QFD based Information Technology Planning Approach for Collaborative Product Development

Gülçin Büyüközkan, Sezin Güleryüz

Abstract **—While collaborative product development (CPD) is a technology intensive process, the planning of this technology is a highly neglected topic. The implementation of planned information technologies (IT) can be an enabler of the CPD performance, as collaboration requires coordination on the integrated platforms. This paper aims to put forward a planning framework first by identifying the requirements and system features in the IT domain that support CPD andthen to do prioritization of design requirements and system features for increasing the efficiency of IT planning in CPD process with the assistance of Quality Function Deployment (QFD) based methodology. Incomplete preference relations are considered and a new group decision making approach is provided by merging different preferences into a single one with fuzzy set theory in QFD. The proposed methodology is tested in a real life application of a software development project.**

Index Terms—**Collaborative Product Development, Incomplete Preference Relations, Group Decision Making, Quality Function Deployment.**

I. Introduction

In today's competitive environment companies increasingly tend to develop new products which have higher quality, able to meet customer needs and advantageous in economical return [1]. To fulfill these objectives, collaborative product development is an important tool to make full use of several independent development systems work together and improve their abilities at the same time [2]. Because of being technology oriented process, CPD performance is dependent to the appropriateness of technological infrastructure and its effective planning. For this reason, information technology planning is assessed to be critical process in the effectiveness of CPD management. This paper aims to propose a Quality Function Deployment based IT planning framework for the prioritization of design requirements and system features of CPD.

QFD is well-known technique enable to translate customer requirements to technical requirements. Moreover, the need of QFD is to incorporate the voice of customer in to various phases of the product development process of new product, or an updated version of the former one. Practically, QFD includes different components such as preferences, which are subjective and vague. That's why it is necessary to reach approximate exactness with fuzzy set theory [3]. On the other hand, decision makers (DMs) are confronted with the difficulty of completing their preferences because of missing knowledge or lack of expertise about the analyzed subject. To deal with this problem, incomplete preference relations are integrated with QFD to obtain better analyze of the IT requirements.

The paper is organized as follows. Section 2 gives a literature survey of IT customer requirements and system features for the CPD. Section 3 presents the proposed approach based on QFD with incomplete preference. Section 4 includes the application of the proposed approach in a software development project. Finally, Section 5 gives some concluding remarks.

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II. Literature Review

A. IT requirements for the CPD

CPD is a characteristically distributed collaboration of heterogeneous systems. Quite a few independent systems need to be integrated with others to develop products or service in effective means [4]. Therefore the main component of CPD's technology requirements has a vital importance and there are several studies on this issue.

A wide range of these studies are summarized technical requirements into basic key points. According to Li and Su [5] collaboration and integration over the internet which is related to the web enabled CPD environment's main characteristics are: scalability, openness, heterogeneity, resources access and inter-operation, legacy codes reusability, and artificial intelligence. Rodriguez and Al-Ashaab [6] highlight CPD and its design process into a system. During the design processes, they present a supportive approach which compasses common access of design information, collaborative visualization and design of the component. Shen et al. [2] state that requirements include; ontology and semantics based integration, interoperability of product models, product-centric design methodology, knowledge management, collaborative intelligent user interfaces, distributed design project management, drag and drop functionality, security/privacy, self-management, and social software for CPD. Furthermore, Palacio et al. [7] mention software development requirements and present a conceptual model in collaborative environment. They generalize the software design requirements in four groups: scale, uncertainty, interdependence, and communication. These requirements

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form a starting point for both collaboration and development processes.

Based on a deep literature survey and the opinions of industrials experts, IT requirements of CPD process can be categorized in nine main factors.

