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Identification and Prioritization of Cloud based Global Software Development Best Practices

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ABSTRACT The cloud based global software development (CGSD) is the most widely adopted development paradigm in software industry. The CGSD offers significant economic and strategic benefits; besides, various complexities are faced by the practitioners while deploying CGSD. Hence, this study aims to identify and prioritize the best practices that are important for the success and progression of CGSD paradigm. Using the systematic literature review a total of 30 best practices were identified and were further verified with industry experts using questionnaire survey study. The identified best practices were further prioritize using fuzzy-AHP approach. The fuzzy-AHP is novel in this domain as it successfully applied in other engineering domain to address the multicriteria decision making problems. The findings of this study will provide a prioritization-based taxonomy of the investigated best practices which assists the academic researchers and industry experts to develop and revise the strategies of CGSD.

INDEX TERMS Cloud based global software development (CGSD), Best practices, Fuzzy-AHP

I. INTRODUCTION

To produce the quality projects with low cost, the software organizations are motivated in transforming their development activities from collocated to global software development paradigm. Dhar [1] underlined that the software outsourcing includes allocation or transformation of development activities, management of development process, decision of management and services across the geographical boarder. With the aim to improve the development activities, various development approaches and platforms were developed. Therefore, the cloud computing (CC) is the most recent environment that assist the offshore software development paradigm.

The software organizations widely consider the cloud based global software development (CGSD) paradigm to perform their development tasks beyond the geographical and cultural boarder. The CGSD paradigm provides the dynamic, scalability and availability of distributed resources [2]. The CC provides the services like software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS) that motivates majority of software organizations to deploy the cloud services for CGSD. Though, the CGSD offers the software development organizations to share and access the geographically distributed IT resources and applications [3, 4]. CGSD reformed the business of software engineering industry.

The CGSD paradigm, the organizations working as clients transformed the development activities to vendor organizations for the development of quality projects within time limits and budgets [5]. Niazi et al. [6] mention that "the software organizations of developed countries outsource their development activities to the organizations of developing countries as the development cost is one third less in developing countries as compare to developed countries". Moreover, Ramasubbu [7] mention that CGSD paradigm assists to hire the skilled labor with low cost from developing countries. Furthermore, Niazi et al. [8] argued that CGSD paradigm assists to reduce the development time by arranging the development activities around the globe with respect to the time zone differences.

Besides the significant gains, the management of development activities across the geographical distributed environment is complicated as it causes issues like communication, coordination and control. [1, 9]. The geographical and cultural differences between the clients and vendor organizations causes serious problems e.g. time zone differences, lack of frequent and effective communication, and lack of trust and confidence [10-12]. Kaiser et al. [13] highlighted that the hidden cost causes the budget overrun due to which organization leads towards project failure.

Despite the CGSD importance in software industry, there is limited research available to resolve the problems of CGSD practitioners in global environment. Though, considering the importance of CGSD in software industry, we motivated to empirical explore the best practices that could assists the real-world practitioners for the successful adoption of CGSD paradigm. The study objectives include: (1) to identify the best practices of CGSD reported in the literature and in real-world practices; (2) prioritization of the investigated best practices concerning to their importance for CGSD paradigm. We are confident that the in-depth analysis of CGSD best practices will assist the academic researchers and industry experts to develop the new and effective techniques for the successful execution of CGSD activities. Though, to address the study aims, the developed research questions (RQ) are as follows:

[RQ1]: What best practices of CGSD are reported in the literature and industry practices?
[RQ2]: How to rank the investigated best practices with respect to their significance for CGSD paradigm?
[RQ3]: What would be the prioritization-based taxonomy of investigated best practices?

II. BACKGROUND AND MOTIVATION

The CC offer the CGSD firms to access the shared IT resources and applications[14-16].The most important CC services include: “on-demand self-service”, “virtualization”, “management of IT resources ”, “available over internet”, and “charged on a pay-per use basis”[4]. Moreover, CC offers SaaS, PaaS and IaaS and different types of cloud networks i.e. private, public, hybrid, community models [17]. The services of CC can be access remotely via internet which are managed and own by the service provider organization [4, 17]. The virtual availability of CC services provides the opportunity to software organizations to start their CGSD with low capital investment [18].The public cloud is operated and management by the services provider (external body) to facilitate the general public via internet [18]. Besides, the private cloud is operated and won by an organization to assist their own distributed practitioners (sites) [17]. The private cloud is secure and there is very little threat towards the data security. In hybrid CC the organizations save their data on private cloud and public CC is used for other types of services [4, 17].

The business gains always the priority of every software firm and if the economic benefitsoffer along with additional opportunity like skilled human resources, low time, quality work andupdated technological tools etc. the organization consider such paradigm for log time [6, 11, 19]. Hence, the CGSD paradigm provides the environment for software organizations to conduct development activities across the globe aiming high quality product development reducing time and cost.[20, 21]. In CGSD, the adjustment of development activities with respect to the time zone, significantly impact to reduce the development time [22]. Espino et al.[10]also highlighted that the CGSD provides the opportunity to keep in touch with global market quality and trend.

The global software development paradigm is adopted in software industry since last two decade, but the CGSD paradigm is still not mature enough. We found some studies conducted to highlight the problem of CGSD. Such as, a UK based study was conducted by Oza et al.[23] to address the relationship of CGSD practitioners. They conducted empirical study with Indian client organizations and the vendor organization of USA and European organizations. They reported that the good and cooperative relationship among client and vendor firms is critical for the successful execution of CGSD practices. We further identified the Nguyen et al.[24]study with the vendor organizations of Vietnam and client organizations of European and American countries. Similarly, Sabherwal [25] conducted an empirical study and reported the role of trust in CGSD environment. Raj-Kumar and Dawley[26]reported the critical risks of CGSD between Indian and US software organizations. The CGSD practitioners also faced various challenges that make the development activities more complicated. For example, Bohm et al.[2] and Chang et al.[27] reported the challenge “lack of frequent communication and coordination” between the CGSD practices. Dey et al.[28]argues that the activities of CGSD are more communication and coordination oriented and there is physical meetings which cause issues like weak communication and coordination among team members

Besides the importance of CGSD in current era, limited studies are available that explore and fix the complexities of CGSD paradigm. Though, this research aims to explore the best practices of CGSD reported in the literature and in real-world practices; and prioritize them with respect to them critically for CGSD organizations. The study findings will deliver the prioritization-based taxonomy of the CGSD best practices that help industry practitioners to improve and develop the new approaches for CGSD.

III. RESEARCH DESIGN

This study aims to identify and prioritize the best practices of CGSD paradigm. To answer the study RQs, we adopted following approaches.

- Systematic literature review
- Questionnaire survey approach
- Fuzzy-AHP

All these research approaches are demographically shown in Figure 1, and describe in the following sections:

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A. Systematic literature review (SLR)

An SLR was considered to collect the most related literature according to the need study RQs. SLR is a systematic process to collect the most potential literature related with RQs. SLR provides the opportunity to explore, verify, analyses and synthesis the data from the existing literature[29]. The results of SLR study is less biased and thorough as compare to informal literature[30]. Various existing studies of other software engineering domain adopted the SLR approach [6, 8, 31,32]. By following the guidelines of Kitchenham and Charters[30], we have performed the all the steps of SLR. The adopted SLR protocols are enlisted in Figure 1 and each step explained in the sub-sequent sections

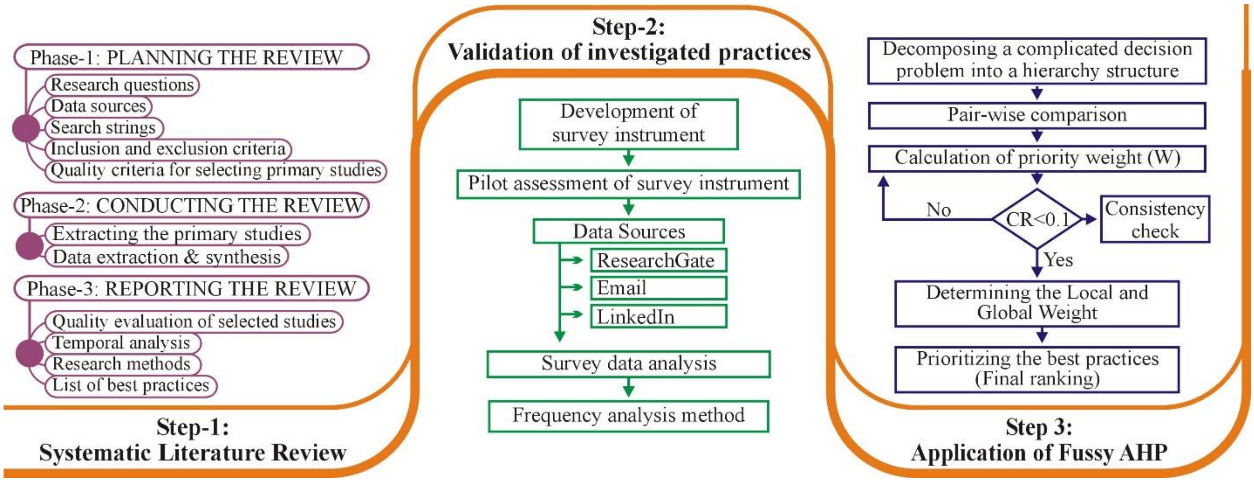

Figure 1: The Adopted set of research methodologies

(1) Planning the review

Research questions

The goal of SLR study is to investigate and analysis the best practices of CGSD reported in the literature. Therefore, the developed research question is RQ1 which is presented in section 1.

Data collection source

For the collection of most related data related to study objectives, the selection of most appropriate digital repositories is significant. Though, we have considered the instruction of Zheng et al.[33]andChen et al.[34] and the following repositories were selected:

- IEEE Xplore (http://ieeexplore.ieee.org)
- ACM Digital Library (http://dl.acm.org)
- Springer Link (http://link.springer.com)
- Wiley Inter-Science (www.wiley.com)
- Science Direct (http://www.sciencedirect.com)
- Google Scholar (http://scholar.google.com)
- IET Software (https://digital-library.theiet.org)

Search string

An appropriate search string plays an important role to explore the most related and potential literature related to the research questions of the study [33]. Therefore, we have used the guidelines of Quasi-Gold Standard (QGS) [35] to collect the key terms and their respective substitutes from the 5 studies i.e. [SS1, SS2, SS3, SS4, SS5]. The Boolean operator "AND" and "OR" were used to concatenate the collected key-terms (Table 1).

