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Limitations of the Analytic Hierarchy Process Technique with Respect to Geographically Distributed Stakeholders

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***Abstract*—**The selection of appropriate requirements for product releases can make a big difference in a product success. The selection of requirements is done by different requirements prioritization techniques. These techniques are based on pre-defined and systematic steps to calculate the requirements relative weight. Prioritization is complicated by new development settings, shifting from traditional co-located development to geographically distributed development. Stakeholders, connected to a project, are distributed all over the world. These geographically distributions of stakeholders make it hard to prioritize requirements as each stakeholder have their own perception and expectations of the requirements in a software project. This paper discusses limitations of the Analytical Hierarchy Process with respect to geographically distributed stakeholders' (GDS) prioritization of requirements. This paper also provides a solution, in the form of a modified AHP, in order to prioritize requirements for GDS. We will conduct two experiments in this paper and will analyze the results in order to discuss AHP limitations with respect to GDS. The modified AHP variant is also validated in this paper.

***Keywords*—**Requirements Prioritization, Geographically Distributed Stakeholders, AHP, Modified AHP.

I. INTRODUCTION

THERE is a tremendous increase in globalization of the software industry which demands an investigation of Requirements Engineering (RE) and prioritization in multi-sites based software development organizations [1]. RE is really difficult task even if it is done locally [1]. It adds more difficulty where cross-culture stakeholders specify and demand requirements across cultural, language and time zone boundaries [1]. This paper describes the Analytical Hierarchy Process (AHP) and its applicability with respect to Geographically Distributed Stakeholders (GDS). AHP is a technique that is used for requirements prioritization. Section I.A describes background of AHP and GDS. The paper is structured as follows. Section I.B described the problem area. Related work regarding the problem area, AHP and GDS can be seen in Section I.C. The research contribution is described in Section I.D, and research design is presented in Section II. Section III provides analysis and interpretation of the results of experiments. Conclusion and future ends the paper.

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A. Background

The term GDS is used when stakeholders, which are linked to a project, are distributed. These distributions can be within same region or continent, but can also be all over the world where each stakeholder has its own perception and expectation of the requirements in a software project. Requirements prioritization is used to identify the most important requirements for a software system [1]. The big challenge is to identify the subset, from given requirements, that maximize the fulfillment of the technical constraint (availability of resources and limited development time), business aspects (financial beneficial or market strategies), and crucial stakeholder's preferences [1]. There are many studies [2, 3, 4] that have been conducted in order to analyze the role of requirements prioritization in software development. For example doing prioritization in the telecom domain (with features such as SMS, MMS, WLAN, GPRS), requirements prioritization techniques are used in order to determine which requirements (features) should be implemented in which release. Requirements prioritization makes a company able to provide software in which most desirable requirements are implemented in order to provide a good business. Sometimes software/hardware has two or three releases. It is very important to decide which requirements will be implemented in first release and which requirements will be implemented in second release? In AHP there is a single process of assigning weight to requirements and proceeds to some systematic calculation steps in order to determine the requirements prioritization. AHP is one of the prioritization techniques used to prioritize requirements, no matter if the stakeholders are located in a same region or geographically distributed.

B. Problem Area

The point of concern in this paper is; how company can develop a single product (mobile product) for whole world by keeping in mind what is needed by whom? More precisely our questions are; *why AHP in its original form cannot be used in a situation where stakeholders are geographically distributed*? And *what are the modifications required in AHP in order to prioritize requirements for GDS*? We also analyzed the results produced by modified AHP. This paper conducted an experiment in order to discuss applicability of

AHP in GDS. This paper also presents solution in the form of modified AHP which can be suitable for prioritizing requirements for GDS. Discussion about these two research questions lead us to identify those problems that can be raised within the organization, where stakeholders are geographically distributed. Modified AHP can, in future, be turned into a new requirements prioritization technique for GDS.

C. Related Work

In [7], authors discuss about AHP and its importance for decision making and describes that it has been used for resolving conflicts. It says that AHP is a quantitative method for performing decision making .But it lacks in sensitive points like identifying the exact tradeoffs and relative size of tradeoffs. In [8], authors discuss that stakeholder's satisfaction is measured by using some dimensions like stakeholder's information, expectation, complaint and trust. In [8], stakeholder's benefits and benefits in social, environment and economy are analyzed and they established a multi criteria evaluation hierarchy using AHP technique.

