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An Empirical Approach to Measure Agility for Secure Agile Development using Fuzzy Analytic Hierarchy Process and Artificial Neural Network

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ABSTRACT

The requirement for fast and lean software delivery from the today's industry leads to adoption of agile development approaches over other conventional approaches. The Dynamic and competitive environment leads to rapid change of customer requirements which has also boosted the use of agile approach as it has merits like simplified documents and fast release which further leads to maximizing effectiveness and productivity. However, from security point of view it is very difficult to decide whether to use an agile approach for a given project or not, as there is no well defined empirical decision making process. This paper provides a roadmap for taking decision using Fuzzy Analytic Hierarchy Process and Artificial Neural Network approach by calculating Global Agility Indicator and in case it is selected, it further provides Local Agility Indicator to decide among popular Agile Development methods like Extreme Programming, Scrum, Feature-driven Development, Crystal Clear, Dynamic Software Development Method and Lean development. The fuzzy AHP deals with the inability of AHP to deal with the subjectiveness in the pair wise comparison process. In order to compensate the decision maker's uncertainty, it takes into account a range of values instead of a single crisp value. Further Artificial Neural Network with back propagation approach is used to train the network and producing correct results even for inconsistent input. By taking such a systematic approach for development, it inherently addresses the major concern of security on projects using agile approach.

Keywords: Fuzzy Analytic Hierarchy Process, Agile Development, Global Agility Indicator, Local Agility Indicator, Agile Security, ANN, Scrum, DSDM, XP, Crystal Clear, FDD.

I. INTRODUCTION

1.1 Agile Development

Instead of control and formalization the agile development follows an opposite approach compared to plan-driven development. Agile development rather formalizes processes only if necessary and to develop systems with high business value it gives emphasis to intensive and informal interaction. The Agile Manifesto [1] gives the core values in given abstract terms:

- Responding to change over following a plan,
- Working software over comprehensive documentation,
- Individuals and interactions over processes and tools,
- Customer collaboration over contract negotiation.

The meaning of the word agile differs in practice. In addition, it is very difficult to define agile methods, as it is a collection for the well-defined methods that also differs in practice. One of the initiators of agile

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approach, Alistair Cockburn defines agile as "agile implies being maneuverable and effective. It is both sufficient and light. The lightness means, staying maneuverable and sufficiency is a matter of remaining in the game" [26].

1.2. Agile Development Methods

Since the beginning of 1980s several agile development methods have been came into existence [24]. In order to cover the whole breadth in agile development, we have chosen popular methods like Extreme Programming, Scrum, the Dynamic Software Development Method (DSDM), Crystal Clear, Feature-driven Development (FDD) and Lean development. The elaboration and its relation to security in software development is out of the scope of this paper. These methods primarily differs in their values, practices and principles [27], based upon these certain calculations can done which will help in selecting one of these methods according to the requirement of the project.

1.3. Fuzzy Analytic Hierarchy Process

The AHP was developed by Saaty [21] in 1980s. It is one of the methods of Multi Criteria Decision Making (MCDM). Decision making process is to select among different alternatives based upon multiple criteria. In each of these decisions, we have several factors or criteria deep in our mind on what to consider and on the other hand we also have several alternatives choices among which we should decide. One of the most important steps in AHP is to create the comparison matrixes. In fuzzy AHP the membership scales of 1-9 are substituted by linguistic variables thus it deals with the inability of AHP to deal with the subjectiveness in the pair wise comparison process.

1.4. Security in agile development

As per as the security in agile development is concerned the main issues are that the dynamic and tacit-knowledge-driven methods and team-emphasizing, does not confers to the assurance activities as required by security engineering in conventional software development methods. However, early planning of security activities may conflict with the ever changing requirements in practice, but by systematically decision making about the use of agile approach and best suited agile development method according to the requirements can create an environment in which agile development is better prepared for security [28]. Also, with the help of security engineering and lightweight methods for security enhancement the challenges to security in agile development can be addressed [25].

II. PROPOSED APPROACH

2.1. Selecting Agile Development Approach or Not?

In the absence of any empirical approach for decision making, it is always a mammoth and complicated task for a project analyst to evaluate the development methodology and to make estimation by considering every important aspect of the project. The primary goal of this section is to design an approach for simplifying this task with the help of Fuzzy Analytic Hierarchy process and Artificial Neural Network.

