in their agility and discipline factors research [1]. Also, other criteria such as personnel, dynamism, techniques, organization and knowledge are proposed. Most of these criteria might be found in our previous work [5].

The benefit of the approaches is that they utilize various criteria that reveal different aspects of the environment for agile methods. Hence, most of analyzed approaches share the same problems. First, there is an absence of proposals for discrete status evaluation. This means that most of those approaches are educational and superficial. Second, there is a lack of process guides for performing the suitability evaluation of agile methods. Third, there is an absence of relative weights for different criteria because some criteria are more important than others. Most of the prioritization methods for creating weights were analyzed in our previous work [6]. Therefore analytic hierarchy process method [9] was selected for the approach of the construction of the evaluation model.

Definitions of proposed terms

We defined terms during the development of the approach of agile method suitability evaluation. In this section, the nomenclature is presented:

Definition 1. Let *C* denote as a set of *m* criteria used for the evaluation of an environment of the suitability of agile methods at any IT company

$$C = \{c_1, c_2, \ldots c_m\} . \quad (1)$$

Definition 2. Let *V* denote as a set of *n* paired fuzzy (f_i) and crisp range (p_j) values used for the criteria evaluation

$$V = \{(f_1, p_1), (f_2, p_2), \ldots (f_n, p_n)\} . \quad (2)$$

Definition 3. Let $r(c_k, c_p)$ denote as a function of significance ratio of two compared criterions c_k and c_p

$$r(c_k, c_p) = \frac{c_k}{c_p} . \quad (3)$$

Definition 4. Let w_j denote as a relevance weight of the j-th criterion. The total of criteria weights is equal to 1

$$\sum_{j=1}^{m} w_j = 1 . \quad (4)$$

Definition 5. Let *y* denote as a total of evaluations of each criterion (c_i) that represents the characteristics of the suitability of the agile methods at any IT company

$$\sum_{i=1}^{m} Eval(c_i) = y . \quad (5)$$

Definition 6. Let *A* denote as a set of u action recommendations where each element is expressed as a pair of action recommendation a_i and corresponding output (*y*) range value k_j

$$A = \{(a_1, k_1), (a_2, k_2), \ldots (a_u, k_u)\} . \quad (6)$$

Definition 7. Let *T* denote as a set of the company's *h* experts that are needed for the process of the suitability evaluation of agile methods at any IT company

$$T = \{t_1, t_2, \ldots t_h\} . \quad (7)$$

Proposed process for constructing model of evaluation of agile methods suitability

The process for creating evaluation model consists of seven steps (Fig 1). Each step is defined below the schema.

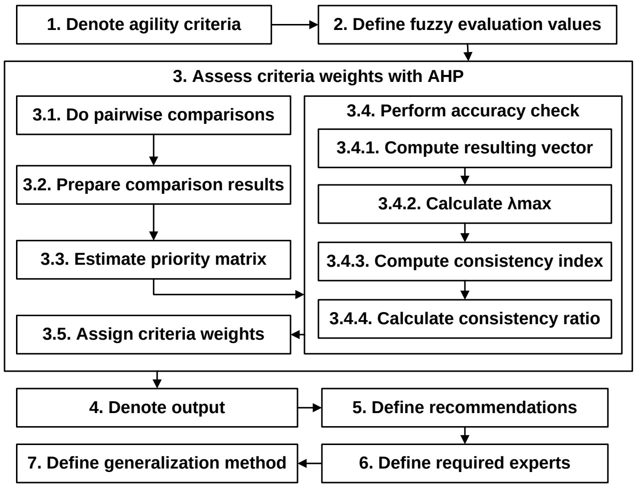

Fig. 1. Proposed process model for constructing the model of suitability evaluation of agile methods at IT company

Step 1. Denote agility criteria. Define environmental criteria *C* that identify suitable conditions for the successful use of agile development methods. Most of the criteria are established in our previous research [5].