Communication involves definition of critical data and associates with information flows between participants of the project in order to provide information about achievements, problems, solutions, and justifications [7],[8],[9]. ***Project Management*** serves to control and coordinate the virtual team and their tasks [2],[6],[10],[11]. It compasses interaction mechanism for team members, status updates and task progress [7],[12],[13],[14]. The key merit of ***Knowledge Management*** is to assure information flows and synchronize key factors [15]. Besides, processes of managing knowledge in collaborative teams, members allow mutual knowledge flow between sources of internal expertise and create networks of workers within and outside the organization. [2],[6],[12],[13],[16] [17]. ***Interoperability*** requirement emerges as a natural result of collaboration in order to assure diverse systems to work together [2],[5],[11]. ***Risk Management*** controls uncertainties and unattended project failures, help to reduce risks by anticipating, preventing and mitigating problems [9],[18],[19]. ***Data Integration and Analysis*** defines as a mechanism to integrate data available from different collaborating teams and to analyze the data in the most efficient manner [5],[15],[20],[22] Another important requirement is ***Product Model Design Specifications*** which allow representation, visualization, and modification of the product mode [2],[14],[22],[24],[25]. ***Security*** requirement implicates data protection as well as system back-up in collaborative environment [2],[14],[22],[24],[25]. Lastly, CPD infrastructure requires ***Technical Support*** given that collaborative infrastructure consisting of technology products may often necessitate maintenance and repair services [14].

B. Collaborative system features

Based on a deep literature survey and opinions of industrials experts, collaborative system features are described in ten groups. ***Synchronous Communication*** tools enable people to have real time communication and collaboration when they are in different places at a same point of time. On the other hand, ***Asynchronous Communication*** tools enable people to communicate and collaborate over a period of time through a different time and place mode [14],[22],[24]. Hillebrand and Biemans [26] and Fraser et al. [9] mention that product development involves the coordination of internal functional groups therefore it requires the integration of both internal and external networks which is associated as ***System Integration*** **Mechanisms** as a system feature [2]. ***Project Management*** tools are indispensable in CPD project and its main functions are; to organize, control and manage the development process consisting of resources, personnel, capital, information and data. [6],[14],[27]. ***Product Visualization*** presents a subset of computer-supported cooperative work applications in which provides the user to visualize, annotate, and control 3D design model interactively [6],[24],[25],[27]. ***Document Management*** tools aim to store electronic documents and images [22]. ***Content Management*** tools are another feature that defines as a system that supports the creation, administration, distribution, publication and collection of information [28]. ***Data Tracking and Analysis*** enables the collaborating teams to comprehend the data they are handling. It provides detailed history of data and its origin [7],[16],[22]. ***Decision Support*** tools are required to analyze all data and present a comprehensible report to assist decision makers. ***Archiving*** tools are also an important feature, where large data is shared by distributed teams as storing, retrieving, and accessing the data are assured by archiving [22].

III. METHOD AND APPLICATION

A. Incomplete preference relations in QFD

QFD is a well-known technique for translating customer requirements (CRs) into relevant design requirements (DRs). Each translation uses a matrix called the house of quality (HOQ) for identifying CRs and establishing priorities of DRs to satisfy the CRs [29]. To design and acquire a more integrated CPD, QFD can be an effective structure development tool.

In some cases experts do not have detailed knowledge about problems. In such situations, because of the difficulty to compare alternatives or not to have sufficient level of knowledge, experts present incomplete preferences, such as missing preference values [30],[31]. In this cases group decision making (GDM) is important issue in QFD to unify opinions of multiple DMs. Moreover, GDM not only avoid bias but also helps to minimize partiality [29]. Different techniques applied with incomplete preference relations in different areas. These studies are summarized in Table 1.