Table 1: Components of search string

Related topics	Search elements
ST1 (Intervention)	"practices" OR "Tools" OR "methods" OR "techniques" OR "processes" OR "programs" OR "approaches" OR framework" OR "guidelines"
ST2 (Intervention)	("IaaS" OR "PaaS" OR "SaaS" OR "XaaS" OR "Infrastructure as a Service" OR "Platform as a Service" OR "Software as a Service" OR "IT service" OR "Application Service" OR "ASP").
ST3 (Population)	"global software development" OR "GSD" OR "distributed software development" OR "offshore software development" OR "outsourcing" OR "Multisite software development" OR "global software teams" OR "collaborative software development" OR "collaborative software engineering"
ST4 (Experimental)	("grounded theory", "interviews" "case studies", "questionnaire survey", "theoretical studies", "content analyses", "action research").
Complete search string = (ST1) AND (ST2) AND (ST3) AND (ST4)	

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Initial inclusion and exclusion criteria

We have developed the inclusion criteria's to initially refine the selected studies considering the study RQs. To develop the criteria, we have used the instruction of Kitchenham and Charters[30]and the existing studies of Niazi et al.[6] and Inayat et al.[36].

- The collected literature should be published as a conference paper, journal articles or book chapters.
- The selected literature should elaborate the best practices of CGSD paradigm.
- The findings of the selected literature should be based on empirical investigations.
- The selected articles or book chapter should provide the detailed description of CGSD paradigm.

Moreover, we developed the exclusion criteria considering the existing studies of Niazi et al.[6] and Inayat et al.[36] and Akbar et al.[32].

- The studies do not provide the detail discussion of CGSD best practices.
- The content of the extracted data not in English language.
- The article having less than 6 pages were not entertained.
- If research article is from same research group or project, the most recent and completed version was entertained.

Study quality Assessment (SQA)

Quality of the selected literature was assessed aiming to determine the worth of selected literature with respect to the study objective. To do this, the quality assessment criteria was developed using the instruction of Kitchemhm and Charctros[30] and by following the studies published in other domains of software engineering [5, 8, 37]. The list of quality assessment criteria's checklist and the considered Likert scale is presented in Table 2.

Table 2: SQA criterion

QA Questions	Checklist	Likert scale
QA1	Does the selected study explore CGSD best practices?	Yes=1, Partial=0.5, NO=0
QA2	Does the results and analysis of the study related with proposed RQs?	Yes=1, Partial=0.5, NO=0
QA3	Does the findings of selected study based primary data?	Yes=1, Partial=0.5, NO=0
QA4	Is any CGSD standard or framework has been discussed in the selected primary study?	Yes=1, Partial=0.5, NO=0
QA5	Does the best practices are explicitly discussed?	Yes=1, Partial=0.5, NO=0

(2) Conducting the review

Final study selection

To address the RQs of this study, the literature was selected via three different approaches. Firstly, we have considered the guidelines of QGS [35] and 5 papers were selected. Secondly, by carefully executing the search string (section *3.1.3*) 520 papers were collected. The collected literature was further purify by applying the tollgate technique introduced by Afzal et al.[38]. By carefully applying tollgate approach steps, finally 54 were selected for data collection process. At third step, we have performed the backward and forward snowballing considering the cited references in the paper and the references in which a selected paper is cited. Using the snowballing technique, 47 papers were extracted and by applying the tollgate approach, finally 12 studies were considering from Phase-3 (snowballing, Figure 2). Though, as presented in Figure 2, Finally 71 studies were considering for data extraction process. All the selected studies were labeled as "SS" to indicate their use in this paper. The final list of SLR studies is presented in Appendix-A.

Data extraction and synthesis

The final selected studies were considered in data extract process. First three authors of this study participated in article reviewing and data extraction process. The data extraction team, continuously reviewed the data from the selected studies. Author no. 4 and 5 arbitrary involved and validate data extraction process.

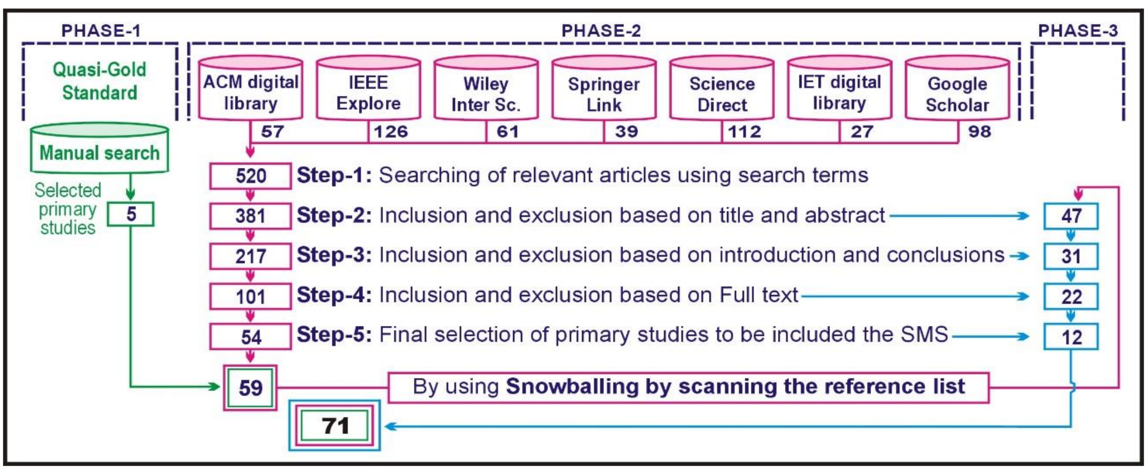

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Figure 2: Final refinement of formal studies

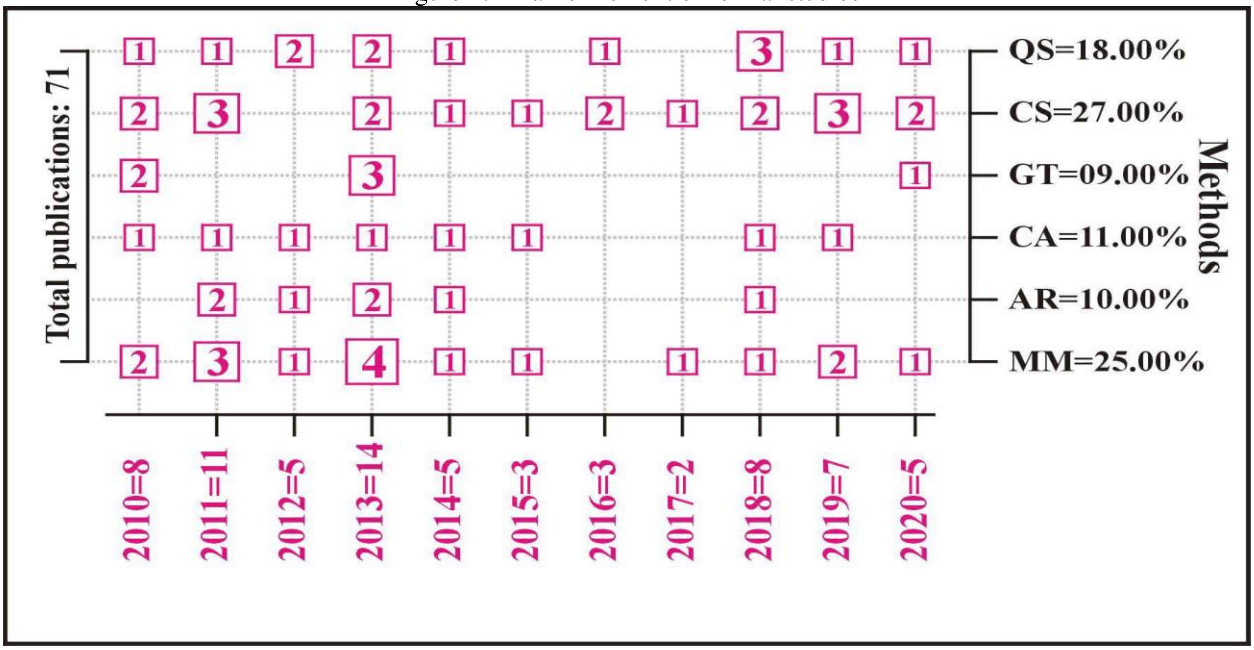

Figure 3: Used research techniques and publication year based analysis

Firstly, the themes, statements, concepts and ideas are captured and enlisted. The selected data were rephrased and finally formed the list of best practices of CGSD paradigm. The list of investigated best practices is given in Table5.

There might be a chance of researcher's biasness in data extraction process. Though, we have conducted an inter-rater reliability test[38], to determine the researchers biasness. We have invited 3 external experts from empirical research lab. They selected 15 paper and conducted the data extraction process. Based on the data extraction results of research team and external experts, we have determined the "non-parametric Kendall's coefficient of concordance (W)"; the value of W=1 and W=0 presents the complete agreement and disagreement, respectively. Hence, the determined results (W=0.89, p=0.004) presented that there is no biasness in the data extraction process. Though, we are confident that the extracted SLR results are consistent.

(3) Reporting the review

Quality of selected studies

In SLR, it is important to check the quality of selected studies with respect to the study RQs. To measure effectiveness of selected literature, the developed criteria presented in section 3.1.6 were used. The summarized results revolved that 80% of the selected studies score ≥60% and this indicates that the selected literature has the potential to answer the proposed RQ of this study. The detail quality assessment score is presented in Appendix-A.

Adopted research methods and the publication years of selected studies

In order to check the frequency of publication with respect to time duration on the CGSD context. It is noted that the selected studies are published between 2010 to 2020. This renders that the current era is the critical research period for cloud based global software development paradigm. The year-wise frequency of publication is presented in Figure 3.

