Quantitative Evaluation of Website Quality Dimension for Web 2.0 Environment

Rajeev Saha and Sandeep Grover

YMCA University of Science & Technology, Faridabad, Haryana – 121006 INDIA
rajeevsaha@gmail.com, groversandeep@hotmail.com

Abstract

Measuring website quality has been a major concern since the invention of web. Moreover with the advancement of web technology the dimensions to evaluate quality kept on changing. As such it becomes difficult to analyze and focus upon the critical dimensions which should be paid more attention relative to others. Additionally comparing similar websites on quality front need some quantitative approach. In such a scenario, the necessity to develop a quality system model for web 2.0 environment arose which could be pursued quantitatively. Key website quality dimensions are identified and discussed. The effect of interactions of identified website quality dimensions among themselves and overall effect on website quality has been quantified. The purpose of this paper is to represent the effect of 'website quality dimension in web 2.0 environment' in terms of a single numerical index by considering their inheritances and interactions. The practical implication of this approach is to provide a methodology for website managers in order to evaluate key quality attributes affecting overall website quality.

Keywords: *Web 2.0 environment, website quality, graph theory*

1. Introduction

With increasing rate of growth of rich internet applications, the factors defining its environment change in continuum. Many factors considered important during web 1.0 environment seem trivial in web 2.0 environment.

Web 2.0 environment generally employ combination of one or more technologies such as AJAX (Asynchronous JavaScript And XML (Extended Mark-up Language)), Mash up, Flux, etc. in website development, providing richer user experiences through robust functions and elegant user interfaces [1-3]. The focus of such development is getting real time interactions between websites and users or among users, thereby enhancing the website quality and rich user experience.

Web 2.0 environments are all about harnessing collective intelligence. Collective intelligence applications depend on managing, understanding, and responding to massive amounts of user-generated data in real time. Thus, real time data usage is the backbone of the next generation of web 2.0 applications.

The most significant characteristics that a core 'Web 2.0 service' portrays could be summarized as:

a) Web as Platform: Applications based on web 2.0 need not rely on the browser of a particular operating system (Mac, Mobile based or Windows). Contrary to the earlier concept of relying heavily on downloading supportive programs onto the desktop for

accessing various web applications, Web 2.0 services don't require a client download condition. The web 2.0 applications are self-reliant with its own environment working as its platform. With Cloud computing on a roll, more and more web services are taking the route of SaaS (Software as a Service). Software's are available as a web service with no platform dependency at all.

b) User-centered Design: The attraction of a webpage depends upon the user's empowerment to perform certain customizations within the design. The appearance of the design may thus be altered according to a user preference. User-centered designs are cleaner, often AJAX based and easy to navigate. One of the most appropriate examples of a User-centered design is iGoogle, a customizable Google homepage.

c) Rich User Experience: A great user experience plays a vital role in making users come back again to the web service. Use of XHTML, CSS 2.0, Ajax, flex, Mash up and similar other rich media producing technologies have potentially helped making web services lighter, faster, less cluttered and more appealing to the end user.

d) Crowd-sourcing: Web 2.0 services are highly dynamic and proactive due to user's contribution and active participation towards its contents. Millions of such contributions eventually lead the website to state of higher relevance. Blogs are producing extremely frequent and relevant content as millions of users are acting as a contributor, building up a large resource within much lesser span of time.

e) Collaboration: Collaboration is the process of extraction of useful content from content provider website and displaying it on some other website. The content being regularly checked and updated by concerned users or content providers, the information provided is of good quality. Wikipedia is one such example of collaboration.

Little research exists which considers web 2.0 environment variables as being interdependent and studies them as a system. So this paper tries to develop a theoretical framework that holistically considers quality dimensions of web 2.0 environment and their interrelationships.

The major objectives of this study can be stated as:

- To identify the variables that may impact the web 2.0 environment
- develop a conceptual framework that could effectively analyze the interrelationships among the identified variables and
- suggest a metric to quantify variables of web 2.0 environment.

2. Website Quality Dimension

The exponential growth in web users resulted in better managed and technology oriented user-friendly interface giving birth to web 2.0 era characterized by a highly interactive environment.