Table 1. Used Incomplete Preference Techniques with Application Areas

Authors	Application Areas	Used Techniques
Alonso et al. [32]	Interactive support system	Linguistic Preference Relations, Consistency
Alonso et al. [33]	Illustrative example	Incomplete Preference Relations
Büyüközkan and Çifçi [31]	Sustainable supply supplier selection	Fuzzy Analytic Network Process, GDM, Incomplete Preference Relations
Chiclana et al. [34]	Comparison between Fedrizzi and Giove's method and Herrera-Viedma et al.'s method	Estimating Missing Pair-wise Preference Values Based on Additive Consistency
Fedrizzi, and Giove [35]	Illustrative example	Incomplete Pair-wise Comparison, Consistency Optimization
Gong [36]	Illustrative example	Least-square Method, Fuzzy Preference Relations, Incomplete Preference Relations
Han et al. [37]	Illustrative example	Incomplete Preference Relations, Linear Partial Ordering, QFD
Herrera-Viedma et al.[38]	Illustrative example	Incomplete Fuzzy Preference Relations, GDM
Herrera-Viedma, et al.[39]	Illustrative example	Incomplete Preference Relations, Consistency
Hsu and Wang [40]	Durable consumer goods selection	Incomplete Linguistic Preference Relations, Analytic Hierarchy Process
Liu et al.[41]	Illustrative examples	Incomplete Interval Multiplicative Preference Relations, Goal Programming, GDM
Porcel and Herrera-Viedma [42]	Web quality evaluation	The 2-tuple Fuzzy Linguistic Approach, Incomplete Fuzzy Preference Relations
Wang and Chen [43]	Illustrative example	Fuzzy Preference Relations
Wang et al. [44]	Evaluation of performance of web shops	Incomplete Linguistic Preference Relations
Xu [45]	Illustrative example	Incomplete Preference Relations, GDM, Goal Programming
Xu [46]	Illustrative example	Incomplete Multiplicative Linguistic Preference Relations
Xu [47]	Illustrative example	Incomplete Linguistic Preference Relations
Xu [48]	Illustrative examples	Four formats Incomplete Preference Relations, GDM
Zhang, Dong and Xu [49]	Illustrative example	Linear Optimization Models, Fuzzy Preference Relations
Zu and Chen [50]	Illustrative example	Incomplete Multiplicative Preference R.

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B. Technique of the proposed evaluation model

In order to apply proposed approach, the following steps are used:

Step 1 - "Whats - Identifying the customer requirements": CRs are identified with the help of literature, industrial and scientific background of experts, researchers thesis and articles.

Step 2 - "Prioritizing and evaluation of CRs": When DMs are in difficulty of comparing factors, incomplete preference relations technique is used in order to compute the importance degrees.

Step 2.1 - "CRs evaluation": A comparison scale is required to measure the importance degrees of the CRs. The scale in Table 2 is used to indicate the relative strength of each pair of elements as in Eq. (1).

$$\tilde{P} = \begin{bmatrix} \tilde{p}_{11} & \tilde{p}_{12} & \cdots & \tilde{p}_{1n} \\ \tilde{p}_{21} & \tilde{p}_{22} & \cdots & \tilde{p}_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \tilde{p}_{n1} & \tilde{p}_{n2} & \cdots & \tilde{p}_{nn} \end{bmatrix} \quad (1)$$

Where $\tilde{p}_{ij} = (p^l_{ij}, p^m_{ij}, p^u_{ij})$ indicates the importance among the compared criteria (importance of i over j) where $i = j = 1,2,\ldots,n$.

Table 2. Corresponding linguistic terms for evaluation

Linguistic variables	Fuzzy Scales
No influence (No)	(0, 0, 0.1)
Very low influence (VL)	(0, 0.1, 0.3)
Low influence (L)	(0.1, 0.3, 0.5)
Medium influence (M)	(0.3 , 0.5, 0.7)
High influence (H)	(0.5, 0.7, 0.9)
Very high influence (VH)	(0.7, 0.9, 1)
Extreme influence (E)	(0.9, 1, 1)

Step 2.2 - "Completion of missing values": When DMs construct and evaluate the fuzzy pair wise comparison matrices of interdependent components, defuzzify those using Eq. (2).

$$F(\tilde{p}_{ij}) = 1/2 \int_0^1 \left(\inf_{x\in\Re} \tilde{p}^{\alpha}_{ij} + \sup_{x\in\Re} \tilde{p}^{\alpha}_{ij} \right) d\alpha \quad (2)$$

Then, missing values in a DM's incomplete preference relation can be computed.

$$p_{ij} = p_{iy} + p_{yj} - 0.5, \forall\, i, j, y \in \{1, 2, \ldots, n\} \quad (3)$$

Given a reciprocal preference relation, Eq. (3) is employed to calculate an estimated value of a preference degree using other preference degrees. Indeed, by using an intermediate alternative a_y, the preference value of p_{ij} $(i \neq j)$ can be calculated in three ways [38].

