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Prioritizing Geographical based Communication Oriented Risks and Associated Mitigation Strategies of Global Software Development

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Abstract: The global software paradigm brings many opportunities but with some complicated challenges. The most influential drivers behind these challenges are temporal distances, socio-cultural differences and geographical distances. Due to these challenges the communication, coordination and control issues arise. These issues badly affect the quality level, cost and schedule of the project. Due to these issues the risk management process becomes more complicated as compare to traditional software engineering. In this study a frame work will be presented to quantify the relative importance of communication oriented risks and corresponding mitigation strategies. A Multi Criteria Decision Making (MCDM) approach will be employed in order to deal with conflictive, multi-criterion situations and also subjective expert judgments.

Keywords: Global Software Development; Communication oriented risk; Analytical Network Process;

I. INTRODUCTION

The new concept of software development which is termed as Global Software Development (GSD) has been used by many researchers in different ways [2, 3, 4, 5], however still it has no precise definition [7]. It always refers the concept i.e. developing software across the boundaries. References [8, 2] define it "Distributing different modules across different continents and countries in order to benefit the time zone differences, varying cost of development and different level of expertise".

The GSD unfortunately have some ambiguous status i.e. it does not focus on developing global software rather than using the global setting for software development. Therefore, it means that actors which are developing software are located globally around the world which has diverse cultures and different mindset. The team distances do not mean always the global distances e.g. when co-located team working in different locations. References [9, 10] describe the concept of distributed development which uses Geographical setting however not necessary at global scale.

The term "Globally Distributed Software Development" was used by [11, 12, 13] which was less ambiguous. This terms also some reputation during first international conference in 2006.

In the last thirty years or more, the manufacturing industry is off shoring their processes to destination of lowest costs; in 1980 a major part of software development was being sent offshore [14]. Since that India get dominancy in GSD paradigm which have huge quantity of IT expertise and English language proficiency. In 1997, it was estimated that India exports is one billion US$ in software and in 1999 the country have 200000 well trained and high-profile experts in software industry [11].

Before the birth of GSD, it was already realized by multinational companies that lower countries can be used to outsource the manufacturing process. The software industry followed this concept and used new developing countries to start development activities for capitalization purposes. This new software development paradigm has been supported by some historical factors [16].

The maintenance work related to millennium bug was sent offshore, which start new era. In this phenomenon the most outstanding parameters were cheaper labor markets and domain expertise. Organizations are more encouraged by government policies to establish software development activities in the target country [19].

The nature of GSD makes the risks identification process more complex because project manager has limited or no knowledge about the expected risks sets [13]. The inherited three most important factors of GSD i.e. Temporal Distance, Geographical Distance and Socio-Culture Distance disputed the benefits. Further these factors may complicate the process of coordination, communication and control which are three most critical parameters of software development projects. Pervasiveness of numerous challenges in GSD makes it a risky venture and more challenging [3, 10, 15].

In GSD setting the project management concepts like face to face communication, monitoring and controlling the project progress, building trust among developers and other different stack holders become more challenging due to distance involved [15][18]. To tailoring the conventional

project management concepts to GSD domain, need proper understanding of the GSD nature, the techniques and procedure reported by research. So, the risk management can be characterized in unique fashion in case of GSD domain [1, 13].

GSD needs a more innovative structure as compare to conventional development and especially for risk management during the whole development process [18]. There is a need of mapping between risk management and different levels of management like operational, tactical and strategic levels. At tactical and strategic level, risk management model the mostly decision-making parameters however at operational level it includes development processes as well [17]. GSD have now well-established position and have proper department in major world software development companies [20]. The pressure to distribute more and more work is increasing gradually due to new global markets emergence. In future GSD will sustain this prominent position due to probable situation of new parameters [21]. India will play a key role in ruling this paradigm [22]. GSD is development paradigm which is working in distributed environment. This paradigm inherits the conventional processes like coordination, communication and control [23, 32, 33]. However, as distance factor involved like temporal, socio-culture and geographical risks therefore executing the above mentioned processes become more challenging. There is need of research to explore new mitigation strategies to mitigate these emerging risks.