Step 2. Define fuzzy evaluation values. Define a set *V* of fuzzy and crisp range values for the criteria evaluation. The fuzzy value represents a qualitative evaluation of the criterion and the corresponding crisp range value defines a quantitative range that covers the fuzzy value (Table 1).

Table 1. The values for criterion evaluation

Value pair, (f_i, p_j)	Fuzzy value, f_i	Crisp value range, p_j
(f_1, p_1)	f_1	p_1
(f_2, p_2)	f_2	p_2
…	…	…
(f_n, p_n)	f_n	p_n

Step 3. Assess criteria weights with AHP. Calculate priority matrix and its eigenvalues that represent criteria weights w_j with AHPP method. The analysis of different prioritization methods and motivation for AHP method is covered in the previous researches [6, 7, 10].

Step 3.1. Do pairwise comparison. Perform pairwise comparisons (Table 3) of the denoted criteria according to their significance. The fundamental scale used for this purpose is shown in Table 2.

Table 2. Scale of pairwise comparisons [9]

Relative intensity	Definition	Explanation
1	Equal value	Two criteria are of equal value
3	Slightly more value	Experience slightly favors one criterion over another
5	Essential or strong value	Experience strongly favors one criterion over another
7	Very strong value	A criterion is strongly favored and its dominance is
9	Extreme value	The evidence favoring one over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed between two judgments

Table 3. The results of pairwise comparison of the criteria

	c_1	c_2	…	c_m
c_1	1	$r(c_1,c_2)$	…	$r(c_1,c_m)$
c_2	$r(c_2,c_1)$	1	…	$r(c_2,c_m)$
…	…	…	…	…
c_m	$r(c_m,c_1)$	$r(c_m,c_2)$	…	1

Step 3.2. Prepare comparison results. Calculate the total of the n columns for every row in the comparison results matrix. Then divide each matrix element by the sum of the column the element is a part of.

Step 3.3. Estimate priority matrix. Calculate the sums of each row in the normalized matrix and divide each row sum by the number of criteria. The result of this computation is referred to as the priority matrix and is an estimation of the eigenvalues of the matrix.

Step 3.4. Perform accuracy check. Check the evaluated eigenvalues for inconsistency.

Step 3.4.1. Compute resulting vector. Multiply the comparison matrix by the priority vector then divide each element of the resulting vector by the corresponding element in the priority vector.

Step 3.4.2. Calculate λ_{max}. It determines the maximum eigenvalue of the comparison matrix and is estimated by calculating the average over the elements in the resulting vector.

Step 3.4.3. Compute consistency index. It is the first indicator of the accuracy of the pairwise comparisons and is calculated as

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} \ . \quad (8)$$

The closer λ_{max} is to n, the smaller the errors of the performed judgments are.

Step 3.4.4. Calculate consistency ratio. It defines the accuracy of the pairwise comparisons and is calculated as

$$\mathrm{CR} = \frac{CI}{RI} \ , \quad (9)$$

where RI is a random indices value picked up from Table 4. As a general rule, consistency ratio CR of 0.10 or less is considered acceptable. If it is higher, step back to the pairwise comparison and reconsider the judgments.

Table 4. Fragment of Random Consistency Index (RI) values [9]

n	3	4	5	6	7	8	9	10
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Note: n is the number of compared alternatives

Step 3.5. Assign criteria weights. Assign each criterion its priority, i. e. a relative significance based on the estimated eigenvalues in the priority matrix.

Step 4. Denote output. Define the purpose and value range of the result y that will represent the overall quantitative evaluation value of the suitability of agile methods.

Step 5. Define recommendations. Break down the value range of the result y into sub-ranges reflecting each sub-range as a different status of the suitability evaluation.

Table 5. Action recommendations and corresponding outputs

Recommendation pair, (a_i, k_j)	Action, a_i	Output value range, p_j
(a_1, k_1)	a_1	k_1
(a_2, k_2)	a_2	k_2
…	…	…
(a_u, k_u)	a_u	k_u

Step 6. Define required experts. There are different roles in information systems development. Therefore, we need to define required experts (T) of IT company and their roles needed for performing the evaluation.