In [9], authors describes that software success depends on how it fits with its user needs. The whole article determined to tell the importance of stakeholder in the requirements engineering activities. Many articles have discussed variables that can effect requirements prioritization in a company. In [10], authors presented an empirical study aiming at evaluating two state-of-art tool-supported requirements prioritization. They focus on ease of use, time consumption and accuracy. In [11], authors discuss that requirements selection for distributed stakeholders are very important and difficult. This problem is become more difficult when inadequate requirement prioritization technique is used for prioritizing them. This paper also combined different prioritization techniques in order to rank priorities. In [12], authors discuss the problem raised by geographically distributed stakeholders on requirements prioritization. This article is about all the activities in requirements engineering so it does not discuss requirements prioritization in detail. In [13], author discusses socio-technical coordination with respect to GDS. The challenges faced during requirements engineering activities in the area of global software development are discussed in [12]. In [14], author discusses all the key factors that have an impact on the global software development i.e. knowledge acquisition, communication and iterative process. The author throws a light on the importance of strong interaction among the stakeholders and software development organization. In [15], authors discuss the challenges company faces when dealing with GDS. These challenges are about overall company software development process rather than requirements prioritization.

In [16], authors present their argument for drawbacks of AHP in its invariable weight system. They introduced an improved ranking approach for AHP in their paper. This approach is also validated to be applicable.

In [17], authors discuss AHP in a scenario where you need to prioritize two requirements having different weight at different time. This discussion is about knowledge assets of company against company performance. In [17], authors raised discussion regarding limitations of AHP in a practical environment. In [18] authors explain different stakeholder perceptions about the requirements and the problem rose by this situation. This paper also introduced a framework which can help coping with this situation. It also discuss that high priority of stakeholder will provide high priority to requirements generated by them. In [19], authors combined AHP technique with some other technique in order to prioritize requirements properly. This combination was not made for GDS. In [20], authors discuss the limitations of AHP properties. The success of any public project depends on its stockholder. Social and Environmental factors play a very important role in the success of project. In [14], author proposed that AHP technique are most suitable for the evaluation of the social and environmental factors and help in the decision making process. "Giving decision makers the chance of including both objective and subjective decisions in decision making process is the most significant feature of AHP [20]". The method discussed above is generally used for complex, ambiguous and unstructured problems, and based on three principles discussed in (Saaty, 2005):

II. Research Methodology and Design

Limitations of AHP with respect to GDS are explored with qualitative and quantitative methods. The solution (modified AHP) is also provided with qualitative and quantitative methods. Both questions are lead by experiments and the results are analyzed. The goal of experiment can be described as: *To analyze the AHP approach for the purpose of finding the suitable requirements selection for each releases with respect to "Geographically Distributed Stakeholders" during requirements prioritization from research point of view in the context of academia by selecting a MS student and one project manager with domain knowledge* [6].

A. Hypothesis Formulation

In this study we have two hypotheses as follows:

Null Hypothesis **H0:** AHP can be used in order to prioritize requirements with respect to GDS.

Alternate Hypothesis **H1:** AHP has some limitations with Respect to GDS and needs some modifications in order to prioritize requirements with respect to GDS. In our experiment, we have one factor GDS and two treatments AHP and modified AHP. The validity of the points/weight given to the requirements could be much improved if the stakeholders have deep knowledge about their own field(s). One solution is to have people working with segments, a segment being a petro graphical defined area and a specific market – say business users in Middle East. By that the segment people easily could share ideas and experience in two areas - technical and geographical.

B. Instrumentation

We have developed seven requirements for a mobile cell phone. First four requirements having higher priority will be implemented in first release and other will be implemented in second release. We need to prioritize requirements (features) which are as follows:

- SMS
- MMS
- Make/Receive a Call
- Torchlight
- Change Language Preferences
- Additional Battery
- WLAN

III. Analysis and Interpretation

We prioritized requirements with AHP in experiment and will analyze to check its weight with respect to GDS.

A. Descriptive Statistics

Requirements prioritization's weight in percentage has been provided in TABLE I. These weights are calculated by applying simple AHP technique on seven requirements provided in Section II.B. The source table which led to the concluded values of TABLE I have been provided in TABLE II. TABLE II has been drawn with the comparison among requirements.

TABLE I
REQUIREMENT FINAL WEIGHTS

Requirements	Weight
R1 (SMS)	17%
R2 (MMS)	13%
R3 (Make/Receive Call)	30%
R4 (Torchlight)	3%
R5 (Change Language Preference)	8%
R6 (Additional Battery)	12%
R7 (WLAN)	17%

B. Graphical Representation

Graphical representation of requirements weight (TABLE I) has been shown in **Fig. A**. As per diagram, R1, R2, R3 and R7 have higher priorities and thus should be implemented in first release. R4, R5 and R6 should be implemented in second release. Discussion about these requirements weights in Section III.C will provide justifications; why these weights cannot be applicable in the situation where stakeholders are geographically distributed.