1. From $p_{ij} = p_{iy} + p_{yj} - 0.5$, we obtain the estimate
$$cp^{y1}_{ij} = p_{iy} + p_{yj} - 0.5 \quad (4)$$
2. From $p_{yj} = p_{yi} + p_{ij} - 0.5$, we obtain the estimate
$$cp^{y2}_{ij} = p_{yj} - p_{yi} + 0.5 \quad (5)$$
3. From $p_{iy} = p_{ij} + p_{jy} - 0.5$, we obtain the estimate
$$cp^{y3}_{ij} = p_{iy} - p_{jy} + 0.5 \quad (6)$$

The preference value of one alternative over itself is always assumed to be equal to 0.5.

Step 2.3 - "Checking the consistency level": The following sets can be used to estimate its consistency level:

$$H^1_{ij} = \{y \neq i, j \mid (i, y), (y, j) \in \text{EV}\} \quad (7)$$

$$H^2_{ij} = \{y \neq i, j \mid (y, i), (y, j) \in \text{EV}\} \quad (8)$$

$$H^3_{ij} = \{y \neq i, j \mid (i, y), (j, y) \in \text{EV}\} \quad (9)$$

Where EV is the set of pairs of alternatives for which the expert provides preference values, and $H^1_{ij}, H^2_{ij}, H^3_{ij}$ are the sets of intermediate alternative a_y $(y \neq i, j)$ that can be used to estimate the preference value p_{ij} $(i \neq j)$ using (7)-(9), respectively. The consistency level CL_{ij}, associated with a preference value p_{ij} $(i \neq j) \in$ EV,

$$CL_{ij} = (1 - \alpha_{ij}) \cdot (1 - \varepsilon p_{ij}) + \alpha_{ij} \cdot \frac{CP_i + CP_j}{2},\; a_{ij} \in [0,1] \quad (10)$$

is defined as a linear combination of the average of the completeness values associated to the two alternatives involved in that preference degree CP_i and CP_j,

$$CP_i = \frac{\#EV}{2(n-1)} \quad (11)$$

where $\#EV$ is the number of preference values known. Its associated error εp_{ij}, can be calculated as in Eq. (12)

$$\varepsilon p_{ij} = \frac{2}{3} \cdot \frac{\varepsilon p^1_{ij} + \varepsilon p^2_{ij} + \varepsilon p^3_{ij}}{\kappa} \quad (12)$$

where

$$\varepsilon p^1_{ij} = \begin{cases} \dfrac{\sum_{j \in H^l_{ij}} \left| cp^{kl}_{ij} - p_{ij} \right|}{\# H^l_{ij}}, & if\, (\# H^l_{ij} \neq 0); l \in \{1,2,3\} \\ 0 & , otherwise \end{cases} \quad (13)$$

and

$$\kappa = \begin{cases} 3, & if\, (\#H^1_{ij} \neq 0) \wedge (\#H^2_{ij} \neq 0) \wedge (\#H^3_{ij} \neq 0) \\ 2, & if\, (\#H^a_{ij} = 0) \wedge ((\#H^b_{ij} \neq 0) \wedge (\#H^c_{ij} \neq 0)); a, b, c \in \{1,2,3\} \\ 1, & otherwise \end{cases} \quad (14)$$

α_{ij} is a parameter to control the influence of completeness in the evaluation of the consistency levels.

$$\alpha_{ij} = 1 - \frac{\#EV_i + \#EV_j - \#(EV_i \cap EV_j)}{4(n-1) - 2} \quad (15)$$

In order to prove p_{ij} is consistent, CL_{ij} have to be higher than 0.5. If p_{ij} is not consistent and $\varepsilon p_{ij} \neq 0$, then preferences should be revised by DM. If p_{ij} is not consistent and $\varepsilon p_{ij} = 0$, then known preferences should be increased [38].

Step 2.4 - "Aggregation of the evaluations": The evaluators are categorized into K groups and each group member is denoted as $\{p^{kl} : k = 1, \ldots, K; l = 1, \ldots, L_k\}$ where L_k is the size of the group k. Let $\{p^{k1}_{ij}, \ldots, p^{kL_k}_{ij}\}$ be the set of values to be aggregated for any $i, j \in R$ and group k DMs. Then, the ordered weighted geometric (OWG) operator is defined as:

$$\Phi^G \left(\left\{ p^{k1}_{ij}, p^{k2}_{ij}, \ldots, p^{kL_k}_{ij} \right\} \right) = \prod_{l=1}^{L_k} \left(\bar{p}^{kl}_{ij} \right)^{w_l} \quad (16)$$

where, $W=(w_1,...,w_{L_k})$ is an exponential weighting vector, such that $w_l \in [0,1]$ and $\sum w_l = 1$, and each $\overline{p}_{ij}^{kl}$ is the lth largest valued element in the set $\{p_{ij}^{k1}, p_{ij}^{k2},..., p_{ij}^{kL_k}\}$ [31].