The term Web 2.0 is associated with web applications that facilitate participatory information sharing, interoperability, user-centered design, and collaboration on the World Wide Web.

Web 2.0 can be described in 3 parts which are as follows [4]:

a) Rich Internet application (RIA) — defines the experience brought from desktop to browser whether it is from a graphical point of view or usability point of view. Some buzzwords related to RIA are Ajax and Flash.

b) Service-oriented architecture (SOA) — is a key piece in Web 2.0 which defines how Web 2.0 applications expose their functionality so that other applications can leverage and integrate the functionality providing a set of much richer applications (Examples are: Feeds, RSS, Web Services, Mash-ups)

c) Social Web — defines how Web 2.0 tends to interact much more with the end user and make the end-user an integral part.

Web 2.0 being an emerging paradigm that is intertwined with the change in the Internet culture and the progress in the Internet technologies, all the dimensions mentioned in the prior studies are not applicable in Web 2.0 environment. One of the reasons is that some of the dimensions became redundant or insignificant with the progress in the internet technologies. Second reason could be attributed to the fact that most of the studies were focused on a specific type of website and hence were not applicable in all websites. Also, the emotional factor was used sparingly in few papers with limited set of criteria.

Evaluation of website quality in Web 2.0 environment needed a broader and general collection of criteria applicable for all type of websites. The limitations in previous studies and the changes that Web 2.0 paradigm has brought call for identifying new website quality dimensions appropriate for Web 2.0 environment.

Identification process for appropriate dimensions has been conducted in three steps. First the conceptual and operational definitions of dimensions from previous papers were examined thoroughly. Second, trivial dimensions and dimensions specific to a particular type of website were eliminated. Third, dimensions with similar meanings were grouped and synthesized into final dimensions. The final list of dimensions produced following above process is listed in Table 1 and discussed below.

2.1 Interface

The interaction with a website using its front-end aspects constitutes interface. In Web 2.0 environment, the interface quality becomes more essential with an increase in users' demand for more effective interactions [5]. Interface quality can be classified into proximity, compatibility, navigation, appearance, and layout dimensions.

Proximity: means the degree to which users can locate to reach a website either through search engines or easily remembered URL.

Compatibility: is the degree to which a website can be accessible and usable in various sorts of user environment such as Web browsers or operating systems. In the era of Web 2.0 which emphasizes the use of standardized technologies in website development, the website services should work regardless of type of operating systems (OS) or Web browsers users' use. Also, users need to easily transfer data between different devices such as mobile phones through Web regardless of OS platform [3]. This compatibility allows getting more contents users, that is, customers in Web 2.0 environment.

Navigation: refers to the degree to which the sequence of pages is properly arranged, and navigation-related components such as links, labels, or site maps are consistently

and efficiently used. The links between pages in a website should be properly organized and text labels or image icons of the links should correctly indicate where the links connect so that users can navigate wherever they want to go [6]. In web 2.0 though, the navigation is heading towards dynamic nature wherein each user will have certain links as per their interest.

Appearance: 'Appearance' means the degree to which color, graphics, images, font, style, and animations are properly and consistently used. A website should display visually appealing design [7]. For this purpose RIA (Rich Internet Application), providing richer user interface, has been realized in Web 2.0 environment with the use of Ajax, Adobe Flex, Microsoft Silverlight, etc. [3, 8].

Layout: 'Layout' implies the degree to which visual elements such as texts, forms, frames, or tables are well placed and organized in a page to be easily recognizable and usable to user. The goals of proper layout are simplicity, consistency, and focus [6]. Nonetheless, layout needs to be designed to effectively reflect the purpose and strategy of a website [9].

2.2 Performance

The performance quality dimension may consist of availability, efficiency, reliability, security and collaboration.

Availability: 'Availability' means whether a website is available and accessible in 24 hours a day and 365 days a year. Frequent interruptions of website services put the reputation of a company at stake. The website should make considerable efforts to minimize the closing time and notify users well in advance.