2.1.1. Selection Procedure

In order to define a parameter that can help the analyst to choose the best methodology for a given project, we have used one of the famous methods of Multi Criteria Decision Making called Fuzzy Analytic Hierarchy Process or FAHP. It involves both the objective evaluation and the subjective human judgments merely by the use of Eigen vector and verifying the consistency of the evaluation by using Eigen Value.

Decision making is a process to choose among several alternatives based on multiple criteria. In our case these criteria are derived from the agile manifesto and agile principles and also from the comparison of agile methodologies with other methodologies. A linguistic value has to be chosen from Table 1. The value chosen indicates the importance of each factor asked in the criteria. The criteria have been decided based upon the different aspects of each project like project manager's point of view, customer's point of view etc.

Table 1
Scale for Fuzzy Conversion

Linguistic Variable	*Saaty's Scale*	*Triangular Fuzzy Scale*
Equal Importance (EI)	1	(1,1,1)
Moderate Importance (MI)	3	(1,3,5)
Strong Importance (SI)	5	(3,5,7)
Very Strong Importance (VSI)	7	(5,7,9)
Extremely Strong Importance (ESI)	9	(7,9,9)

The major criteria based upon intensive research and study of agile development approach, are:
Experience and Familiarity of Project (EFP)
Democratic Culture and Team Communication (DCT)
Clarity of Requirements (COR)
Documentation and Formalization (DAF)
Reliability and Project Complexity (RPC)
Quality and Risk Management (QRM)
Adaptive and Experienced Team (AET)
Customer Support and Collaboration (CSC)

This is not the exhaustive list thus depending upon project requirement more criteria can be added and in contrast, any needless criteria can be left out. Now we use fuzzy AHP to make a decision by following these steps.

- Problem hierarchy
- Fuzzy comparison matrix
- Calculation of fuzzy synthetic extents
- Normalization of weight vector
- Calculation of local priorities
- Calculation of global priorities

First, set up the analytic hierarchy model of Selection of Development Methodology as the following:

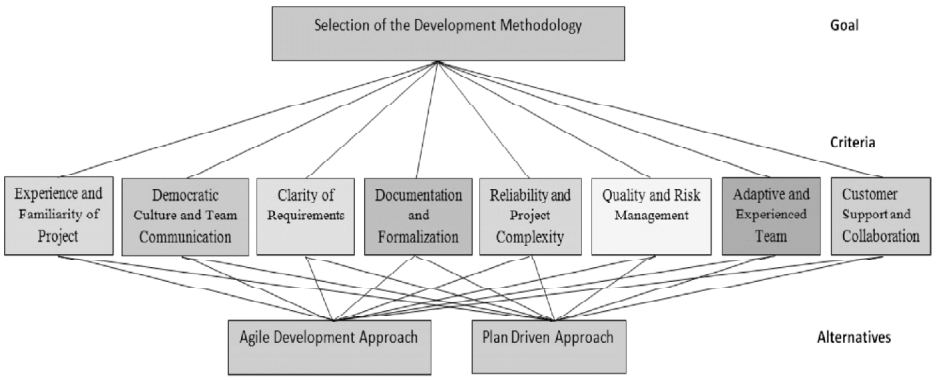

Figure 1: Hierarchy Model of Selection of Development Methodology

To calculate the weightage or ranks, fuzzy comparison matrix has been got filled by 5 experts from industry working in different organizations and Consolidated matrix is created using Weighted Geometric Mean of all participants as shown in Table 2.