C. Hypothesis Testing

Before we analyze and negate our Null hypothesis, we must need to discuss few things. *What are the factors involved during requirements selection in order to have maximum profit?*

TABLE II
INITIAL TABLE FOR REQUIREMENTS MANIPULATION

	R1	R2	R3	R4	R5	R6	R7
R1	1	1	0.333	7	3	3	1
R2	1	1	0.148	3	3	3	1
R3	3	7	1	7	7	7	3
R4	0.148	0.333	0.148	1	0.148	0.148	0.148
R5	0.333	0.333	0.148	7	1	0.2	0.333
R6	0.333	0.333	0.148	7	5	1	0.333
R7	1	1	0.333	7	3	3	1

These requirements selections cannot depend on some expert judgment. It also requires us to keep in mind some factors which can play a vital role for product success. There are many factors but some can be:

- Target Market
- Market's Previous Record
- Market's Current Need
- Affordability
- Competitive edge

Target market will help you to identify which market you want to target. Some products are developed for Europe and sometimes product is particularly developed for Middle East. This is also true that in other region, the same product gives you profit but there is always a target market for a product.
Market previous records help to analyze the past records of market (target market) and predict future strategy. The most important factor that can affect the success of product can be market's current need. What is the most important thing required by the market? Adding which features in product can increase the probability of success of the product. This is also important to keep track of cost of development, when you add some new features in a product. These features can increase the cost of the product and can affect the profit of product. Competitive edge cannot be ignored during product development. In order to stay in a market, you must keep an eye on your competitors. We assume that project managers and software engineers keep all above factors in mind when they are assigning weight to the requirements for its prioritization. But keeping these factors in mind does not guarantee that it will be reflected on requirements selection. User must apply these factors in form of some numerical value which can affect the weight of requirements. AHP does not deal with these attributes. AHP does not ask for any of above attributes for requirements prioritization. In this paper, we will discuss one factor '*Market Current Need*' and particularly we will discuss '*Power Breakdown Issue*'. Following is the discussion about data provided in TABLE I. and in graphical representation (Fig. A).

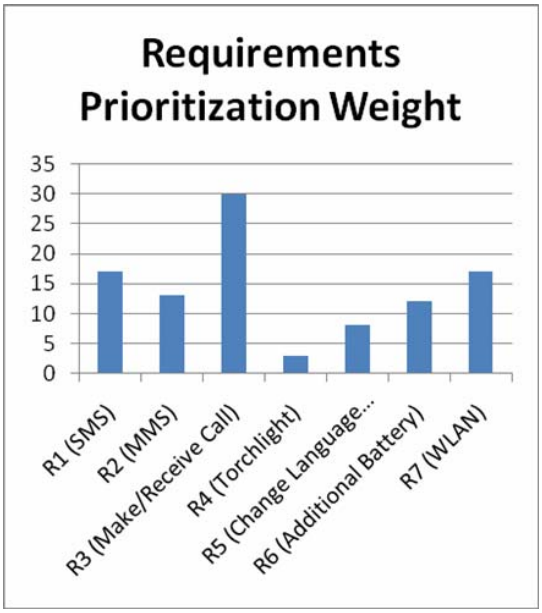

Fig. A Graphical Representation

If we just follow the requirements results provided in TABLE I and in Fig. A. We can say that R1, R2, R3 and R7 will be implemented in first release whereas R4, R5, R6 will be implemented in second release. We are considering Asia and Europe region in term of GDS. Suppose the market target in this product is Asia.

"When you have grown up in Asia or have spent a good part of your life there, power failures seem a part of life. Even if you originally came from Europe or North America, there is a tendency to forget how it was [21]." This power breakdown issue can affect the requirements prioritization. R4 (torchlight) and R6 (additional battery) can make a big difference if we include them in first release due to power breakdown issue. Torchlight (R4) feature will help people to use it in the absence of power and additional battery (R6) keep cell phone switched on even, if primary battery goes down. Additional battery is always welcomed by everyone as it provides ease to user. If we include these two requirements (R4 & R6) in first release, it will probably increase the success rate of product. Fig. B represents requirements weight that can be most suitable to a product. These weights are calculated by applying modified AHP (discussed in Section III.D) on same requirements. These weights are calculated by keeping in mind the factors, discussed in Section III.C that can affect overall product success. AHP does not deal with these factors and if the factors are ignored then it can affect the product success. There might be the possibility, that during assigning weight to requirements, organization keep in mind these factors but we have provided our motivation to measure these factors in term of number rather than memorizing it.