The OWG operator reflects the fuzzy majority if we calculate its weighting vector W by means of a fuzzy linguistic quantifier. Proportional quantifiers, such as *most*, *at least half*, may be represented by fuzzy subsets of the unit interval [0,1]. Then, for any $r \in [0,1]$, $Q(r)$ indicates the degree to which the proportion r is compatible with the meaning of the quantifier it represents. For a non decreasing relative quantifier, Q, the weights are obtained as $w_l = Q(l/L_k)-(Q(l-1)/L_k)$, $l = 1,\ldots,L_k$ where $Q(y)$ is defined as: 0, if $y <$ a; $(y - a)/(b - a)$, if $a \le y \le b$; and 1, if $y \ge b$. Note that $a, b, y \in [0,1]$ and $Q(y)$ indicates the degree to which the proportion y is compatible with the meaning of the quantifier it represents. Some examples for the relative quantifiers are "most" (0.3, 0.8), "at least half" (0, 0.5) and "as many as possible" (0.5, 1). When the fuzzy quantifier Q is used for calculating the weights of the OWG operator Φ_W^G, it is represented by Φ_Q^G. Therefore, the collective multiplicative relative importance relation is obtained as follows;

$$p_{ij}^k = \Phi_Q^G\left(p_{ij}^{k1}, p_{ij}^{k2},..., p_{ij}^{kL_k}\right), \quad 1 \le i \ne j \le n. \tag{17}$$

Step 2.5 - "Obtaining priorities from the judgment matrix": After the group opinion is collected in the matrix P^k using Eq. (17), it must be exploited to determine the importance weights of the criteria. Note that in P^k, the element ij reflects the relative importance of criterion i compared to criterion j. Next, calculate the quantifier guided importance degree of each criterion, which quantifies the importance of one criterion compared to others in a fuzzy majority sense. By using the OWG operator, we have

$$QGID_i^k = \Phi_Q^G\left(p_{ij} : j=1,...,n\right) \tag{18}$$

for all i=1,...,n. Finally, the obtained QGID$_i$ values should be normalized, i.e., $QGID_i^k = QGID_i^k / \sum_i QGID_i^k$, to have the importance degrees in percentage for the group k. These steps need to be pursued in all nodes of the evaluation model. The importance degree of each hierarchy leaf node requirement is calculated by multiplying its importance value with the importance values of its up level requirements. Finally, we calculate the weighted sum of CR's group importance values given group importance weights to obtain the aggregate CR importance.

Step 3 - "Hows - Developing/defining design requirements (DRs): In this step, DR part is transforming CRs to technical attributes.

Step 4 -"Relation Matrix": A relationship matrix is constructed between CRs and DRs. Depending upon the impact of the DRs in meeting CRs for the attribute, values "Empty = no relationship", "1= possible relationship", "3 = moderate relationship", and "9 = strong relationship" are assigned.

Step 5 - "Prioritizing DRs": The importance of each technical/design requirement is computed using the relationship matrix and the relative importance of each CR. The resulting value determines the relative weight of each DRs as compared to CRs. The importance of each DR is calculated as the sum of each CR importance value multiplied by the quantified relationship between the same CR and the current DR.

IV. Case Study

This section provides a case study to illustrate the proposed approach for assessing the most important IT requirements for CPD process. Figure 1 shows the application steps of the proposed QFD based IT planning approach.