Table 2
Fuzzy Comparison Matrix

	RPC	*EFP*	*QRM*	*AET*	*DCT*	*DAF*	*CSC*	*COR*
RPC	(1,1,1)	(0.2,0.33,1)	(1,1,1)	(0.14,0.2,0.33)	(0.2,0.33,1)	(1,1,1)	(0.2,0.33,1)	(1,3,5)
EFP	(1,3,5)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(3,5,7)	(1,1,1)	(1,3,5)
QRM	(1,1,1)	(0.2,0.33,1)	(1,1,1)	(0.14,0.2,0.33)	(0.2,0.33,1)	(1,1,1)	(0.2,0.33,1)	(1,1,1)
AET	(3,5,7)	(1,1,1)	(3,5,7)	(1,1,1)	(1,1,1)	(3,5,7)	(1,1,1)	(1,3,5)
DCT	(0.2,0.33,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(3,5,7)	(1,1,1)	(1,3,5)
DAF	(1,1,1)	(0.14,0.2,0.33)	(1,1,1)	(0.14,0.2,0.33)	(0.14,0.2,0.33)	(1,1,1)	(0.2,0.33,1)	(1,1,1)
CSC	(1,3,5)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,3,5)
COR	(0.2,0.33,1)	(0.2,0.33,1)	(1,1,1)	(0.2,0.33,1)	(0.2,0.33,1)	(1,1,1)	(0.2,0.33,1)	(1,1,1)

If the value of Consistency Ratio is less than 10%, the inconsistency is acceptable [21] otherwise we have to revise the subjective judgment. As the consistency ratio comes out to be 2.8% thus the approximation is quite good. Based upon this matrix and using (1), the corresponding weights are calculated as given in the Table 3 and the value of Global Agility Indicator is calculated as in Table 4. If the value of agility indicator is high it reflects the high suitability of using agile development approach and vice versa.

$$w_k^S = \frac{\left(\prod_{j=1}^{n} a_{kj}^S\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}^M\right)^{1/n}} \tag{1}$$

Table 3
Weights and Ranks of Criteria

Criteria	*Weights*	*Rank*
Reliability and Project Complexity (RPC)	7.64%	5
Experience and Familiarity of Project (EFP)	19.27%	2
Quality and Risk Management (QRM)	6.65%	7
Adaptive and Experienced Team (AET)	22.23%	1
Democratic Culture and Team Communication (DCT)	15.37%	4
Documentation and Formalization (DAF)	5.53%	8
Customer Support and Collaboration (CSC)	17.98%	3
Clarity of Requirements (COR)	7.19%	6

Table 4
Calculation of Global Agility Indicator

Criteria	*Weights*	*Input*	
Reliability and Project Complexity (RPC)	0.076398	**MI**	0.305593
Experience and Familiarity of Project (EFP)	0.192705	**ESI**	1.541636
Quality and Risk Management (QRM)	0.066504	**SI**	0.33252
Adaptive and Experienced Team (AET)	0.222331	**ESI**	1.778648
Democratic Culture and Team Communication (DCT)	0.153653	**ESI**	1.229226
Documentation and Formalization (DAF)	0.05526	**MI**	0.165781
Customer Support and Collaboration (CSC)	0.17977	**ESI**	1.438159
Clarity of Requirements (COR)	0.071928	**SI**	0.359641
Global Agility Indicator			**7.151205**

As the input taken can vary from person to person as there is a lot of subjectivity in defining the criteria so we can use Artificial Neural Network with Back Propagation Approach to train the network and producing the correct results even if the input data is inconsistent [22] as shown in next section. Selecting most Appropriate Agile Development Method

As we know, each agile development method is a collection of principles, which are supported by values and practices. In this section we have followed the same approach used in earlier section. Thus we have used fuzzy AHP in which we have defined Problem hierarchy, fuzzy pair wise comparison matrix and calculation of local priorities. To further deeply analyze the different agile methods we have defined four high level criteria based on agile values. These four criteria are following:

Rigidity to Change

Level of Formalization

Process Cost

Reliability and Project Complexity

To calculate the weights and ranks, fuzzy comparison matrix has been created as shown in Table 5. Although these can also be calculated with the help of above defined eight criteria but to take advantage of expertise of security experts we have got it filled from them only.