This issue was the main theme of international Workshop on Global Software Development and, more recently, the International Conference on Global Software Engineering have studied the distance and their effects during distributed context [25, 4, 10].

In GSD the term of "global" can be explained as using separate countries, continents and time zones for software development, while distributed aspect of GSD mostly considered the geographical distance. Research shows that most of the cores concepts of GSD are related to socio-culture distance risks specially culture and language differences. These culture differences may vary the interpretation and responses to various situations of different team members which belongs to different cultures and having different social values and varying practices for executing different tasks [34]. Another distance which is termed as socio-culture distance risks which have different time zone parameters.

The rest of the paper is organized as follows: Section II gave literature report which analyzes the problem area from different angles. Section III gave research methods which justify the selection of specific research method for the problem at hand. Section VI gave the proposed frame work and Section V presents the discussion on generated results.

II. LITERATURE REVIEW

In this section, we briefly describe the related work on prioritizing the communication oriented risks of Global software development. The literature survey reports different parameters which are used to describe the given problem. This survey identifies different angles to analyze the problem at hand. GSD (Global Software Development) is very active research area in these days whose main objective is to covert the natural processes in to business objectives. The main drivers behind the research in this paradigm is to analyze other areas like social sciences, economics and management sciences etc and discover new theories and study its feasibility in GSD.

A. Communication and Geographical Distance

The main objective of software development project is to produce qualitative product according to user requirements. The factor of quality depends on the best designs which can be achieved through establishing proper communication and coordination among different stack holders. Now GSD makes this communication and coordination more complicated due to distance involved. The distance may geographical, socio-culture or temporal. The following parameters are used to characterize the communication process:

1) Proximity to market/customer: The establishment of subsidiaries in different countries of the world where company have their valuable customers, the GSD paradigm gave the opportunity to understand their customers by getting much of the local market by close observation [18]. The distributed development allows the teams to be located in different part of the world [39]. The diverse allocation can allow increasing your local market knowledge and their local conditions which further enhance requirements elicitation process [40].Companies are continuously searching and looking for strategic partnerships with other organizations in order to get access to new emerging markets but local government enforces these organizations to locate some of the development activities in the target market for participation and their local people skills development [19].

2) Improved focus on documentation: In distributed teams, there is more focus on documentation in order to support their communication process. Written documentation is not adequate during resolving misunderstanding such as ambiguities and misunderstanding during requirements and designs etc. [5]. If there is uncertainty then failure may be faced. Geographically dispersed agents have more obstacles and difficulties in tem of effort and severity into formal documentation and processes in improving team communication [10]. Literature reports that this concept can benefit GSD because the increased focus on documentation can improve the development process.

3) Lack of informal and face-to-face communication: Literature reveals that lack of face to face communication is major resistive component of the GSD paradigm development. Informal communication is one of the best characteristics of collocated team development, which is takes place during tea, over meal before and after formal

meetings [20]. The process of face to face communication provides natural flow and sequence of communication which throughout support the software development process. Carmel [11] identified the core and a fundamental force which pullsglobally dispersed teams, in which loss of communication is one force which is severe threat to the integrity of software teams. Misunderstanding can be resulted during design conventions due to breakthrough in informal communication. There is need face to face meeting and communication to overcome these misunderstanding in requirements. Kraut and Streeter [49] found that lack of face to face communication is more pronounced during early software development phases.

4) Increased effort to initiate contact: To initiate contact in case of geographical dispersed teams, there is increase effort required due to obstacles in communication [51]. If the status of remote colleague is not clear i.e. either he is on desk or not then there is lost in opportunistic interaction. In a co-located setting, a team member could simply glance over at their colleague's desk to ascertain their level of availability [51].Kotlarsky et al. (2008c)[52] uses a knowledge base model for analyzing the coordination, considering the cross site coordination in term of knowledge processes. Who knows what concept can be more useful during interaction with remote and diverse team members.Oshri et al. (2008)[53] termed this type of knowledge as transitive memory. This type of concept can be arises from social interaction.