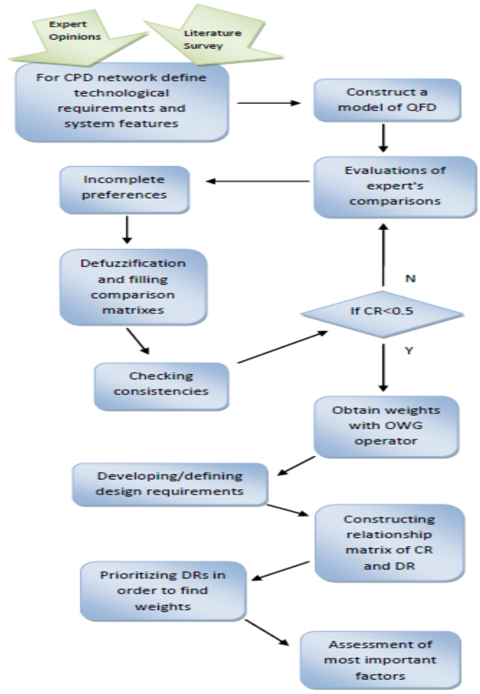

Figure 1. Application steps of proposed approach

Step 1 - "What's - Identifying the CRs": We group in two main dimensions, namely, management and technological requirements, the factors that are given in Section II.A. Management requirements (CR_1) includes Communication (CR_{11}), Project Management (CR_{12}), Knowledge Management (CR_{13}), Interoperability (CR_{14}), Risk Management (CR_{15}) and Technological requirements (CR_2) includes Data Integration and Analysis (CR_{21}), Product Model/Design Specifications (CR_{22}), Security (CR_{23}) and Technical Support (CR_{24}).

Step 2 - "Prioritizing and evaluation of CRs": To determine the importance degrees of CRs, three DMs, company manager, R&D manager and software developer, who are experts in their branch, are identified. The evaluation matrix of company manager is given in Table 3 as an example. Values in the comparison matrix are seen as the linguistic form, besides the missing values are seen with x.

Table 3. Company manager's evaluation of technological requirements factors

	Data Int.& Analysis	Product Model/ D.S	Security	Technical support
Data Int A.	-	M	L	L
P.M.D.S	x	-	H	H
Security	x	x	-	x
Technical s.	x	x	M	-

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Step 2.1 - "Completion of missing values": In this step, linguistic values are converted to defuzzied numbers (Table 4). Later, comparison scale from Table 2 is required to measure the importance degrees of the CRs.

Table 4. Defuzzified evaluation of pair wise comparison matrix of technological factors

	Data Int.& Analysis	Product Model/ D.S	Security	Technical support
Data Int A.	-	0.5	0.3	0.3
P.M.D.S	x	-	0.7	0.7
Security	x	x	-	x
Technical s.	x	x	0.5	-

After these, defuzzified preference values are formed and calculated with equation (2). Later, the missing values are estimated using Eq. (4) to (6) and constituted in Table 4. An example computation procedure to estimate p_{34} is as follows:

$H^1_{34} = \emptyset$ as $cp^{11}_{34} = p_{31} - p_{14} - 0.5 =$ unknown

$H^2_{34} = \{1\}$ and $cp^{12}_{34} = p_{24} - p_{23} + 0.5 = 0.50$

$H^3_{34} = \emptyset$ and $cp^{13}_{34} = p_{33} - p_{43} + 0.5 =$ unknown

So, $cp_{13} = 0.5$ and other estimated values and their completed form of are shown in Table 5.

Table 5. Determining the estimated evaluation of values by DM

	Data Int.& Analysis	Product Model/ D.S	Security	Technical support
Data Int A.	-	0.5	0.3	0.3
P.M.D.S	0.5	-	0.7	0.7
Security	0.7	0.3	-	0.5
Technical s.	0.7	0.3	0.5	-

Step 2.2 - "Checking consistency level": There is necessity to measure consistency level in order to understand that estimated values are consistent or not. The consistency level matrix is created using Eq. (10) to (15) and is shown in Table 6.