Table 5
Fuzzy Comparison Matrix

	Level of Formalization	*Rigidity to Change*	*Process Cost*	*Reliability and Project Complexity*
Level of Formalization	(1,1,1)	(0.2,0.33,1)	(1,1,1)	(1,1,1)
Rigidity to Change	(1,3,5)	(1,1,1)	(1,3,5)	(1,3,5)
Process Cost	(1,1,1)	(0.2,0.33,1)	(1,1,1)	(1,3,5)
Reliability and Project Complexity	(1,1,1)	(0.2,0.33,1)	(0.2,0.33,1)	(1,1,1)

The value of Consistency Ratio comes out to be 0.2%, which confirms that the approximation is good. Based upon this matrix and using (1), the corresponding weights and ranks are calculated as given in the Table 6. The value of Local Agility Indicator is calculated for each method as shown in Table 7.

Table 6
Weights and Ranks of Criteria

Criteria	*Weights*	*Rank*
Level of Formalization	17.55%	3
Rigidity to Change	47.90%	1
Process Cost	22.86%	2
Reliability and Project Complexity	14.62%	4

Table 7
Calculation of Local Agility Indicator

	Weights	*LEAN*	*SCRUM*	*CRYSTAL*	*XP*	*DSDM*	*FDD*
Level of Formalization	0.175	EI	SI	SI	SI	VSI	ESI
Rigidity to Change	0.479	MI	MI	MI	EI	ESI	ESI
Process Cost	0.229	SI	MI	EI	MI	VSI	VSI
Project Complexity and Reliability	0.146	VSI	SI	MI	MI	ESI	ESI
Local Agility Indicator		**4.66**	**3.61**	**2.84**	**3.20**	**8.21**	**8.63**

The following conclusions are made which are elaborated in the form of graphs shown in figures 2 and thus we can easily classify these agile methods into two broad categories, one with more liberal methods like XP, Scrum, Crystal Clear and Lean development and another with the more heavy-weight agile methods like DSDM and FDD.

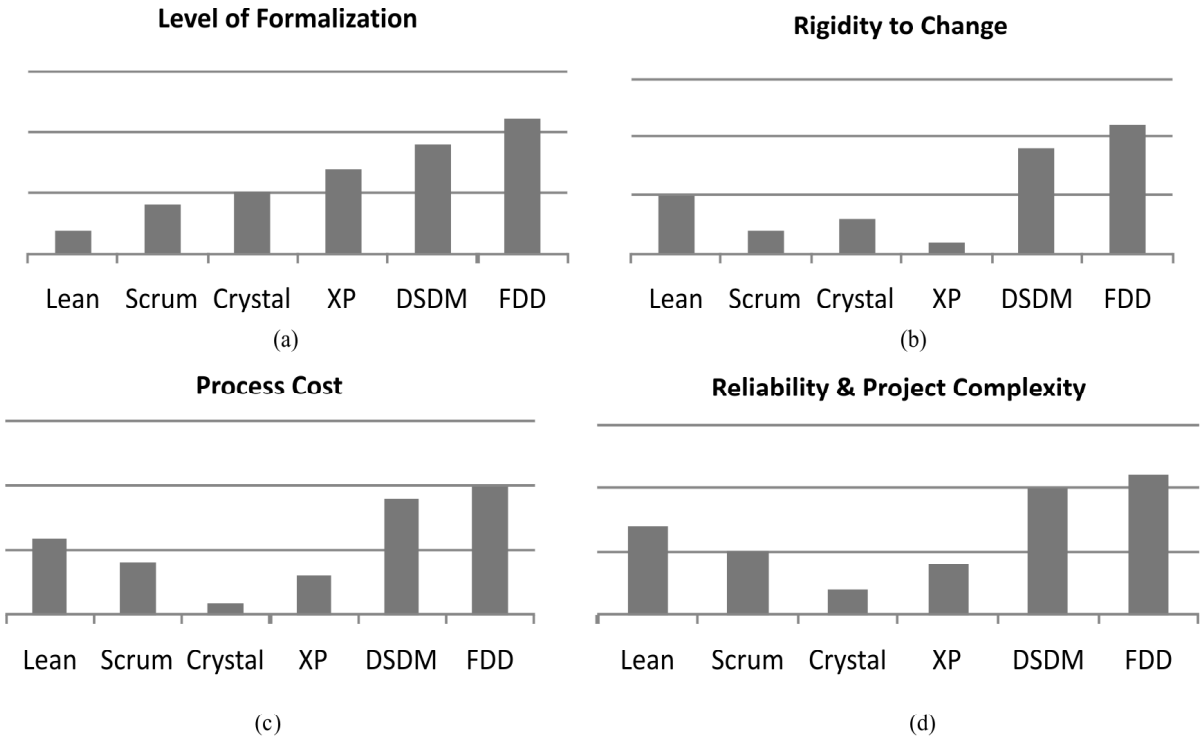

Figure 2: (a) Level of Formalization (b) Rigidity to change (c) Process Cost (d) Project Reliability & Complexity