Step 7. Define generalization method. During evaluation of the suitability of agile methods, different experts will give different evaluations. Therefore, a method for the generalization of separate evaluation data into overall result y is needed to be defined.

Two case studies will clarify the usage of presented approach. The first case study will present a concrete example of construction evaluation model. The second case study will present a usage example of constructed evaluation model.

Case study of the construction of the evaluation model

The proposed approach for constructing evaluation model consists of 7 steps therefore we will walk through each of that step and present the result of those steps.

Step1. Denote agility criteria. We have adapted criteria established in our previous research [5]. Presented criteria reveal common characteristics of IT company that is ideally suitable for the usage of agile methods (Table 6).

Table 6. Adapted agility criterions [5]

Category	Agility criterion	Shortcut
Business	Customer collaboration over contract negotiation	CC
Project	Primary goal working software	PG
	Low criticality	LC
	Ambiguous, changing requirements	AR
	Eliminate waste	EW
Customer	Dedicated, motivated, knowledge expert, on-site	DC
Team	Empowered, self-organized	ET
	Small size	SS
	Face-to-face communication	FC
	Skilled, motivated individuals	SI
Environment	Open workspace	OW
	Co-located team members	CT
	Democratic culture, tolerance and respect	TR
	Technical tools for automated unit testing, integration, build compilation, version control, collective code ownership	TT

Due to the limitations of the paper space, further, we will use 8 criteria: PG, AR, EW, DC, ET, SI, OW, and TT.

Step2. Define fuzzy evaluation values. During case study, we have defined five major fuzzy and crisp values for the evaluation of the degree of criterion satisfaction (Table 7).

Table 7. Defined fuzzy and crisp values for criterion satisfaction

Fuzzy value, f_i	Crisp value range, p_j
Not acceptable	[0; 0.2]
Very little	[0.2; 0.4]
Yes and No	[0.4; 0.6]
Satisfied	[0.6; 0.8]
Extremely satisfied	[0.8; 1.0]

Step3. Assess criteria weights with AHP. This composite step consists of five sub-steps related to the usage of AHP method. We propose the use of one importance criterion when performing prioritization of agile suitability criteria.

Step 3.1. Do pairwise comparison. Criteria from the selected 8 ones are compared each to other (Table 8). Each cell value indicates the ratio of two compared agile suitability criteria with respect to their importance. The values for comparison are taken from Table 2.

Table 8. Pairwise comparison with respect to importance

	SS	AR	DC	LC	SI	CT	TT
SS	1	1/5	1/9	1/6	1/8	1	1/3
AR	5	1	1/4	1	1/2	5	3
DC	9	4	1	2	2	8	7
LC	6	1	1/2	1	1/3	4	2
SI	8	2	1/2	3	1	8	6
CT	1	1/5	1/8	1/4	1/8	1	1/3
TT	3	1/3	1/7	1/2	1/6	3	1

Step 3.2. Prepare comparison results. The intermediate calculation results are presented in Table 9.

Table 9. Prepared result matrix

	SS	AR	DC	LC	SI	CT	TT
SS	0,03	0,023	0,042	0,021	0,029	0,033	0,017
AR	0,152	0,115	0,095	0,126	0,118	0,167	0,153
DC	0,273	0,458	0,38	0,253	0,471	0,267	0,356
LC	0,182	0,115	0,19	0,126	0,078	0,133	0,102
SI	0,242	0,229	0,19	0,379	0,235	0,267	0,305
CT	0,03	0,023	0,048	0,032	0,029	0,033	0,017
TT	0,091	0,038	0,054	0,063	0,039	0,1	0,051

Step 3.3. Estimate priority matrix. The results of the prioritization with respect to agile criteria importance are presented in Table 10.