Moreover, the adopted research approaches used in selected studies were also extracted (Figure 3). The frequency analysis shows that Questionnaire survey (QS) 18%, Case studies (CS) 27%, grounded theory (GT) 9%, Content analysis (CA) 11%, Action research (AR) 10% and Mixed methods were adopted by 25% of the selected studies. The analysis shows that case studies and the mixed methods are the most widely adopted research method in SLR studies.

B. Questionnaire survey study

The questionnaire survey study in an effective approach to collect the data from dispersed and potential population.

Kitchenham et al.[39] highlighted that the selection of data extraction process is based on nature of data "available data collection resources", "controlling mechanism of selected approach" and "skill to operate the variable of interest". It is hard to collect the representative set of data using observational data collection process [31, 32]. Though, we have used the questionnaire survey approach to collect the data from the experts of CGSD working across the globe at different geographical locations.

Questionnaire development

To get the perceptions of industry practitioners concerning to the collected best practices from the literature, an online questionnaire was developed. The developed questionnaire was hosted via Google form (docs.google.com/forms). The questionnaire survey is an effective way to collect and find the potential population working across the border. The key objective of questionnaire survey approach is to verify the best practices identified via SLR study. Though, the developed questionnaire was based on three core parts. The first part consists of the questions related to bibliographic information of survey respondents. The second part contain the list of best practices and their core categories. The third section is close-ended and an in which we request the participants to add additional best practices that are not enlisted in second section.

Pilot assessment of the questionnaire survey

The survey instrument was developed based on the previous experiences of study authors. The developed questionnaire was further verified with experts to check the correctness and understandability of the questionnaire [12, 37, 40]. In pilot assessment procedure, three experts were invited; form with one is from City University Hong-Kong and rest of both are from industry i.e. AMAZON India and QSoft-Vietnam. The participants give some important suggestion to improve the understandability and readability of the questionnaire. Firstly, they suggest to present the queries in table form. They also suggest some questions for collection of bibliographic information. All the points highlighted by the experts were entertained and the questionnaire was updated. The updated questionnaire (Appendix-B) was used for data collection process.

Ethics approval

The ethical approval was obtained from research advisor committee of "Department of Computer Science, Nanjing University of Aeronautics and Astronautics-Nanjing-China". Once the permission is granted, we have stated the data collection process by sending the online link of questionnaire survey to the targeted population.

Data sources

The aim of empirical investigations is to verify the best practices identified using SLR. To address the RQs of this study, we adopted the snowballing technique to approach the potential population. The snowballing is an effective approach to collect the data from dispersed population, and it is also cost effective approach [37][41, 42]. The snowballing is carried using the Email, LinkedIn and Research-Gate. The data collection process was executed between November-2019- to March-2020. During data collection process 98 response were collected and the collected responses were manually checked to found the completeness of identified responses. During manual checking we noted 12 incomplete responses. Though, based on the suggestions of our research team, only the complete responses were used for further analysis.

Survey data analysis

We have consider the frequency analysis approach to analyses the data collected from the reviewers, as it is considered more approach to analyses the descriptive data [43]. This method has been consideredby other researcher of software engineering domain [44-46].

C. Phase 3: Fuzzy Set Theory and AHP

Over the decades the AHP is considered as an effective approach to address the MCDM problems. AHP is a traditional MCDM techniques that consider the judgment of industry experts as it is and use the crisp number that leading to insensitivity of the uncertainty that came from linguistic variable[47]. In AHP method, it is prerequisites to check the expert's opinions with respect to harmony, proficiency and carefulness. If the above stated criteria are satisfied then AHP is considered to be an efficient approach for addressing the MCDM problems[48]. Though, the AHP approach does not consider the vagueness of once judgment. Therefore, the vagueness and fuzziness exists in several MCDM problems may cause to imprecise the judgment of a decision maker in AHP method[49]. Hence, the fuzzy-AHP technique consider values between 0-to-1 to address the vague statements.

In fuzzy-AHP, the theme of fuzzy logic was used to address the vague data and gives a systematic roadmap for controlling the ambiguous and undefined situations [50]. Thus, the experts can specify their opinions in natural language expression with respect to the criticality of each criteria [51].

The questionnaire was used to collect the experts opinions working in GSD. The collected data contains the experts judgements with respect the best practices of CGSD projects. Therefore, we apply the fuzzy-AHP approach to fix the uncertainties and vagueness in the expert's opinions with respect to the best practices of CGSD paradigm.

Fuzzy set theory

Zadeh [52] introduced a of fuzzy set theory which is an extended version of traditional fuzzy set theory. The updated fuzzy set theory is more effective and oriented to manage the vagueness and uncertainties exist in industry practices. The membership function μF(x) of fuzzy set theory assist to map the object in the range of 0 and 1. This approach has been considering by various studies to fix the MCDM problems exist in industry practices. For example, supplier selection in electronics market [53], gearmotor company[54] and personnel selection[55] etc. The steps and definition of fuzzy set theory is elaborated in sub-sequent sections.

Fuzzy analytical hierarchy (Fuzzy-AHP) process

The fuzzy-AHP is one of the most powerful approach adopted to address the MCDM problems. The key advantage of fuzzy-AHP approach are the relative ease which assist to manage the multicriteria, easy to understand, and it can efficiently address both quantitative and qualitative data.

Definition: "A triangular fuzzy number (TFN) F is denoted by a set (fl, fm, fu) as presented in Figure 4. The Eq.1 presents the membership function μF(x) of F."

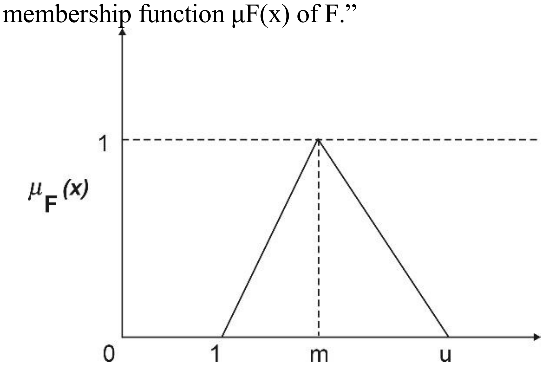

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Figure 4. Triangular fuzzy number

Table 3. Triangular Fuzzy Numbers

Operation Law	Expression
Addition ($F_1 \oplus F_2$)	$(f^l_1, f^m_1, f^u_1) \oplus (f^l_2, f^m_2, f^u_2) = (f^l_1 + f^l_2,\ f^m_1 + f^m_2,\ f^u_1 + f^u_2)$
Subtraction ($F_1 \oplus F_2$)	$(f^l_1, f^m_1, f^u_1) \oplus (f^l_2, f^m_2, f^u_2) = (f^l_1 - f^l_2,\ f^m_1 - f^m_2,\ f^u_1 - f^u_2)$
Multiplication ($F_1 \oplus F_2$)	$(f^l_1, f^m_1, f^u_1) \oplus (f^l_2, f^m_2, f^u_2) = (f^l_1 * f^l_2,\ f^m_1 * f^m_2,\ f^u_1 * f^u_2)$
Division ($F_1 \oplus F_2$)	$(f^l_1, f^m_1, f^u_1) \oplus (f^l_2, f^m_2, f^u_2) = (f^l_1 / f^l_2,\ f^m_1 / f^m_2,\ f^u_1 / f^u_2)$
Inverse ($F_1 \oplus F_2$)	$(f^l_1, f^m_1, f^u_1)^{-1} = (1/f^l_1,\ 1/f^m_1,\ 1/f^u_1)$
For any real number k (kF_1)	$k(f^l_1, f^m_1, f^u_1) = k f^l_1, k f^m_1, k f^u_1$

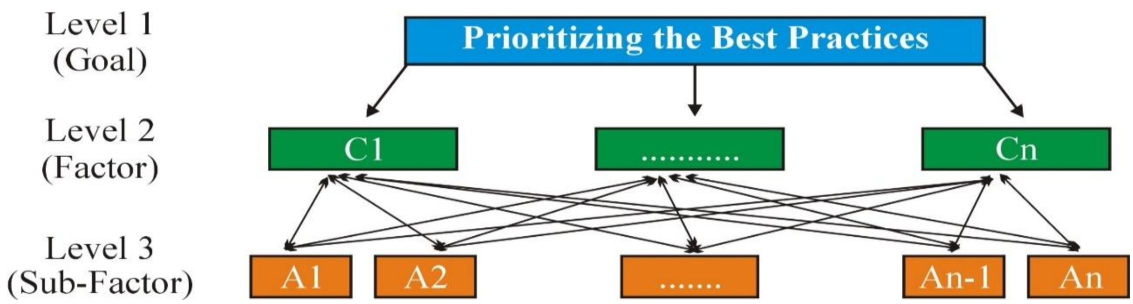

Figure 5. FAHP decision hierarchy

$$\mu_F(x) = \begin{cases} \dfrac{x - f^l}{f^m - f^l}, & f^l \le x \le f^m \\ \dfrac{f^u - x}{f^u - f^m}, & f^m \le x \le f^u \\ 0, & Otherwise \end{cases} \quad (1)$$

Where, f^l, f^m and f^u are the crisp numbers denoting the lowest, most promising and highest possible values respectively.

The algebraic operational laws using two TFNs, namely (F_1, F_2) are given in Table 3.

Following steps are required to perform the fuzzy-AHP.

Step1: Hierarchy development of the key problem (Figure 5).

Step2: Determination of priority weigh using the pair-wise comparison matrix.

Step3: Perform the consistency check

Step4: Calculation of final ranking.

Though the traditional AHP has several benefits and complexities at the same time. The most critical disadvantage of AHP is its limitation with respect to the usability in Crisp situations, the unbalanced judgment scale, uncertainty and the judgment selection is subjective.

Therefore, the extended version of AHP is fuzzy-AHP was developed to address the MCDM problems more effectively[59]. The fuzzy-AHP has the capacity to address the vagueness and uncertainties in the expert's opinions more effectively [51, 60-62]. We have adopted the fuzzy-AHP approach proposed by Chang [63], to rank the investigated set of best practices.