To compensate for the subjectiveness and inconsistency in user input we have used Artificial Neural Network with Back Propagation Approach. Figure 3 shows the trained network with modified weights and the output for a given input.

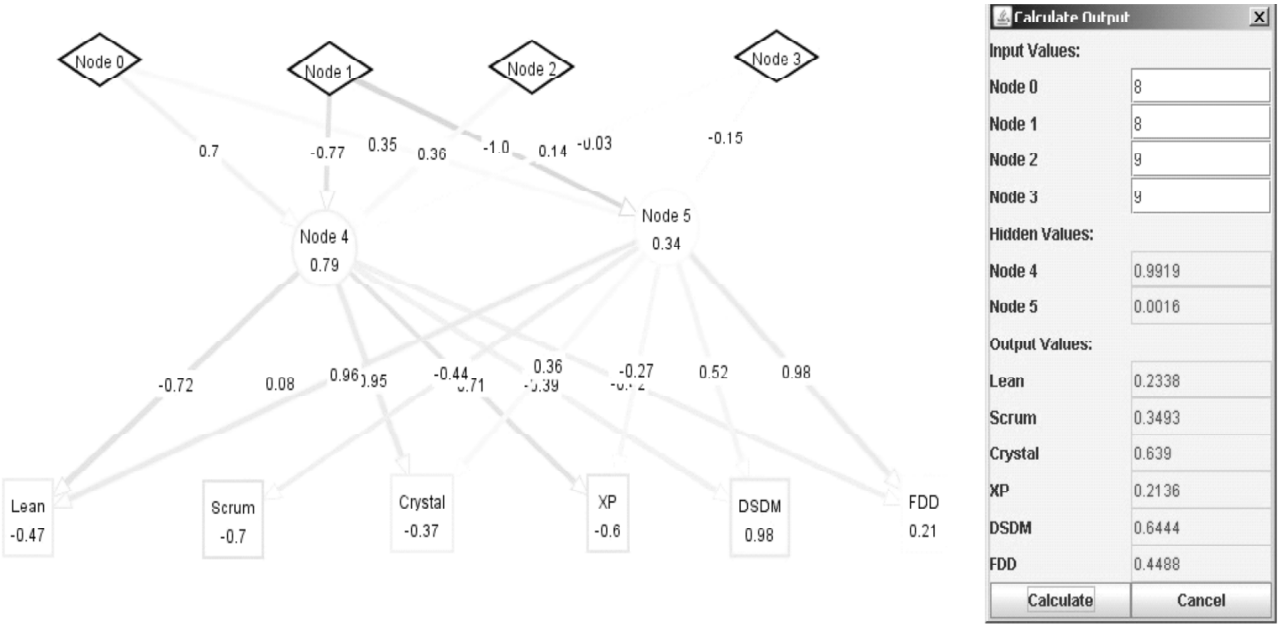

Figure 3: Trained Network producing Output for a given Input

IV. CONCLUSION

This paper provides an empirical approach to choose agile development methodology as well as the most appropriate agile method suited according to a specific project. Because of lack of any empirical work in this field, we have used globally accepted and tested methods like fuzzy AHP and Artificial Neural Network, so as to produce more authentic and reliable results. As there were no metrics defined to measure the agility for this purpose so far thus we have introduced the global and local agility indicators. The fuzzy AHP is used to deal with the inability of AHP to deal with the subjectiveness in the pair wise comparison process. In order to compensate the decision maker's uncertainty, it takes into account a range of values instead of a single crisp value. Further Artificial Neural Network with back propagation approach is used to train the network and producing correct results even for inconsistent input. By taking such a systematic approach for development, it inherently addresses the major concern of security on projects using agile approach.

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