By looking into the difference between requirements weight (Fig. A and B), we can say that AHP should take some additional attributes, in form of numeric values, when dealing with GDS. It must add those values into final weight of requirements for appropriate requirements prioritization.

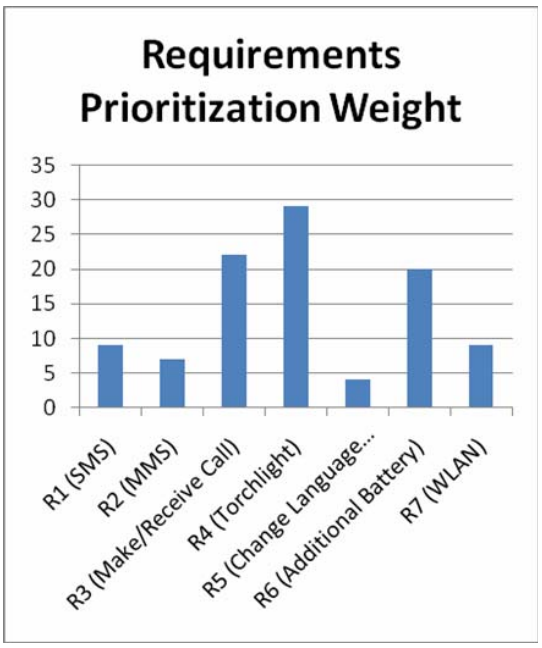

Fig. B Requirements weight that can be suitable after concerning power breakdown issue.

D.Modified AHP

Requirements can be better prioritized for GDS, if AHP consider geographical factors in its calculations. TABLE II is used for initial values of requirements just like first experiment. The next step in AHP is to start with some calculations in order to prioritize requirements. But before we proceed with next step, our solution (modified AHP) recommends additional steps at this stage. These additional steps will make AHP to prioritize requirements for GDS. The values in TABLE II will lead to final prioritizations of requirements. We recommend some changes in TABLE II. These changes will be in the values (weight of requirements). We must add some additional weight to those requirements which can increase the success of product, if added in first release. *But the question is how would we know that which requirements weight should be changed? These can be a single requirement or more than one. We recommend the systematic way to determine those requirements. Fig. C represents the steps to be followed for determining those requirements.*

Determine Target Market, as the name itself indicates, will help us to identify particular region. In geographically distribution, it is very important to have a particular market targeted. Once you have determined, which market, this product will target than you can analyze the needs of that market. This analysis can be done by the experts of the companies, surveys, or by market analysis. It is very important to be precise in particular need, for example there might be the case that when you analyze market needs, than

you end up in many needs. It is very important to choose one particular need that can be addressed by the developed product. In this paper, we discussed power breakdown issue.

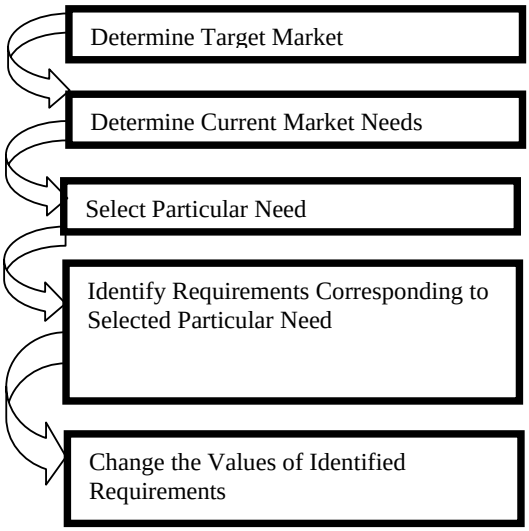

Fig. C. Systematic steps for determining the requirements

Once you have selected particular need out of available market needs, it's time to identify those requirements, which are corresponding to a particular identified need, from available set of requirements. In this paper, when we took a need/factor (power breakdown), we found two requirements very closely related to this issue, R4 (Torchlight feature) and R6 (Additional Battery feature). Now as we have identified requirements, we need to change the values of these requirements. These changes have been implemented in TABLE III.