Table 10. Priority matrix

	SS	AR	DC	LC	SI	CT	TT
EV	0,028	0,132	0,351	0,132	0,264	0,03	0,063

Step 3.4. Perform accuracy check. The next step is to check the accuracy of the results. The result of computation of the resulting vector (Step 3.4.1.) is presented in Table 11. The results of computation λ_{max} (Step 3.4.2.), consistency index (Step 3.4.3.) and consistency ratio (Step 3.4.4.) are presented in Table 12.

Table 11. Resulting vector

R1	R2	R3	R4	R5	R6	R7
7,12	7,292	7,416	7,118	7,355	7,114	7,08

Table 12. Accuracy results

λ_{max}	CI	CR
7,214	0,036	0,027

As a general rule the results of pairwise comparison are considered to be acceptable when consistency ratio CR is of 0.10 or less. In our case it is 0,027 therefore the results are acceptable with minimum level of error.

Step 3.5. Assign criteria weights. After all calculations are done, it is possible to assign the weights to agile criteria from the priority matrix (Table 13).

Table 13. Assigned weights of the criteria

	SS	AR	DC	LC	SI	CT	TT
w_j	0,028	0,132	0,351	0,132	0,264	0,03	0,063

Step 4. Denote output. The purpose of the evaluation is to assess the suitability of agile methods at IT company. Therefore the final result *y* must fall into the quantitative value range of [0; 1] where the boundary value such as “0” means total incompatibility and “1” means full compatibility to the agile methods. The value range of [0; 1] is used as an output for the final evaluation result.

Step 5. Define recommendations. After the evaluation of the suitability of agile methods at IT company is made, further recommendations are needed. We present 5 action recommendations with respect to output value (Table 14).

Table 14. Action recommendations with respect to output value

Action recommendation, a_i	Output value range, p_j
Agile methods are not suitable	[0; 0.1]
Minimal suitability. Use only essential practices from the agile methods	[0.1; 0.3]
Intermediate suitability. Incremental usage of agile methods is advised	[0.3; 0.7]
Suitable environment. Consider full usage with tracking and monitoring	[0.7; 0.9]
Ideal environment for the use of agile methods. Consider full usage	[0.9; 1.0]

Step 6. Define required experts. There are various roles in software development projects. However, five major roles are met almost in all projects. Therefore, we have defined them in this evaluation model (Table 15). These roles will be as experts and will present domain knowledge of the company that will be evaluated. They will evaluate the company themselves using the evaluation model.

Table 15. Selected roles of software development

Expert, t_i	Shortcut	Is responsible for presenting
Project manager	PM	the values and priorities of IT company
Lead analyst	LA	the knowledge of analysis process at IT company
Lead designer	LD	the knowledge of design process at IT company
Senior programmer	SP	the knowledge of programming process at IT company
Quality manager	QM	the knowledge of testing process at IT company

Step 7. Define generalization method. Each expert will provide a separate evaluation *Eval*(c_j) for each criterion. Therefore, the summary of the values of

weighted criterions will be used that will allow to generalize into overall evaluation result y

$$y = \sum_{i=1}^{h} \sum_{j=1}^{m} Eval(c_{ij}) * w_{ij} \ . \qquad (10)$$

The evaluation model is defined. The next section holds an example on how to use this model for the evaluation of agile methods suitability at any IT company.

Example of the usage of the constructed evaluation model

The constructed evaluation model was tested at project of order processing software creation at company X. The project team consisted of 7 members (project manager, analyst, designer, three programmers and tester). One of the programmers acted as skilled senior programmer. It was a small project according to agile criteria. Therefore analyst, designer and tester were interpreted as leading roles. Further, the persons of five major roles evaluated the conformance to eight criteria (PG, AR, EW, DC, ET, SI, OW, and TT) defined in the evaluation model. The results of their evaluation are presented in Table 16.