In prioritization problem, let X = $\{x_1, x_2,..., x_n\}$[64] indicates the attributes of main categories as a set of object and U = $\{u_1, u_2,..., u_n\}$ present the each category elements as a goal. With respect to the Chang [63]approach, every attribute was entertained, and the extent analysis of each goal (gi) was determined, respectively. Though, (m) extent value for each object value can determined using the Equation (2) and (3):

$$F^1{}_{gi}, F^2{}_{gi}, \ldots, F^m{}_{gi}, \quad (2)$$

$$i = 1, 2, \ldots, n \quad (3)$$

And $F^j{}_{gi}$, (j = 1, 2, ..., m) are all fuzzy triangular numbers (TFNs).

The main steps of Chang's extent analysis approach is as follows[63]:

Step 1: The fuzzy synthetic value concerning to i[th] objective are defined using Eq. (4):

$$S_i = \sum_{j=1}^{m} F^j{}_{gi} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} F^j{}_{gi} \right]^{-1} \quad (4)$$

To accomplish the expression $\sum_{j=1}^{m} F^j{}_{gi}$, execute the fuzzy addition operation of m extent analysis such as:

$$\sum_{j=1}^{m} F^j{}_{gi} = \left(\sum_{j=1}^{m} f^l{}_{gi}, \sum_{j=1}^{m} f^m{}_{gi}, \sum_{j=1}^{m} f^u{}_{gi} \right)$$

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and to achieve the expression $\left[\sum_{i=1}^{n}\sum_{j=1}^{m}F^{j}_{gi}\right]^{-1}$, the fuzzy addition operation is executed on $F^{j}_{gi}(j=1,2,....m)$ value, as follow:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}F^{j}_{gi}=(\sum_{i=1}^{n}f^{l}_{i},\sum_{i=1}^{n}f^{m}_{i},\sum_{i=1}^{n}f^{u}_{i})$$

and finally, calculate the inverse of the vector with the help of Eq. (7):

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}F^{j}_{gi}\right]^{-1}=(\frac{1}{\sum_{i=1}^{n}f^{l}_{i}},\frac{1}{\sum_{i=1}^{n}f^{m}_{i}},\frac{1}{\sum_{i=1}^{n}f^{u}_{i}}) \quad (7)$$

Step 2: AsF_a and F_b are two triangular fuzzy number then the degree of possibility of $F_a=(f^l_a, f^m_a, f^u_a) \geq F_b=(f^l_b, f^m_b, f^u_b)$ is defined as follows.

$$V(F_a \geq F_b) = sup[min(\mu_{Fa}(x), (\mu_{Fb}(x))] \quad (8)$$

Equation 8 can also be similarly specified as below:

$$V(F_a \geq F_b) = hgt(F_a \cap F_b) = \mu_{F_a}(d) = \begin{cases} 1 & if\ f^m_a \geq f^m_b \\ \frac{f^u_a - f^l_b}{(f^u_a - f^m_a)+(f^m_b - f^l_b)} & f^l_b \leq f^u_a \\ 0 & Otherwise \end{cases} \quad (9)$$

Here, d indicates the ordinate of the highest intersection point between D, μ_{Fa}andμ_{Fb}(Figure 6). The values of $V_1(F_a \geq F_b)$ and $V_2(F_a \geq F_b)$ are mandatory for determining the value of P_1 and P_2.

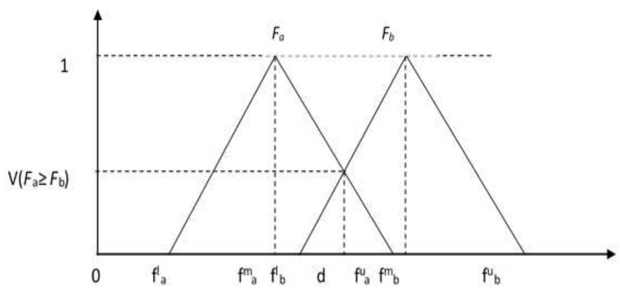

Figure 6 Triangular Fuzzy number

Step 3: Calculation of overall degree of possibility of a convex fuzzy number and the other convex fuzzy numbers F_i (i= 1, 2,..., k) can be defined as follow.

$$V(F \geq F_1, F_2, F_3....F_k) = \min V(F \geq F_i) \quad (10)$$

Assuming that,

$$d^{'}(F_i) = \min V(F_i \geq F_k) \quad (11)$$

for k = 1,2,...,n; $k \neq i$.

With the help of Eq. 12, calculate the weight vector using Eq. 11.

$$W^{'} = (d^{'}(F_1), d^{'}(F_2), d^{'}(F_3), ...d^{'}(F_n)) \quad (12)$$

Where, F_i (i= 1,2,...,n) are n distinct elements.

Step 4: Determine the normalized weights vector using equation 13 and their outcome will be not fuzzy value which indicates the priority weight of each criteria:

(6)

$$W = (d(F_1), d(F_2), d(F_3), ...d(F_n)) \quad (13)$$

Where W is a non-fuzzy number.

Step 5: Consistency check: The pairwise comparison matrix should be consistent in fuzzy-AHP analysis [65]. Therefore, the determination of consistency check of all the pairwise comparison matrix is necessary. To address this concern, we applied the graded mean integration for the defuzzification of matrixes. A triangular fuzzy number, denoted as P = (l, m, u), can be defuzzified to a crisp number as follows:

$$CR = \frac{CI}{RI} \quad (16)$$

$$P_{crisp} = \frac{(4m+l+u)}{6} \quad (14)$$

Once the matrixes are defuzzified, the consistency index could be determined easily by using the equation 15 and 16. If the determined value of consistency ration (CR) is less than 0.10, the matrixes are consistent, else the fresh opinions were required for pairwise comparison matrixes.

$$CI = \frac{I_{\max} - n}{n-1} \quad (15)$$

Where,

I_{max}, Indicate the largest eigenvalue of pair-wise comparison matrixes.

n: Present the elements of each matrix.

RI: The standard values of RI are presented in Table 4.

Table 4. Random consistency index (RI) according to matrix size

Matrix size	1	2	3	4	5	6	7	8	9	10
RI values	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

IV. RESULTS AND ANALYSIS

This section consists of the result and discussion of study findings.

A. SLR Findings

The best practices of CGSD paradigm were identified by following the step by step procedure of SLR. During the SLR data extraction and synthesis process, a total of 30 best practices were identified that are particularly related with core knowledge areas of PMBOK[66]. The identified best practices present the guidelines to the successful execution of CGSD activities. The list of explored best practices and their respective categories are enlisted in Table 5.

Table 5: List of investigated best practices

Categories	Sr. No.	Best Practices
C1 (Human Resource Management)	P1	Organization management makes the CGSD process improvement practices as an important part of the development processes.
	P2	Promote efficient offshore relationship.
	P3	Conduct regular training session for team members.
	P4	Promote process improvement awareness among CGSD team members.
C2 (Integration)	P5	Management committed to support CGSD team members.
	P6	Arrange training and workshop to understand both the culture of the people participating in distributed CGSD process improvement.
	P7	Team members should plan for frequent daily meetings
	P8	Detail process improvement knowledge
	P9	Frequent planning of interactions between distributed sits: daily stand-up/call improves this largely”
C3 (Communication)	P10	Frequently visit the geographically distributed teams to decrease the communication gap
	P11	Motivate CGSD team members to use the advance tools and techniques or effective communication
	P12	Organize frequent visits CGSD team practitioners at overseas sites
C4 (Stakeholders)	P13	Develop criteria to continuously assess the efforts of CGSD team members
	P14	Management commits to provide adequate resources and training for CGSD improvement activities
	P15	Management commits to participate in CGSD improvement workshops and evaluations meetings
	P16	Top level management should lead the initiation and implementation of CGSD program
	P17	Management encourages and drives the bottom-up staff in CGSD activities
C5 (Procurement)	P18	Establish technical infrastructure to implement the CGSD program
	P19	Use application of process, implementation or product indicators as an effective management tool for process improvement
	P20	Promote the awareness of CGSD paradigm application tools and stands among team members
	P21	Use of licensed software tools
C6 (Time)	P22	Management commits to allocate sufficient time for CGSD activities
	P23	A mechanism developed to avoid time pressure
	P24	Team members agree to allocate time for CGSD activities
C7 (Scope)	P25	Project planning done in order to estimate all the required resources
	P26	Users see that the change is of benefit to them as individuals and to the entire organization
	P27	Explicitly describe the benefits of CGSD to both team members and organization
C8 (Quality)	P28	Adopt standers for the assessment of processes
	P29	Test earlier, provide examples and reiterate fast
	P30	Explicitly discuss the results of the pilot implementation

B. Empirical data analysis

This study consists of the summarized results collected from the questionnaire survey study.

Bibliographic data analysis of survey practitioners

The bibliographic data was collected aiming to analyze the appropriateness of survey particiapents with respect to the domain andstudy objective. A summary of collected bibliographic data is discussed in this section and the detail information is given in Appendix –C.

Designation of survey participants

Finstad et al. [38] and Niazi et al. [31] emphasized that the position of experts mater a lot while collecting their opinions. They also underlined that an expert can give correct feedback if he has good experience on dealing the same types of daily maters. Though, using the bibliographic data, we have summarized the positions of the survey respondents (Figure 7). The results show that most of survey participates are software project manager and software developer. This renders that the collect data has the potential to address the research objective.

Participants experience based analysis

The participant's experienced based analysis is presented in Figure 8. The results shows that the participants experience ranges from 2 to 10 years. The calculated mean and median (6 and 5.5) illustrates that most of the participants renders young pool. Thus, the results show that there is a good mix of participants having different level of experience in software development process.