5) Cost of Travel: Some time and particularly during early phases of projects, establishing face to face meeting with remote colleagues is vital. In Global Software Paradigm, travelling to the remote site in order to know their colleagues, exchange some important ideas with them and overlapping linguistic and cultural barriers [54]. But such type of travelling are time consuming activities and have cost more, because amount of time consumed is much greater than flight time alone.

6) Dependency on information and communication technologies: GSD is communication and coordination oriented activity with the distance as an extra factor. When there is communication gap amount team members then nearly it become impossible to validate and create design solutions and do affective management of team deliverables. There are different technologies used in GSD like telephone, email, telephone and video conferencing, instant messaging and mailing list.

7) Providing technical infrastructure: During software design in global context, third party tools can be used for which their support is mandatory. In different countries, different vendors offer different versions, hindering the provision of a technical infrastructure. For example, the latest version of tools was made available in the US, with older versions still being offered in other countries. Trust model like PGP (Pretty Good Privacy) can be used for security of communication links. The communication quality infrastructure in India still has negative effect on business process.

B. Analytic Network Process (ANP)

The Analytic Network Process (ANP) is one of the most important methodology of the MCDM family. This theory used to obtain relative ranking of the absolute numbers from human individual judgment. These judgments provides the inter comparison of criteria and determine their relative importance.

The super matrix, which is an important component of the ANP approach, consists of other matrices of column priorities. The ANP model the feedback and dependence view between clusters of elements [43]. AHP (Analytic Hierarchy Process) is special case of the ANP which is based on independent assumptions between upper levels and lower levels and independency among elements of the same level. The ANP is power full tool to articulate decision problem comparisons and super matrix. The ambiguity in decision making problem can be modeled using pair wise comparisons Saaty[44]. Let we consider a set of criteria of different and independent nature i.e. *(C1, C2…Cn)* and having corresponding weights *(W1, W2...Wn)* respectively. The decision maker does not know the values in advance, but he is capable of doing pair wise comparisons.

At the completion of pairwise comparison, the Eigen vector (w) can be calculated using relation $Aw = \lambda_{max} w$ Where λ_{max} is the largest Eigen-value of matrix *A*.

The normalization process occurs of all obtain priority vectors to get local priority vectors. Then super matrix can be designed by doing entry of appropriate columns in order to obtain global prioritizations. In order to calculate the overall priorities, the limit matrix can be raised to limit powers. Table I represent the generalized super matrix which model a system of N clusters, where W_{21} is a vector that represents the impact of the goal on the criteria, W_{22} is a matrix that represents the interdependence of the criteria, W_{32} is matrix that represents the impact of the criteria on each of the alternatives, and I is the identity matrix, andW_{34} is matrix that refers to the impact of the sub-criterion on each of the alternatives.

TABLE I. Generalized Super Matrix 1

	Goal	**Criteria**	**Alternative**
Goal	0	0	1
Criteria	*W*21	*W*22	0
Alternative	0	*W*32	1

III. ALGORITHM

There are four steps used in ANP approach [44]

*Step 1: construction of model and structuring of problem***:** The problem must be clearly specified and decompose into rational system in the form of network.

Step 2: Pair wise comparisons and priority vectors: A control criterion is used to compare the decision elements at each cluster level. The concept of control criteria is very important concept in ANP approach. The Eigen vector is used to represent the influence e of one element over other. Saaty's scale can be used to determine the relative importance.

Step 3: Super matrix formation: The Markov chain process and super matrix designing are similar concepts. Global priority with independent influence can be obtained by entering local priority vectors in appropriate columns of matrix. In super matrix, each matrix represents the cluster relationship with in clusters.

Step 4: Synthesis of the criteria and alternatives' priorities and selection of the best alternatives: The priority weights of the criteria and alternatives can be found in the normalized super matrix.

$$A = [a_{ij}] = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \end{array}$$

where $a_{ii} = 1$ and $a_{ji} = 1/a_{ij}, (i, j = 1, 2, \ldots, n)$.

Figure 1. Super Matrix [44]

A. Communication Oriented Distance Risks

The Global market is extremely competitive, so its need most mature risk management process in organization to design development process in detail and the culture. In GSD projects, geographical distance are often characterize the distributed stack holders. But there are always challenges with opportunities. The nature of software development is depends mainly on communication and coordination and these two factors are badly affected by distance involved in GSD.