Table 16. The results of the evaluation of eight agility criteria

Criterion	weight	Evaluations of the experts				
		PM	LA	LD	SP	QM
SS	0,028	0,7	0,6	0,6	0,7	0,7
AR	0,132	0,6	0,4	0,5	0,7	0,5
DC	0,351	0,3	0,4	0,4	0,2	0,3
LC	0,132	0,6	0,4	0,4	0,6	0,5
SI	0,264	0,6	0,4	0,5	0,4	0,6
CT	0,03	0,5	0,4	0,7	0,3	0,5
TT	0,063	0,7	0,4	0,4	0,6	0,6
Expert results:		0,5	0,41	0,45	0,41	0,47
		Overall generalized result:				0,45

The overall compatibility result was calculated as a value of 0,45. Using the action recommendations from the model (Table 14), we concluded the intermediate suitability status with advice of incremental usage of agile methods. This means that evaluated company X had only a partial compatibility, though partial and incremental usage of agile methods might be useful.

Conclusions

The approach for the construction of evaluation models of suitability of agile methods was presented using analytic hierarchy process. The contribution of this paper is threefold. First, it improves the usage of agile methods by detecting where they are suitable and where not. Second, it facilitates the process of defuzzification of fuzzy evaluations made by separate experts. Third, the proposed approach serves as a basis for constructing the models of suitability evaluation of agile methods at IT companies.

The proposed approach includes existing criteria found in related researches, and furthermore, it extends them with the process guide of the construction of the suitability model, that is missing in related researches. The two performed case studies prove presumption that it is possible to evaluate the level of the suitability of agile methods, and that reveals the advantage of the proposed approach over the other existing approaches.

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Agile methods are rapidly growing in popularity software development methods that are not suitable everywhere due to their specifics. The results of previous researches including agility criteria and weights construction are used in this research. The approach for the construction of evaluation models of the suitability assessment of agile methods at IT companies is presented. The terms and concepts used for the approach are defined. The process of the construction the evaluation model is presented. A widely used Analytic Hierarchy Process (AHP) method is used for the construction of the relative weights of agility criteria. The case study of the creation concrete evaluation model is presented. The example of the usage of the constructed evaluation model at some IT company is presented. The accuracy check of the correctness of evaluations is performed. The conclusions of the research are presented, stating that proposed approach increases the effectiveness of the use of agile methods and facilitates the process of suitability evaluation. Ill. 1, bibl. 10, tabl. 16 (in English; abstracts in English and Lithuanian).

G. Mikulėnas, R. Butleris. „Agile“ metodų tinkamumo nustatymo modelio sukūrimas analitiniu hierarchiniu metodu // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 10(106). – P. 99–104.

„Agile“ metodai – tai naujos kartos programų kūrimo proceso valdymo metodai, kurie dėl savo specifikos ne visur yra tinkami naudoti. Šiame straipsnyje remiamasi anksčiau publikuotų dviejų tyrimų rezultatais – „agile“ metodų taikymo kriterijais ir svorių suteikimu pagal prioritetizavimo metodus. Pasiūlyta metodika kurti modeliams, skirtiems „agile“ metodų tinkamumui IT įmonės projektams įvertinti. Apibrėžti terminai ir sąvokos, pateikti formalūs jų sudėties aprašai. Aprašytas „agile“ metodų tinkamumo įvertinimo modeliui sudaryti procesas. Pritaikytas plačiai naudojamas analitinio hierarchinio proceso metodas svoriniams įverčiams sudaryti. Atliktas ir aprašytas metodikos taikymo pavyzdys, iliustruojantis modelio sudarymą. Aprašytas pagal metodiką sudaryto modelio taikymo pavyzdys. Atliktas įverčių teisingumo patikrinimas. Suformuotos tyrimo išvados, kuriose teigiama, jog taikant šią metodiką padidėja „agile“ metodų taikymo efektyvumas ir supaprastėja jų tinkamumo nustatymo procesas. Il. 1, bibl. 10, lent. 16 (anglų kalba; santraukos anglų ir lietuvių k.).