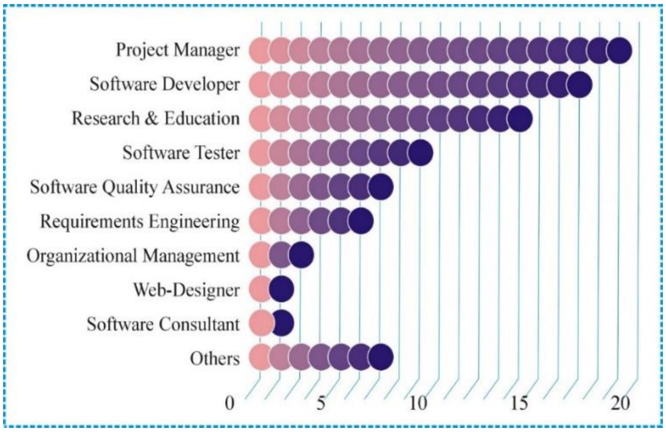

Figure 7: Designations of survey participants

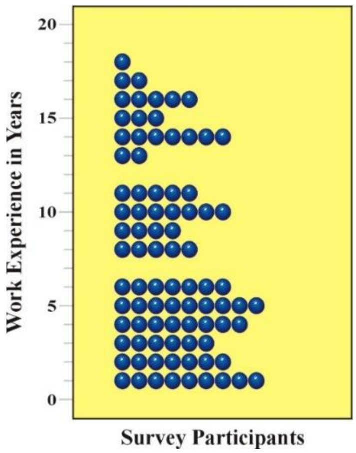

Figure 8: experience of survey participants

Participant's organization size-based analysis

The organization size of survey participants is presented in pie chart (Figure 9). The presented results indicated that from total population of participants 25% belongs to small scale organization, 50% works in medium size organization and 35% of participants are from large well-established organization.

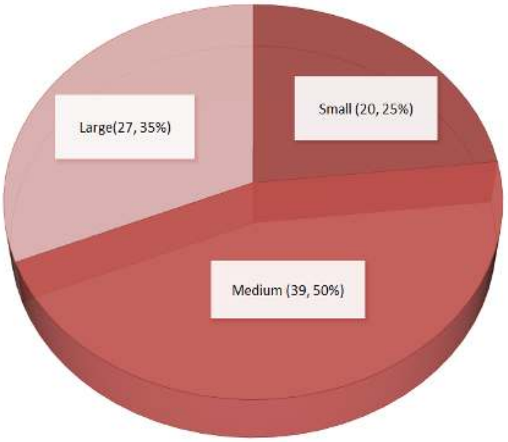

Figure 9: Survey participant's organizations

Feedback of industry practitioners

A total of 30 best practices of CGSD paradigm were enlisted by conducting SLR study. The identified best practices and their core categories were further validated with the industry practitioners. To empirically verify the identified best practices and their core categories, an online survey questionnaire was developed using Google Form platform. The question of survey instrument is based on the list of best practices explored via SLR study. The survey responses were collected considering the Likert scale "i.e. five points scale" and the values of Likert scale are classified into core three categories i.e. positive ("strongly agree and agree"), negative (strongly disagree, disagree) and neutral. The positive category consists of the response who considered as the investigated best practices are related with CGSD paradigm in real-world industry. The negative category renders the responses of those participants who do not consider as the explored best practices for real world practices. The response of neutral category presents those participates who do not sure about the impact of investigated best practices on CGSD paradigm. The Table 6 shows the calculated results of survey participants.

Table 6: Summarized results of questionnaire survey study

S. No.	Best practices	Empirical Investigation (N=86)							
		Positive			Negative			Neutral	
		A	SA	%	D	S.D	%	N	%
C1	**Human Resource Management**	**51**	**24**	**87**	**3**	**2**	**6**	**6**	**7**
P1	Organization management makes the CGSD process improvement practices as an important part of the development processes.	37	24	71	6	4	12	15	17
P2	Promote efficient offshore relationship.	33	18	59	8	7	17	20	23
P3	Conduct regular training session for team members.	37	16	62	7	6	15	20	23

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P4	Promote process improvement awareness among CGSD team members.	31	25	65	6	2	9	22	26
C2	**Integration**	**40**	**32**	**84**	**4**	**1**	**6**	**9**	**10**
P5	Management committed to support CGSD team members.	40	16	65	14	3	20	13	15
P6	Arrange training and workshop to understand both the culture of the people participating in distributed CGSD process improvement.	51	20	83	3	2	6	10	12
P7	Team members should plan for frequent daily meetings.	43	24	78	8	2	12	9	10
P8	Detail process improvement knowledge.	40	13	62	10	6	19	17	20
P9	Frequent planning of interactions between distributed sits: daily stand-up/call improves this largely.	31	25	65	6	2	9	22	26
C3	**Communication**	**48**	**28**	**88**	**4**	**2**	**7**	**4**	**5**
P10	Frequently visit the geographically distributed teams to decrease the communication gap.	31	23	63	11	6	20	15	17
P11	Motivate CGSD team members to use the advance tools and techniques or effective communication.	41	20	71	8	5	15	12	14
P12	Organize frequent visits CGSD team practitioners at overseas sites	30	17	55	12	6	21	21	24
C4	**Stakeholders**	**40**	**30**	**81**	**7**	**13**	**12**	**6**	**7**
P13	Develop criteria to continuously assess the efforts of CGSD team members.	36	18	63	9	7	19	16	19
P14	Management commits to provide adequate resources and training for CGSD improvement activities.	31	21	61	11	8	22	15	17
P15	Management commits to participate in CGSD improvement workshops and evaluations meetings.	39	22	71	7	4	13	14	16
P16	Top level management should lead the initiation and implementation of CGSD program.	39	17	65	11	7	21	12	14
P17	Management encourages and drives the bottom-up staff in CGSD activities.	31	25	65	6	2	9	22	26
C5	**Procurement**	**44**	**27**	**83**	**4**	**2**	**7**	**9**	**10**
P18	Establish technical infrastructure to implement the CGSD program.	56	13	80	3	1	5	13	15
P19	Use application of process, implementation or product indicators as an effective management tool for CGSD improvement.	49	21	81	6	2	9	8	9
P20	Promote the awareness of CGSD paradigm application tools and stands among team members.	57	17	86	0	0	-	12	14
P21	Use of licensed software tools.	39	21	70	6	5	13	15	17
C6	**Time**	**46**	**32**	**91**	**2**	**0**	**2**	**6**	**7**
P22	Management commits to allocate sufficient time for CGSD activities.	53	18	83	7	2	10	6	7
P23	A mechanism developed to avoid time pressure.	33	24	66	9	4	15	16	19
P24	Team members agree to allocate time for CGSD activities.	41	16	66	9	3	14	17	20
C7	**Scope**	**51**	**26**	**90**	**0**	**0**	**0**	**9**	**10**
P25	Project planning done in order to estimate all the required resources.	51	18	80	5	3	9	9	10
P26	Users see that the change is of benefit to them as individuals and to the entire organization.	35	21	65	13	4	20	13	15
P27	Explicitly describe the benefits of CGSD to both team members and organization.	51	23	86	7	5	14	0	-
C8	**Quality**	**41**	**33**	**86**	**2**	**3**	**6**	**7**	**8**
P28	Adopt standers for the assessment of processes.	39	17	65	11	7	21	12	14
P29	Test earlier, provide examples and reiterate fast.	35	21	65	13	4	20	13	15
P30	Explicitly discuss the results of the pilot implementation.	56	13	80	3	1	5	13	15

A=Agree, S.A=Strongly agree, D= Disagree, S.D= Strongly disagree, N=Neutral

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The results of empirical study shows that survey participants agreed on the identified best practices and their respective categories are related with industry practices. All the enlisted best practices are scored ≥60% for all the reported best practices, hence this indicated the importance of best practices for the success and progression of CGSD paradigm. In addition, we also noted that the survey participants are agree with the categories of identified best practices. The results shows that C6 (Time=91%) is the top ranked category among all the investigated best practices. C7 (Scope=90%) and C3 (Communication=88%) are the 2nd and 3rd most significant categories of the investigated best practices. Though, considering the results of empirical study, we are motivated to further apply the fuzzy-AHP technique aiming to rank them with respect to their significant for CGSD paradigm.

C. Fuzzy-AHP analysis

The fuzzy-AHP analysis approach has been applied aiming to prioritize the investigated set of best practice with respect to their criticality for the successful execution of CGSD paradigm. The experiment was conducted using "MATLAB R2016b"tool developed by American mathematician. The steps adopted to perfume the fuzzy-AHP analysis are briefly discussed in the sub-sequent sections:

Step-1 (Hierarchy structure of best practices and their corresponding categories)

The hierarchy structure was developed to resolve issues of decision making by following step by step application of fuzzy-AHP (like Figure 5). Using the list of best practices and their respective categories, we have designed the hieratical structure (Figure 10) .The Figure 10 shows the key objective of this study at level 1 while level 2 and 3 presents the core categories with their respective best practices.

Step-2 (Conducting the pairwise comparison)

The basic aim of pairwise comparison is to determine the rank order of each best practices with respect to their importance for CGSD paradigm. To address this concern, we have performed the pairwise comparison with with the CGSD experts. Though, to accomplish this task we have designed the questionnaire and contact to the respondents of the first survey (section 3.2). After gathering, all responses from survey participants we have in total 31 responses. The responses were reviewed manually in detail by authors to check incomplete entries. During manual check, we found all the response complete and useable. The used questionnaire for fuzzy-AHP study is presented in Appendix D. The 31 responses of pairwise comparison survey might be not strong enough to generalize the results of fuzzy-AHP analysis. We noted that the FAHP analysis is a subjective approach, and the data collected from a small sample size is also acceptable [52]. Various existing studies used small data sets to [43][54][55][54] also used the small sample size for fuzzy-AHP analysis.

Furthermore, the collected responses for fuzzy-AHP analysis were further transformed into TRN number using the geometric mean. To transform the human judgments into TRN number, the geometric mean is an effective method. Thus, the used formula of geometric mean is given below:

$$\text{Geometric mean} = n\sqrt{t1x\,t2\ \times t3\ldots\ldots\ldots tn} \quad (17)$$

t=indicate the response score

n=Number of responses

Linguistic "variable against their triangular fuzzy Likertscales is given in Table 7. To develop the pairwise comparison matrixes of the investigated best practices and their categories; the triangular fuzzy conversion scale (Table 7), proposed by Bozbura et al.[56]was adopted."