Efficiency: 'Efficiency' is the degree to which a website is accessible efficiently with minimum or no delay. Some literature referred to efficiency as 'performance' [10], or 'download delay' [11].

Reliability: 'Reliability' implies the degree to which a website can perform as intended correctly and consistently without any error or breakdown.

Security: 'Security' means the degree to which a website can be robust against all possible attacks or threats from outside and keep private and confidential information securely. Madu and Madu [12] pointed out that users were worried about providing personal information online since it could potentially fall into the wrong hands or be abused. In Web 2.0 environment, it is necessary for website administrators to be more careful against potential information leakage due to XSS (Cross-Site Scripting) attacks against Ajax-established websites [13], social networking service, wikis, RSS (Really Simple Syndication), etc. [14].

Collaboration: Collaboration is the process of working jointly or in partnership for extracting useful information from each other. Wikipedia takes the first place when it comes to proving the power of collaboration. Before 2001 (year of Wikipedia's inception), there used to exist only driven information sources such as Britannica Encyclopedia, About.com and similar other sources, where collaboration was never implemented. Today, Wikipedia stands way ahead in terms of content quantity as well as quality due to collaboration. In Web 2.0 environment, XSS (Cross-Site Scripting), wikis, RSS (Really Simple Syndication), etc. are widely used for collaboration purpose [14].

2.3 Information

Information quality is substantially required for not only the success of information-extensive websites such as news and investor relations websites but also that of transaction-extensive websites such as Internet shopping or online stock exchange websites, since users generally seek information about products and services before making purchasing decisions.

Businesses based on Web 2.0 business (often called as Web 2.0 Company) in particular need to develop their own information for business success [2].

Completeness: 'Completeness' means the degree to which a website offers a broad range of information which is relevant to users' needs. In the Web 2.0 environment, numerous users can actively produce information and knowledge through the Collective intelligence, so that the completeness of information is enhanced.

The process of creating new, complete information has been constantly improved with collective intelligence achieved through user interaction in Web 2.0.

Timeliness: 'Timeliness' is the degree to which a website provides current and up-to-date information. Web 2.0 brings new technologies like blog and RSS to bridge gap between information providers and consumers in a real-time basis, so that the timeliness of information can be significantly improved.

Comprehensibility: 'Comprehensibility' implies the degree to which information a website exhibits is sufficiently understandable even to users who have little background knowledge.

Trustworthy: 'Trustworthy' means the degree to which information in a website is accurate, credible, and verified.

Presentation Variability: 'Presentation variability' is the degree to which a website presents information in various sorts of format. Few authors have written this factor as 'representational' [15-17].

Architecture: 'Architecture' implies the degree to which information in a website is suitably structured so that users can easily access information they seek.

Search Capability: 'Search capability' means whether a website facilitates search function or engine and the degree to which search results are accurate and relevant to users' intention. In the Web 2.0 environment, new technologies are emerging to help users search more easily, such as recommendations for better key words.

2.4 Service

The service quality dimensions focus on how satisfactorily a website fulfills services. In Web 2.0 environment, users, which are main producers and consumers of contents, share their opinions actively about website services, which greatly affect the success of websites. This service quality dimensions may include customization, support, channel diversity, responsiveness, incentive, and compensation.

Customization: 'Customization' means the degree to which a websites provides a user with contents and interface customized according to the user's particular characteristics or needs. Many studies have mentioned that customization is an important driver of the success of websites [12, 18-19].

Support: 'Support' is the degree to which a website facilitates supportive information or learning tools which can contribute to enhancing users' understanding to the website.

Channel Diversity: 'Channel diversity' implies the degree to which a website offers a variety of channels which enable users to contact staffs conveniently. To make users able to contact administrators of a website whenever they want, the website should offer various channels such as an email sending form, a built-in board system, or an online chatting function.

Responsiveness: 'Responsiveness' means the degree to which a website fulfills users' requests or questions promptly. Complaints from customers must be taken care of immediately through the cooperation between website administrators and staffs in back-end office.

Incentive: 'Incentive' is a benefit given by a website that encourages users to visit it continuously and enhances users' satisfaction and loyalty to the website [7, 20].