Following are Communication Distance risks surveyed from literature as shown in Figure 1. and Figure 2. Geographical risks are also listed below:

- *Lack of team cohesiveness*
- *Communication effort overhead*
- *Lack of Trust*
- *Limited face-to-face meeting*
- *Reduced communication richness or quality*
- *Reduced possibility of informal communication*
- *Extra travelling cost*
- *Restricted inter-personal relationship build-up*
- *Data loss during transfer*
- *Reduced communication frequency*

B. Associated Mitigation Strategies

To achieve some strategic objectives, most of the organizations are trying to enter this paradigm but these organizations have complete strategy for handling the inherited issues in GSD. There must be clear and mature risk management plan within each organization. The literature reports different strategies for mitigation of different types of risks. The following is list of corresponding mitigation strategies reported for geographical risks:

- *Frequent travel*
- *Implement communication model*
- *Use groupware application*
- *Promote frequent communication*
- *Use rich communication media*

C. Proposed Framework

The output of this study will be a decision making framework which assists project managers.

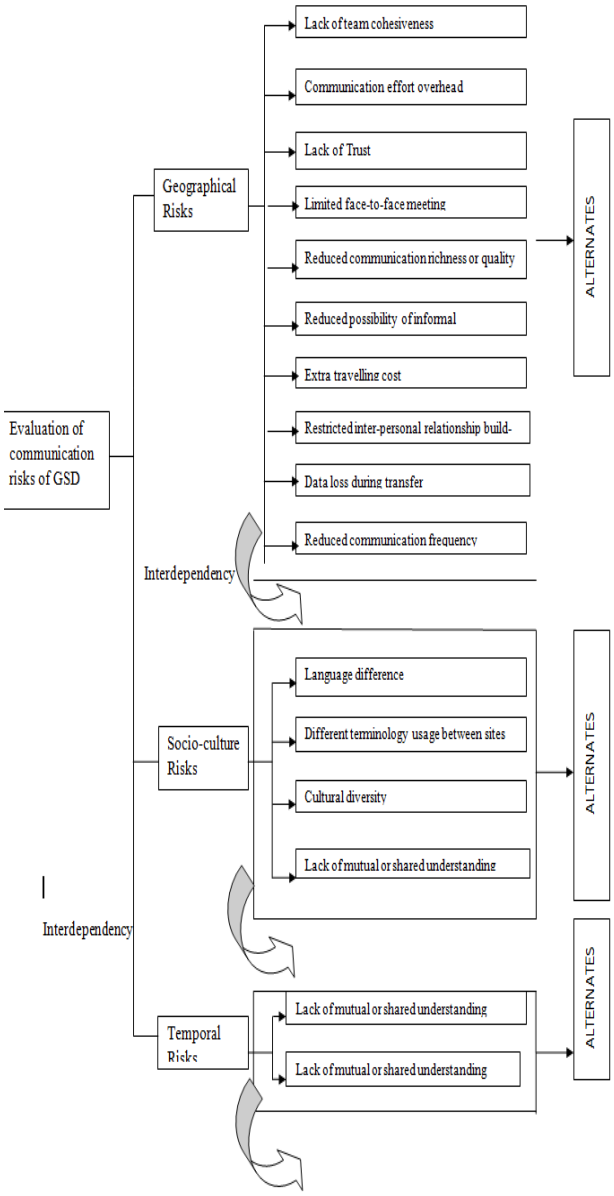

Figure 2. Framework for ANP

IV. ANP ALGORITHM IMPLEMENTATION

Following are the steps according to the algorithm of ANP as shown in the following Tables.