Step-3 (Determining the local priority weight of each best practice)

The priority weight for all the best practices were determined to check the significance of each best practice within their respective category. Firstly, the synthetic extent values of four best practices of human resource management category using Equation 3. Furthermore, the priority weight of all the best practices were determined using Equation 4. An example of local priority weigh calculation of human resource management category best practices is presented below. Table 7 present the pairwise comparison of four best practices of human resources management category.

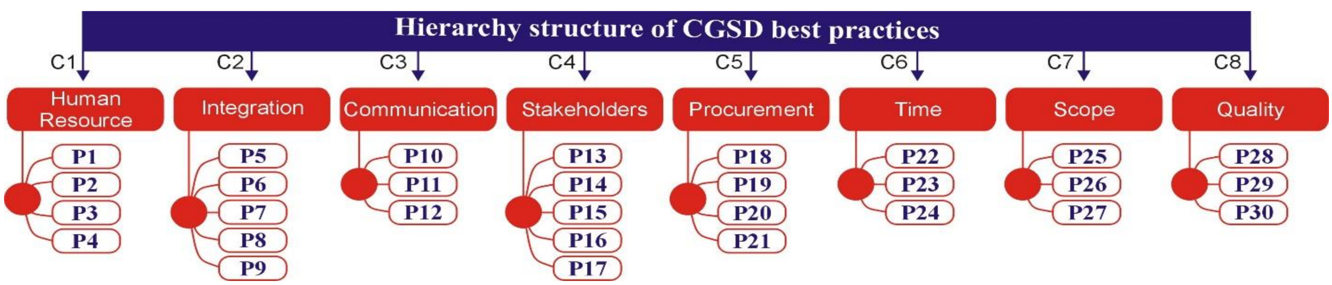

Figure 10: Proposed hierarchy structure

Table 7. Triangular Fuzzy Conversion Scale [56]

Linguistic Scale	Triangular Fuzzy scale	Triangular Fuzzy Reciprocal scale
Just equal (JE)	(1,1,1)	(1,1,1)
Equally important (EI)	(1/2,1,3/2)	(2/3,1,2)

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Weakly important (WI)	(1,3/2,2)	(1/2,2/3,1)
Strong more important (SMI)	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strong more important (VSMI)	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important (AMI)	(5/2,3,7/2)	(2/7,1/3,2/5)

$$\sum_{i}^{n}\sum_{j}^{m} F_{gi}^{j} = (1,1,1) + (1.5,2,2.5) + (1,1.5,2) ... + (0.5,0.6,1) + (1,1,1) = (14.1,18.2,22.8)$$

$$\left[\sum_{i}^{n}\sum_{j}^{m} F_{gi}^{j}\right]^{-1} = (\frac{1}{22.8}, \frac{1}{18.2}, \frac{1}{14.1}) = (0.04386,\ 0.054945,\ 0.070922)$$

$$\sum_{j=1}^{m} F_{g1}^{j} = (1,1,1) + (1.5,2.5,3) + (1,1.5,2) + (1.5,2.0,2.5) = (5,7,8.5)$$

$$\sum_{j=1}^{m} F_{g2}^{j} = (0.3,0.4,0.6) + (1,1,1) + (0.4,0.5,0.6) + (0.5,0.6,1) = (2.2,2.5,3.2)$$

$$\sum_{j=1}^{m} F_{g3}^{j} = (0.5,0.6,1) + (1.5,2,2.5) + (1,1,1) + (1,1.5,2) = (4,5.1,6.5)$$

$$\sum_{j=1}^{m} F_{g4}^{j} = (0.4,0.5,0.6) + (1,1.5,2) + (0.5,0.6,1) + (1,1,1) = (2.9,3.6,4.6)$$

The synthesis values of human resource management category best practices (P1 to P4) were calculated using Equation 4 as follow:

$$P1 = \sum_{j}^{m} F_{g1}^{j} \otimes \left[\sum_{i}^{n}\sum_{j}^{m} F_{gi}^{j}\right]^{-1}$$
$$= (5,7,8.5) \otimes (0.04386,\ 0.054945,\ 0.070922) = (0.219298,\ 0.384615,\ 0.602837)$$

$$P2 = (2.2,2.5,3.2) \otimes (0.04386,\ 0.054945,\ 0.070922) = (0.096491,\ 0.137363,\ 0.226950)$$
$$P3 = (4,5.1,6.5) \otimes (0.04386,\ 0.054945,\ 0.070922) = (0.175439,\ 0.280220,\ 0.460993)$$
$$P4 = (2.9,3.6,4.6) \otimes (0.04386,\ 0.054945,\ 0.070922) = (0.127193,\ 0.197802,\ 0.326241)$$

Table 7: Pairwise comparison of Human Resource Management category best practices

	P1	P2	P3	P4
P1	(1,1,1)	(1.5, 2, 2.5)	(1.5, 2, 3)	(1.5, 2, 2.5)
P2	(0.4, 0.5, 0.6)	(1,1,1)	(0.5, 0.6, 1)	(0.5, 0.6. 1)
P3	(0.3, 0.5, 0.6)	(1, 1.5, 2)	(1,1,1)	(1, 1.5, 2)
P4	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6. 1)	(1,1,1)

Table 8: Results of V values for criteria.

	P1	P2	P3	P4	d (Priority Weight)
V (P1≥….)	-	1	1	1	1
V (P2≥….)	0.030119	-	0.26602	0.62372	0.030119
V (P3≥….)	0.69846	1	-	1	0.69826
V (P4≥….)	0.36415	1	0.64561	-	0.36415

Table 9: Fuzzy Crisp Matrix (FCM) for the best practices of human resources management category

	P1	P2	P3	P4
P1	1.0	2.5	1.5	2.0
P2	0.5	1.0	0.5	0.7
P3	0.7	2.0	1.0	1.5
P4	0.5	1.5	0.7	1.0
Column Sum	2.7	7.0	3.7	5.2

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Using the Equation 6, the degree of possibility is calculated. The minimum degree of possibility (priority weight) for each pair-wise comparison was calculated using Equation 8.

Hence, the determined weights are: W' = (1, 0.030119, 0.69846, 0.36415) (Table 8). By normalizing these values, the significance of attributes was determined as W = (0.4789, 0.01435, 0.3337). The given results reveal that P1(Organization management makes the CGSD process improvement practices as an important part of the development processes) is declared as the most important best practice in human resource management category compared with other three best practices.

Step-4 (Test the consistency of the pair-wise matrix)

This section contains all the steps required to determine the consistency of pair-wise comparison matrixes. To do this, the table of human resource management category best practices (Table 9) was considered. A triangular fuzzy number of the pair-wise comparison matrix of the best practices of human resource management are defuzzified to crisp number using Equation 14 and resulted the corresponding Fuzzy Crisp Matrix (FCM) as presented in Table 9:

To determine the largest Eigen vector (λ_{max}), firstly the sum of each column of FCM matrix was determined; then each element was divided by on the sum of their respective column sum (Table 9). Furthermore, the priority weigh of each element was determined by taking the average of each rows (Table 10).

Table 10: Normalized matrix of human resources management category best practices

	P1	P2	P3	P4	Priority vector weight
P1	0.37027	0.35724	0.40551	0.38452	0.37928
P2	0.18539	0.14276	0.13524	0.13442	0.14935
P3	0.25916	0.28581	0.27037	0.28856	0.27583
P4	0.18529	0.21439	0.18929	0.19221	0.19534

λ_{max}= Σ ([Σ Cj] × {W})
(18)

Where, ΣCj= sum of the columns of Matrix [C] (Table 7), W= weight vector (Table 10), therefore

λ_{max} = 2.7*0.37938 + 7.0*0.14945 + 3.7*0.27593 + 5.2*0.19524 = 4.1067

According to the results the Eigen value (λ_{max}) of the matrix FCM is 4.1067. The FMC matrix is 4×4 which present n=4, and using the Table 5, the RI value is 0.9 for n=4. Hence, using the equation 15 and 16, the consistency ration was determined as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} = \frac{4.1067-4}{4-1} = 0.035553$$

$$CR = \frac{CI}{RI} = \frac{0.035553}{0.9} = 0.039503$$

The determined CR value 0.039503<0.10; though, the pairwise comparison matrix developed for human resource management best practices is consistent and acceptable. Considering the same procedure, the consistency of all the other pairwise matrixes were determined and the results are presented Table 11, 12, 13, 14, 15, 16, 17, and in between the categories Table 18.

Table 11: Pairwise comparison of Integration category best practices

	P5	P6	P7	P8	P9
P5	(1,1,1)	(0.3, 0.4, 0.5)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)
P6	(2, 0.5, 3)	(1,1,1)	(2, 0.5, 3)	(0.5, 1, 1.5)	(1, 1.5, 2)
P7	(0.4, 0.5, 0.6)	(0.3, 0.4, 0.5)	(1,1,1)	(2, 0.5, 3)	(2.5, 3, 3.5)
P8	(1.5, 2, 2.5)	(0.6, 1, 2)	(0.3, 0.4, 0.5)	(1,1,1)	(0.5, 0.6, 1)
P9	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.2, 0.3, 0.4)	(1, 1.5, 2)	(1,1,1)

λ_{max} = 5.51, CI = 0.13, CR = 0.90

Table 12: Pairwise comparison of communication category best practices

	P10	P11	P12
P10	(1,1,1)	(1, 2, 3.5)	(2, 2.5, 3)
P11	(0.2, 0.2, 1.5)	(1,1,1)	(1.5, 0.4, 2.5)
P12	(0.5, 0.3, 1)	(2, 2.5, 3)	(1,1,1)

λ_{max} =3.0707, CI=0.03553, CR=0.061

Table 13: Pairwise comparison of stakeholder's category best practices

	P13	P14	P15	P16	P17
P13	(1,1,1)	(0.3, 0.4, 0.5)	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)
P14	(2, 2.5, 3)	(1,1,1)	(2, 2.5, 3)	(0.5, 1, 1.5)	(1, 1.5, 2)
P15	(1.5, 2, 2.5)	(0.3, 0.4, 0.5)	(1,1,1)	(2, 2.5, 3)	(2.5, 3, 3.5)
P16	(0.4, 0.5, 0.6)	(0.6, 1, 2)	(0.3, 0.4, 0.5)	(1,1,1)	(0.5, 0.6, 1)
P17	(1.5, 2, 2.5)	(0.5, 0.6, 1)	(0.2, 0.3, 0.4)	(1, 1.5, 2)	(1,1,1)