Communication: 'Communication' implies the degree to which a website educates and informs users in a language they can understand. This dimension is very important.

2.5 Emotional

Emotional quality has become an important and significant consideration for the success of a website. In this context, Jarvenpaa and Todd [21] contended that customers are satisfied by not only an extrinsic reward in purchasing products or services but also personal and emotional reward from a purchasing-derived pleasure. Emotional aspects were stressed by Heijden [22] as well, stating that websites serve hedonic purposes as well as utilitarian ones. The emotional quality dimension consists of factors as assurance, empathy, interaction, playfulness, and emotion.

Assurance: 'Assurance' means the extent to which staffs of a website are knowledgeable about their operation and courteous in their responses and can convey trust and confidence to users. Madu and Madu [12] pointed out that many virtual operations on websites rarely encouraged any direct communication except through e-mail services and stressed that they should make considerable efforts to provide impeccable responses to users.

Empathy: 'Empathy' is the extent to which a website can provide caring and individualized attention to customers' concerns and requests. Madu and Madu [12] emphasized that such individualized attention is more effective than typical automatic responses in conveying empathy to the customers; such attention of a website should be cognizant of users' needs and express concern and understanding of their needs.

Table 1 List of References for Website Quality Factors Identification

S.No.	Factor	Reference Paper
1	Proximity	[7, 25-26]
2	Compatibility	[10, 17, 25]
3	Navigation	[7, 11, 17, 25-34]
4	Appearance	[7, 17, 25, 35-36]
5	Layout	[7, 10, 15, 25, 36-37]
6	Availability	[7, 20, 25, 29, 31-33, 38-41, 43-45]
7	Efficiency	[7, 20, 24-25, 29-30, 32, 36-38, 46-48]

8	Reliability	[12, 16-17, 25, 28-32, 36-39, 41, 43-51]
9	Security	[7, 10, 12, 15-16, 24-25, 29, 33-34, 36, 38, 40-44, 46-52, 54]
10	Collaboration	[32]
11	Completeness	[7, 15-17, 19, 24-25, 38, 49]
12	Timeliness	[7, 15-16, 24-25, 38]
13	Comprehensibility	[7, 16, 25, 32, 38]
14	Trustworthy	[7, 12, 16, 19, 25, 53]
15	Presentation Variability	[15-17, 25, 30-32]
16	Architecture	[7, 10, 25, 37]
17	Search Capability	[7, 17, 25, 30-35, 39, 54]
18	Customization	[7, 12, 25]
19	Support	[24-25, 36]
20	Channel Diversity	[7, 24-25]
21	Responsiveness	[7, 11-12, 16, 20, 24-25, 38, 50, 53]
22	Incentive	[24-25, 36]
23	Communication	[7, 19, 25, 36]
24	Assurance	[12, 16, 24-25, 38]
25	Empathy	[12, 16, 24-25, 38, 50, 53]
26	Intimacy	[7, 24-25]
27	Playfulness	[24-25]
28	Emotion	[18-19, 25]

Intimacy: 'Intimacy' implies the degree to which make users feel a close relationship with or affection to a website through interactive processes. Intimacy can be developed while users are interacting with others through active communications. These kinds of interactions are not only one of the most significant characteristics of Web 2.0, but also the fundamental reason for Web 2.0 to be called "Social Web" [23].

Playfulness: 'Playfulness' means the degree to which a website can amuse or entertain users. Liu and Arnett [24] stressed that website designers needed to consider hedonic pleasure seriously in designing a website by motivating customers to participate, by promoting customer excitement and concentration, and by including charming features to attract customers and to make them enjoy the visit.

Emotion: 'Emotion' denotes the extent to which a website evokes emotional reactions from users. Agarwal and Venkatesh [18] included this dimension in their research, and described that its components include challenge, plot, character strength, and pace.

3. Methodology

In our case the purpose is to quantify the factors affecting web 2.0 environment. This depends upon the degree of inheritance of various variables and the amount of interactions present between them. The quantification of inheritances and interactions is not possible by using Delphi, AHP (Analytic Hierarchy Process), ANP (Analytic Network Process), SEM (Structural Equation Modeling) or fuzzy logic. While using graph theory and matrix method the interactions among the variables can be easily analyzed and they can even be transformed into mathematical equations. This would enable web management team to understand the contribution of various factors towards successful implementation of web 2.0 based application.