Similarly, we can do pairwise comparison with respect to Communication effort overhead, Lack of Trust, Limited face-to-face meeting, reduced communication richness or quality, reduced possibility of informal communication,

TABLE II. Pairwise comparison of Geographical risks

Risks	**Lack of team cohesiveness**	**Communication effort overhead**	**Lack of Trust**	**Limited face-to-face meeting**	**Reduced communication richness or quality**	**Reduced possibility of informal communication**	**Extra travelling cost**	**Restricted inter-personal relationship build-up**	**Data loss during transfer**	**Reduced communication frequency**	**E.V**
Lack of team cohesiveness	1	2.6	4	5	7	9	9	9	9	9	32.27%
Communication effort overhead	.385	1	1.7	3	5	7	9	9	9	9	21.85%
Lack of Trust	.25	.588	1	1.3	3	5	7	9	9	9	14.99%
Limited face-to-face meeting	.2	.3	.769	1	1.3	3.5	6	7	9	9	10.64%
Reduced communication richness or quality	.143	.2	.333	.769	1	1.7	5	6	7	9	7.65%
Reduced possibility of informal communication	.111	.143	.2	.286	.588	1	2.6	5	5	8	5.24%
Extra travelling cost	.111	.111	.143	.167	.2	.385	1	1.4	3	5	2.61%
Restricted inter-personal relationship build-up	.111	.111	.111	.143	.167	.2	.714	1	1.3	3	1.95%
Data loss during transfer	.111	.111	.111	.111	.143	.2	.333	.769	1	1.2	1.51%
Reduced communication frequency	.111	.111	.111	.111	.111	.125	.2	.333	.833	1	1.30%

TABLE III. Level of Mitigation of each Strategy w.r.t. Geographical risks

Risks	Lack of team cohesiveness	Communication effort overhead	Lack of Trust	Limited face-to-face meeting	Reduced communication richness or quality	Reduced possibility of informal communication	Extra travelling cost	Restricted inter-personal	Data loss during	Reduced communication
Frequent travel	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0000	1.0000
Implement communication model	0.784	0.800	0.775	0.293	0.781	1.000	0.449	1.000	1.0000	0.6005
Use groupware application	0.360	0.229	0.341	0.229	0.285	1.000	0.374	0.223	0.3452	0.2424
Promote frequent communication	0.271	0.178	0.263	0.139	0.285	1.000	0.104	0.096	0.2542	0.2424
Use rich communication media	0.094	0.096	0.134	0.105	0.066	0.333	0.086	0.096	0.0986	0.0618

TABLE IV. With respect to Lack of Team Cohesiveness

Risks	Communication effort overhead	Lack of Trust	Limited face-to-face meeting	Reduced communication richness or quality	Reduced possibility of informal communication	Extra travelling cost	Restricted inter-personal relationship build-up	Data loss during transfer	Reduced communication frequency
Communication effort overhead	1	1.7	3	5	7	9	9	9	9
Lack of Trust	0.588	1	1.3	3	5	7	9	9	9
Limited face-to-face meeting	0.333	0.77	1	1.3	3.5	6	7	9	9
Reduced communication richness or quality	0.2	0.33	0.77	1	1.7	5	6	7	9
Reduced possibility of informal communication	0.143	0.2	0.286	0.59	1	2.6	5	5	8
Extra travelling cost	0.111	0.14	0.17	0.2	0.385	1	1.4	3	5
Restricted inter-personal relationship build-up	0.111	0.11	0.14	0.17	0.2	0.7	1	1.3	3
Data loss during transfer	0.111	0.111	0.11	0.14	0.2	0.3	0.77	1	1.2
Reduced communication frequency	0.111	0.111	0.11	0.11	0.125	0.2	0.33	0.8	1

Extra travelling cost, and restricted inter-personal relationship build-up, Data loss during transfer and Reduced communication frequency.

We can also do pairwise comparisons for Alternatives as they inter depends upon each other's like with respect to Frequent travel, implement communication model, Use groupware application, promote frequent communication and Use rich communication media.

According to algorithm after pairwise comparisons, we can get Limit super matrix to get final priorities.