λ_{max} = 5.2878; CI = 0.071950; CR = 0.064241

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Table 14: Pairwise comparison of Procurement category best practices

	P18	P19	P20	P21
P18	(1,1,1)	(1.5, 2.5, 3)	(1, 1.5, 2)	(1.5, 2, 2.5)
P19	(0.3, 0.4, 0.6)	(1,1,1)	(0.4, 0.5, 0.6)	(0.5, 0.6. 1)
P20	(0.5, 0.6, 1)	(1.5, 2, 2.5)	(1,1,1)	(1, 1.5, 2)
P21	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(0.5, 0.6. 1)	(1,1,1)

λ_{max} = 4.0616, CI = 0.020528, CR = 0.022808

Table 15: Pairwise comparison of time category best practices

	P22	P23	P24
P22	(1,1,1)	(1, 3.5, 3)	(1.5, 0.5, 2.5)
P23	(0.3, 0.4, 0.5)	(1,1,1)	(01.5, 0.3, 0.5)
P24	(0.5, 0.5, 1)	(2, 3.5, 3)	(1,1,1)

λ_{max} =3.0406, CI=0.03213, CR=0.057

Table 16: Pairwise comparison of scope category best practices

	P25	P26	P27
P25	(1,1,1)	(2, 2.5, 3)	(0.3, 0.4, 0.5)
P26	(0.3, 0.4, 0.5)	(1,1,1)	(1, 1.5, 2)
P27	(0.5, 0.6, 1)	(2, 2.5, 3)	(1,1,1)

λ_{max} =3.0279, CI=0.04261, CR=0.067

Table 17: Pairwise comparison of quality category best practices

	P28	P29	P30
P28	(1,1,1)	(2, 2.5, 3)	(0.5, 0.6, 1)
P29	(0.3, 0.4, 0.5)	(1,1,1)	(1, 1.5, 2)
P30	(0.3, 0.4, 0.5)	(1, 2.5, 3)	(1,1,1)

λ_{max} =3.0513, CI=0.06221, CR=0.074

Table 18: Pairwise comparison of best practices categories

	C1	C2	C3	C4	C5	C6	C7	C8
C1	(1,1,1)	(1, 1.5, 2)	(2.5, 3, 3.5)	(0.6, 1, 2)	(1.5, 2, 2.5)	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.3, 0.4, 0.5)
C2	(0.5, 0.6, 1)	(1,1,1)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.4, 0.5, 0.6)	(1, 1.5, 2)	(2, 0.5, 3)	(1, 1.5, 2)
C3	(0.2, 0.3, 0.4)	(1, 1.5, 2)	(1,1,1)	(0.5, 1, 1.5)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)
C4	(0.5, 1, 1.5)	(0.5, 0.6, 1)	(0.6, 1, 2)	(1,1,1)	(0.2, 0.3, 0.4)	(2, 0.5, 3)	(0.5, 1, 1.5	(2, 0.5, 3)
C5	(0.4, 0.5, 0.6)	(1.5, 2, 2.5)	(1, 1.5, 2)	(2.5, 3, 3.5)	(1,1,1)	(0.4, 0.5, 0.6)	(0.2, 0.3, 0.4)	(1, 1.5, 2)
C6	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.3, 0.4, 0.5)	(1.5, 2, 2.5)	(1,1,1)	(0.4, 0.5, 0.6)	(2, 0.5, 3)
C7	(1, 1.5, 2)	(0.3, 0.4, 0.5)	(0.5, 0.6, 1)	(0.6, 1, 2)	(2.5, 3, 3.5)	(1.5, 2, 2.5)	(1,1,1)	(0.4, 0.5, 0.6)
C8	(2, 0.5, 3)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.3, 0.4, 0.5)	(0.5, 0.6, 1)	(0.3, 0.4, 0.5)	(1.5, 2, 2.5)	(1,1,1)

λ_{max}= 8.7016, CI = 0.10023, CR = 0.071087

Table 19: Local and global ranks determination

Categories	Category Weights	Best Practices	Local Weights	Local Ranking	Global Ranking	Global Ranking
Human Resource Management	0.05671	P1	0.1182	3	0.0067	17
		P2	0.1351	2	0.0076	15
		P3	0.2271	1	0.0128	7
		P4	0.085	4	0.0048	19
Integration	0.07831	P5	0.2521	3	0.0197	5
		P6	0.1543	4	0.0121	9
		P7	0.0623	5	0.0048	19
		P8	0.3441	1	0.0269	2
		P9	0.3173	2	0.0248	3
Communication	0.04619	P10	0.1561	1	0.0072	16
		P11	0.0692	3	0.0032	25
		P12	0.1138	2	0.0052	18

Stakeholders	0.05108	P13	0.3173	1	0.0162	6
		P14	0.0532	5	0.0027	26
		P15	0.0871	2	0.0044	20
		P16	0.0729	3	0.0037	23
		P17	0.0627	4	0.0032	25
Procurement	0.07246	P18	0.0489	4	0.0035	24
		P19	0.1734	1	0.0125	8
		P20	0.1641	2	0.0118	11
		P21	0.0934	3	0.0067	17
Time	0.05159	P22	0.07391	3	0.0038	21
		P23	0.18223	1	0.0094	13
		P24	0.15472	2	0.0079	14
Scope	0.07065	P25	0.4821	1	0.0341	1
		P26	0.0535	3	0.0038	21
		P27	0.3261	2	0.0231	4
Quality	0.05088	P28	0.2334	2	0.0119	10
		P29	0.1972	1	0.0101	12
		P30	0.0729	3	0.0037	22

Table 20: Final ranking

S. No.	Best Practices	Global Ranking
P25	Project planning done in order to estimate all the required resources	1
P8	Detail process improvement knowledge	2
P9	Frequent planning of interactions between distributed sits: daily stand-up/call improves this largely	3
P27	Explicitly describe the benefits of CGSD to both team members and organization	4
P5	Management committed to support CGSD team members	5
P13	Develop criteria to continuously assess the efforts of CGSD team members	6
P3	Conduct regular training session for team members	7
P19	Use application of process, implementation or product indicators as an effective management tool for process improvement	8
P6	Arrange training and workshop to understand both the culture of the people participating in distributed CGSD process improvement	9
P28	Adopt standers for the assessment of processes	10
P20	Promote the awareness of CGSD paradigm application tools and stands among team members	11
P29	Test earlier, provide examples and reiterate fast	12
P23	A mechanism developed to avoid time pressure	13
P24	Team members agree to allocate time for CGSD activities	14
P2	Promote efficient offshore relationship	15
P10	Frequently visit the geographically distributed teams to decrease the communication gap	16
P1	Organization management makes the CGSD process improvement practices as an important part of the development processes	17
P21	Use of licensed software tools.	17
P12	Organize frequent visits CGSD team practitioners at overseas sites	18
P4	Promote process improvement awareness among CGSD team members.	19
P7	Team members should plan for frequent daily meetings.	19
P15	Management commits to participate in CGSD improvement workshops and evaluations meetings.	20
P22	Management commits to allocate sufficient time for CGSD activities.	21
P26	Users see that the change is of benefit to them as individuals and to the entire organization.	21
P30	Explicitly discuss the results of the pilot implementation.	22
P16	Top level management should lead the initiation and implementation of CGSD program.	23
P18	Establish technical infrastructure to implement the CGSD program.	24
P11	Motivate CGSD team members to use the advance tools and techniques or effective communication.	25
P17	Management encourages and drives the bottom-up staff in CGSD activities.	25
P14	Management commits to provide adequate resources and training for CGSD improvement activities.	26

Step-5: Calculation of Global weights

The objective of local weight (LW) calculation is to check determine the priority rank of a best practices within their respective category. For example, the human resource management category consists of 4 best practices (i.e. P1 to P4). The local weigh of each best practices of human resource management category were determined compared with the four best practices. On the other side, the global weight (GW) were determined compared with all the investigated 30 best practices of CGSD paradigm. The objective of global weigh determination is to check the priority order of each best practise for overall CGSD paradigm. The global weigh was determined by multiplying the local weigh of best practicewith the corresponding category weight. For example, best parctice global weight P1= local weigh of P1 ×human resource management category weight (P1=0.1182×0.05671; P1=0.0067). According to prioritization results presented in Table 19, P25 Project planning done in order to estimate all the required resources, GW=0.0341) is ranked as the highest priority best practice for CGSD paradigm. We further noted that P8(Detail process improvement knowledge, GW=0.0269) and P9 (Frequent planning of interactions between distributed sits: daily stand-up/call improves this largely, GW=0.0248) are the second and third highest ranked best practices for GSD paradigm.

Step-6: Ranking of investigated best practices

The global weigh was considered to calculate the final ranks of each bet practices (Table 19). The final raking present the priority order of all the best practices concerning to their significance of CGSD paradigm. The results shows that P25 (Project planning done in order to estimate all the required resources) is declared as the highest priority best practice for the successful execution of CGSD paradigm. As in CGSD, the development is conducted at overseas sits across the globe; though the project planning is significant to estimate the resources required at overseas sites. The results revolved that P8 (Detail process improvement knowledge), P9(Frequent planning of interactions between distributed sits: daily stand-up/call improves this largely), P27 (Explicitly describe the benefits of CGSD to both team members and organization) and P5 (Management committed to support CGSD team members) are declared as the top five most important best practise that must be considered by the practitioner on priority while dealing with agenda of success and progression of cloud based global software development environment. CGSD paradigm. The ranking of all the investigated best practices are presented in Table 20.