Table 6. Consistency level for evaluation of DMs

	Data Int.& Analysis	Product Model/ D.S	Security	Technical support
Data Int A.	-	0.5	0.3	0.3
P.M.D.S	0.5	-	0.7	0.7
Security	0.7	0.3	-	0.5
Technical s.	0.7	0.3	0.5	-

According to DM's evaluations, consistency level of preferences is calculated and their computation steps are as follows:

$EV_1 = \{(1,2),(1,3),(1,4)\}$; $EV_2 = \{(1,2),(2,3),(3,2)\}$;
$EV_3 = \{(1, 2)\}$; $EV_4 = \{(1,4),(2,4),(4,3)\}$
$CP_1 = 3/6$, $CP_2 = 3/6$, $CP_3 = 1/6$, $CP_4 = 3/6$

$\alpha_{34} = 1-[(2+3-1) / 4(4-1)-2] = 0.7$

$CL_{34} = (1- 0). (1 - 0.7) + 0.7 = 0.53$

The result of consistency (CL_{34}) is 0.53. It is obvious that 0.53>0.50 and this shows a consistent preference.

Step 2.3 - "Aggregation of evaluations": All matrixes evaluated from DM's opinions have to aggregate to each other using Eq. (16), (17). In this step OWG operator with fuzzy linguistic quantifier 'at most' is used to compute the group importance relation matrix as shown in Table 7 with weighting vector (0.066, 0.667, 0.267).

Table 7. Importance relation matrix of DMs

	Data Int.& Analysis	Product Model/ D.S	Security	Technical support
Data Int A.	0.50	0.31	0.44	0.31
P.M.D.S	0.64	0.50	0.70	0.70
Security	0.51	0.30	0.50	0.50
Technical s.	0.64	0.30	0.50	0.50

Step 3 - "Obtain priorities and ranking": Firstly, as explained in the Section II.B, DRs are defined as: Synchronous Communication tools (DR_1), Asynchronous Communication tools (DR_2), System Integration Mechanisms (DR_3), Project Management tools (DR_4), Product Visualization (DR_5), Document Management tools (DR_6), Content Management tools (DR_7), Data Tracking and Analysis tools (DR_8), Archiving Tools (DR_9), Decision Support tools (DR_{10}).

In the following steps group opinion is collected in the matrix priorities and importance values are constructed between CRs and DRs, each of DRs is correlated individually to each of the CRs by considering to what extent a requirement contributes to meeting customer needs for the attribute. After that, the importance of each technical/design requirement is computed using the relationship matrix and the relative importance of each CR. The resulting value determines the relative weight of each DRs as compared to CRs. The importance of each DR is calculated as the sum of each CR importance value multiplied by the quantified relationship between the same CR and the current DR. The importance of each DR is calculated as the sum of each CR importance value multiplied by the quantified relationship between the same CR and the current DR. The summary of obtained results in House of Quality is given in Table 8. According to these results, the most important IT DRs for CPD are Synchronous Communication tools, Asynchronous Communication tools and System Integration tools.

V. CONCLUSION

This study presented a QFD based IT planning methodology for effective CPD projects. Given that CPD is a highly technology-centric process, it is important to identify the IT requirements correctly and prioritize these technologies appropriately. The applicability of the methodology is demonstrated through the software development project case study. As a future work, the presented methodology is considered to be adapted to different collaborative projects to verify its performance within other CPD networks.

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Table 8. Final HOQ for IT requirement planning for CPD

Relationship Strength: S: Strong M: Moderate P: Possible		Synchronous com. tools	Asynchronous com. tools	System integration mechanisms	Project man. tools	Product visualization	Document Man. tools	Content man. tools	Data tracking analysis	Archiving tools	Decision support tools	Decision Mak. Evaluations	Overall Importance
Management Requirements	Communication	S	S	S								18.46 %	21 %
	Project Management	S	M	P	S	M						15.62 %	18 %
	Knowledge Management	M	S		P		S	S		M		14.2 %	15 %
	Interoperability	S	S	S	M	S		P				12.78 %	11 %
	Risk Management	S	P	P			P		S	P	M	9.23 %	6 %
Technical Requirements	Data Integration & A.		M				M	P	S	S	M	6.38 %	6 %
	Product M.D.S.	S	S	M		S		P				8.99 %	11 %
	Security	S	P	P			P		S	P		6.96 %	6 %
	Technical Support	S	P	P		P	P		M	P	M	6.96 %	6 %
Importance of DRs		7.536	5.790	3.241	1.817	2.497	1.700	1.559	2.240	1.231	0.677		
Importance %		0.266	0.204	0.114	0.064	0.088	0.060	0.055	0.079	0.043	0.023		
Ranking		1	2	3	6	4	7	8	5	9	10		

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