V. RESULTS AND DISCUSSION

To answer the problem (research question), we need a systematic research approach. This section provides detail analysis of result related to reported risks and their corresponding mitigation strategies. MCDM tools have been used extensively to produce results in order to reduce much human intervention work. Pair wise comparison of reported risk is used to determine their relative impact used the expert judgment approach. TABLE II provides the pair wise comparisons of the reported Geographical risks during communication in GSD projects. This pair wise comparison gave relative impact of the individual risks based on the expert opinion which is further based on their personal judgment and experience. After the pair wise comparison, ANP algorithm is used to in order to identify the pair wise comparisons among the rest of factors. According to ANP there are fourteen control criteria used to do pair wise comparison among other criteria. TABLE III shows 6 different mitigation strategies with respect to geographical risk. These mitigation strategies are prioritized by applying ANP algorithm. ANP considers the inner and outer dependence among the factor within the clusters and out of clusters. Different control criteria are defined for the geographical risks in GSD. *Team Cohesiveness* is defined

one of the control criteria for the decision making. TABLE IV shows the impact of all geographical risks with respect to the lack of *team cohesiveness.* TABLE V represents the limit matrix where some of alternatives are also defined and one-to-one limits are provided among the different geographical risks. After the defining limits matrix between different control criteria, priorities are assigned to different geographical risks with respect to their calculated risks and presented in TABLE VI. It shows that the *lack of team cohesiveness* risk has high related weight leads to give high priority. TABLE VII presents the mitigation strategy with respect to their priorities.

VI. CONCLUSION

Our evaluation found that ANP is the most promising method among the available prioritizations methods as shown in Table II to Table VIII. ANP deals with interdependent requirements to prioritize. ANP produces most reliable results which are based on ratio scale. ANP is fault tolerant. ANP includes consistency check. AHP also includes these features but AHP fails to calculate the priority of interdependent requirements. Karlsson et al have suggested AHP as the best method, ANP is completely based on AHP but the only difference is that it calculates the priority of interdependent criteria's. ANP calculates better priority than AHP. While doing risk mitigation through ANP, the participants will clearly and completely understand the criteria first. They will know the relationship among the criteria's and alternatives, under which these risk mitigations will be prioritized. So the system will be clear to the participants and can easily and effectively calculate the priority of the risks for GSD. ANP has better procedure to calculate the priority than AHP. To produce the better results, ANP needs greater comparisons than AHP, this is problematic when the project becomes large. So tool support is needed to overcome this problem. Although ANP required greater number of decisions to complete the prioritizations process, hence process of ANP to prioritize requirements is complex. But it provides reliable and fault tolerance results.

TABLE V. Limit Matrix

	Lack of team cohesiveness	**Communication effort overhead**	**Lack of trust**	**Limited face to face meeting**	**Reduce communication richness or quality**	**Reduce possibility of informal communication**	**Extras travelling cost**	**Restricted inter-personal relationship build-up**	**Data loss during transfer**	**Reduced communication frequency**	**Frequent travel**	**Implement communication model**	**Use groupware application**	**Promote frequent communication**	**Use rich communication media**
	Geographical Risks										**Alternates**				
Lack of team cohesiveness	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Communication effort overhead	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Lack of trust	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Limited face to face meeting	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Reduce communication richness or quality	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Reduce possibility of informal communication	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Extras travelling cost	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Restricted inter-personal relationship build-up	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Data loss during transfer	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Reduced communication frequency	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Frequent travel	0.16	0.16	0.167	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Implement communication model	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Use groupware application	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Promote frequent communication	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Use rich communication media	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

TABLE VI. Prioritize Order of Geographical Risks

S.no	Risk	Relative weight
1	Lack of team cohesiveness	0.136
2	Communication effort overhead	0.105
3	Lack of trust	0.078
4	Limited face to face meeting	0.061
5	Reduce communication richness or quality	0.045
6	Reduce possibility of informal communication	0.031
7	Extras travelling cost	0.016
8	Restricted inter-personal relationship build-up	0.011
9	Data loss during transfer	0.009
10	Reduced communication frequency	0.007

TABLE VII. Prioritize form of Geographical risks Mitigation Strategies

S.No	Mitigation strategies	Relative weight
1	Frequent travel	0.167
2	Implement communication model	0.023
3	Use groupware application	0.079
4	Promote frequent communication	0.055
5	Use rich communication media	0.176

Complexity can be overcome with the development of tool for ANP.

It is identified from the studies that some more work is needed in the area of requirement prioritization to improve the performance of ANP. Requirements in industry. Also, there is a need of development of easy to use tool for ANP.

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