V. SUMMARY AND DISCUSSIONS

The objective of this work is explored and prioritize the best practices of CGSD paradigm. For the success and progression of CGSD projects, it is required to develop the new strategies and tools of CGSD activities. The exploration and prioritization of best practices will assist to focus on the key area of CGSD paradigm. The list of best practices, their categorizations and their prioritization, also provides the prioritization-based taxonomy of the best practices, which provides the body of knowledge to practitioner to develop the effective strategies for the success and progression of CGSD paradigm. The summarized description of study research questions is discussed below:

RQ1 (Identification of CGSD best practices)

A systematic literature study was conducted to explore the best practices of CGSD paradigm reported in the literature. By conducting the SLR study, a list of 30 best practices were identified that are important for the successful execution of CGSD paradigm.

Moreover, we used the core categories of PMBOK, and classified the identified best practices into eight key categories. In addition, to verify the best practise collected from the literature and their categorization process, we have performed questionnaire survey study with industry experts. The survey study results revolved that the identified best practices using SLR and the mapping process of identified best practices into PMBOK categories are useful for industry practices.

RQ2 (Prioritization of investigated best practices)

The fuzzy-AHP approach has been applied to rank the investigated set of best practices and their respective categories. To perform the fuzzy-AHP analysis, we have conducted fuzzy-AHP survey study with experts. Based on the finding of fuzzy AHP survey study, the pairwise comparison matrixes were developed. All the steps of fuzzy AHP approach were carefully applied and determine the local and global weights of identified CGSD best practices. Considering the calculated local weights, the best practices were locally ranked in their respective categories. The local ranking assists to determine the significance of best practices within their respective categories. Moreover, the global ranking was determined to check the significance of identified set of 30 best practices. The global ranking assists to determine the priority order of all the best practices compared with the set of identified set of 30 best practices. The according to the results presented in Table 20, P25 (Project planning done in order to estimate all the required resources), P8(Detail process improvement knowledge), P9 (Frequent planning of interactions between distributed sits: daily stand-up/call improves this largely), P27 (Explicitly describe the benefits of CGSD to both team members and organization) and P5 (Management committed to support CGSD team members) are declared as the top five best practices for the successful execution of CGSD paradigm.

RQ3 (Prioritization based taxonomy of best practise)

The prioritization-based taxonomy of the best practices was developed considering the local and global ranks obtain by applying the fuzzy AHP approach. The local ranks refer to the priority order of a best practice with in their respective category. Besides, the global ranks present the significance level of a specific best practice compared with all the identified best practices. Therefore, the prioritization-based

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taxonomy shows the variation in the ranking of best practices with respect to local and global ranking. For example, P3 (Conduct regular training session for team members) is ranked as 1st within the human resource management category and considering the global ranking, it standout at 7th most significant best practice for CGSD projects. We further noted that, P25 (Project planning done in order to estimate all the required resources) is standout at 1st with respect to both local and global rankings. This indicated that, P25 is the most critical best practice for 'Scope' category, and for overall study objective which is the prioritization of CGSD paradigm.

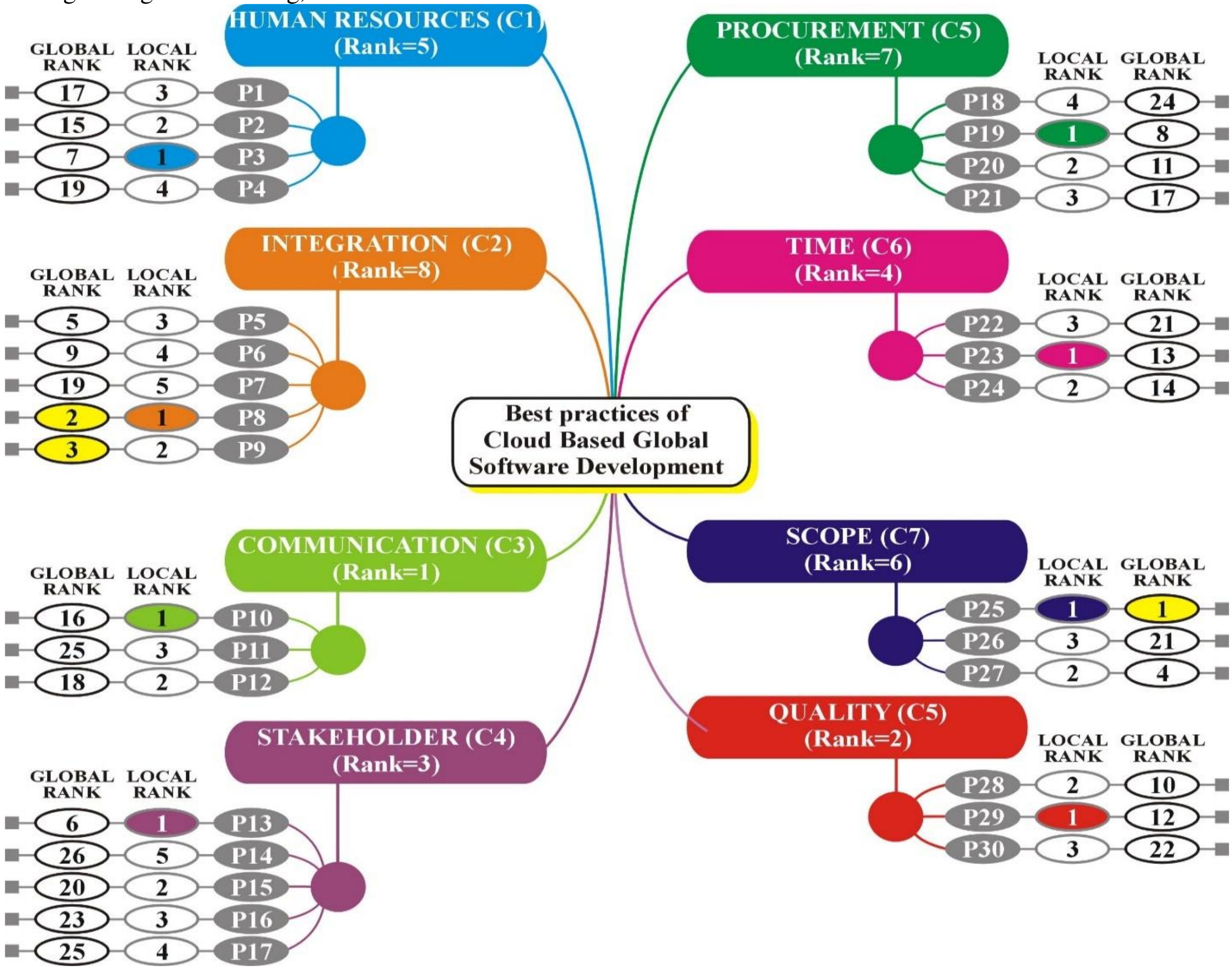

Figure 11: Prioritization based taxonomy

Furthermore, the significant variation in the local and global rankings of the best practices is also observed. For example, in communication category, P10 (Frequently visit the geographically distributed teams to decrease the communication gap) is ranked as 1st with respect to local ranking and 16th by considering the global ranking. In Time category P23 (A mechanism developed to avoid time pressure) is ranked as 1st and 13th by using the local and global rankings, respectively. This variation between local and global ranking help the practitioner to adopt the highest priority best practices, with respect to their working position and objectives. The developed prioritization-based taxonomy of the CGSD best practices provides the body of knowledge to industry experts and academic researchers to develop the new and effective plan and strategies for the success and progression of CGSD paradigm.

VI. THREATS TO VALIDITY

The data was extracted from the limited digital repositories and this might cause the missing of some related studies. Based on the other studies, this is not a systematic problem [36, 45, 67,68].

Similarly, the extracted data from the selected studies might be not consistent and have uncertainties. We address this threat by conducting the inter-rater reliability test and the results shows that there is no researcher's baseness and the extracted data is consistent.

An external threat towards the generalization of study results is the small sample size of empirical study. The data set consists (n=86) might not strong enough to generalize the results of this study. Though, with reference to the other studies of software engineering domain [16, 46, 47], this sample size is representative of generalizing the study results.

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Most of the survey participants were from developing countries (Asian countries); this may hinder to generalize the study results. Moreover, we also noted that a representative number of respondents are form developed continents (the USA or Australia), and this allows the generalization of results.

VII. CONCLUSION AND FUTURE DIRECTIONS

This study aims to explore the best practices of cloud based global software development reported in the literature. Though, conducting the systematic literature review a set of 30 best practices were investigated. The explored best practices were further categorized into core categories of PMBOK. With the aim to get the feedback and perception of industry practitioners, we have further conducted the questionnaire survey study. The results of questionnaire survey study revolved that, the investigated set of best practices and their mapping process is relevant with industry practitioners. In addition, we have adopted the fuzzy-AHP technique aiming to prioritize the identified best practices concerning to their criticality for CGSD paradigm. The prioritization based results revolved that 'project planning done in order to estimate all the required resources, 'detail process improvement knowledge', "frequent planning of interactions between distributed sits: daily stand-up/call improves this largely", "explicitly describe the benefits of CGSD to both team members and organization' and 'management committed to support CGSD team members" are the top five most important best practices for the success and progression of cloud based global software development paradigm. Based on the fuzzy-AHP results, and the core categories of best practices, we have developed the prioritization-based taxonomy of the investigated best practices, which assists the software practitioner and academic experts, to review and develop the new strategies for the successful execution of CGSD paradigm. We believe that the results and analysis of this study will serve as a knowledge base for the industry expert and researchers with respect to the best practices of CGSD paradigm and their significance for the successful execution of CGSD paradigm.

In future, we plan to identify the factors that could negative or positive impact on CGSD practices. We also plan to map the investigated best practise against each challenge and success factor, and this process will provide the guidelines for experts to the successful execution of CGSD paradigm in industry.

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APPENDIXES

Appendix-A: List of selected studies and quality assessment score (https://tinyurl.com/y2yzhkmx)

Appendix-B: Sample of used survey instrument (https://tinyurl.com/y6sl5o6m)

Appendix-C: Detailed bibliographic data of survey participants (https://tinyurl.com/y5qzuw6r)

Appendix-D: Sample of fuzzy-AHP data collection instrument (https://tinyurl.com/y5zu9aau).

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