We can see in TABLE II that the values in row 4 (R4) is in decimals. We need to change it. *Only decimal values (e.g. 2.33, 0.23) in table need to be changed. Each value, that needs to be changed, should be divided by one. Values should be changed row wise*. If identified requirement is R4, then any value in row 4 that is in decimal will be divided by one. After replacing the values, we must proceed with simple AHP steps. What we added at this stage in AHP is, *identify requirements and then replacing values of identified requirements.* Identified requirements are those requirements which are determined by following the steps, mentioned in Fig. C. we have final results in TABLE IV.

The graphical representation of these results has been showed in Fig. D. If we look at Fig. D, we can easily see that R1, R3, R4, R6 has maximum weight. We can implement these requirements into first release and R2, R5 and R7 can be implemented in second release. Modified AHP, has increased the weight of R4 (Torchlight) and R6 (Additional Battery). We have discussed the success factor of product, if we include these requirements into first release of product.

TABLE III
INITIAL TABLE FOR REQUIREMENTS MANIPULATION AFTER BEING CHANGED

	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
R1	1	1	0.333	7	3	3	1
R2	1	1	0.148	3	3	3	1
R3	3	7	1	7	7	7	3
R4	7	3	7	1	7	7	7
R5	0.333	0.333	0.148	7	1	0.2	0.333
R6	3	3	7	7	5	1	3
R7	1	1	0.333	7	3	3	1

Hence it can be seen in Fig. A, that, by applying simple AHP we ignored some factors that could affect the product success but modified AHP helps us to identify those requirements which can increase the product's success, if added in first release.

TABLE IV
FINAL RESULT AFTER MODIFIED AHP

Requirements	**Weight**
R1 (SMS)	9%
R2 (MMS)	7%
R3 (Make/Receive Call)	22%
R4 (Torchlight)	29%
R5 (Change Language Preference)	4%
R6 (Additional Battery)	20%
R7 (WLAN)	9%

IV. LIMITATIONS AND FUTURE WORK

We have applied modified AHP on available requirements and have noticed the change in weight of requirements. We noticed that modified AHP is good to prioritize requirements for GDS and help us prioritize requirements in a way that are mostly needed by regions. But it also affects the weight of other requirements. In our case, R1 (SMS) is commonly used requirement and it is important to add this requirement in first release, but modified AHP has reduced its weight. There might be the case that this requirement can have a lowest priority. We assume this as a limitation of our research. Modified AHP can affect other requirement's weight. We will look into this matter as a future work. In future, we can minimize the affect of modified AHP on other common requirements. Common means, those requirements that is confirmed to be implemented in first release. For example, in this research paper, making and receiving a call (R3) is a basic requirement and cannot be moved to second release.

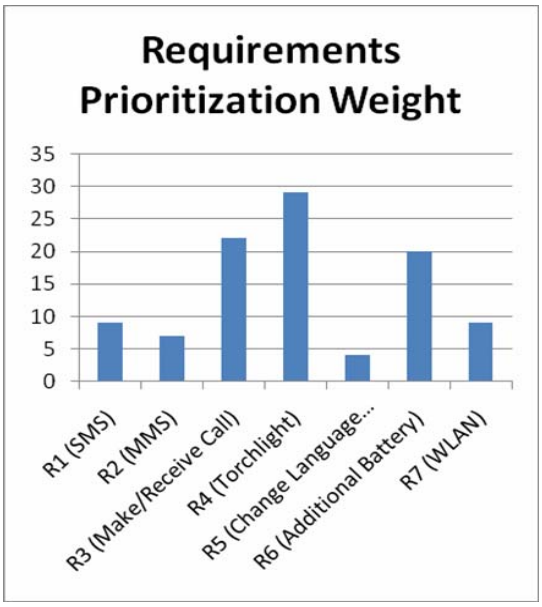

Fig. D Graphical Representation of Requirement after Applying Modified AHP

V. Conclusion

Selection of requirements for different releases has always been difficult task for organization as this selection will determine the product success. It is more difficult, when selection depends on geographical factors. Organization always makes trade-off. Sometimes one should compromise on budget or other times you make trade-off with quality or performance. But keeping in mind these trade-offs can at least help you taking wise decision in future Modified AHP helps you identify those requirements that can probably increase the product success rate. On the other hand, it also affects the weight of other requirements that must be implemented. AHP just prioritize requirements, it does not draw your attention towards success-critical factors and their corresponding requirements. Modified AHP gives us better understanding towards requirements prioritizations with respect to GDS. Now industry has been distributed geographically and SDLC needs to be re-considered with respect to GDS.

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