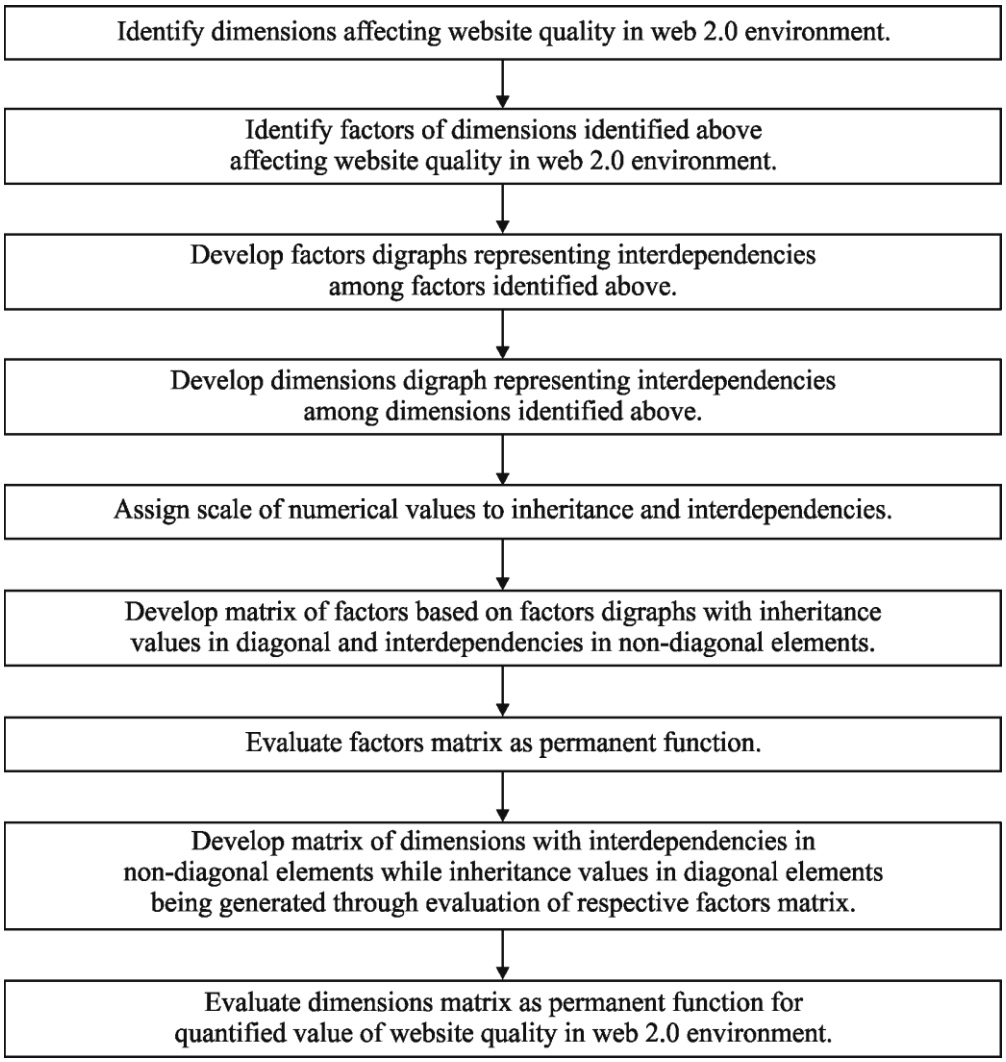

Fig 1 Block Diagram of Methodology for Quantification of Web Quality

Fig 1 represent Block Diagram of methodology employed for quantification of website quality in web 2.0 environment. The graph theory and matrix methods consist of the digraph representation, the matrix representation and the permanent function representation. The digraph is the visual representation of the variables and their interdependencies. The matrix converts the digraph into mathematical form and the permanent function is a mathematical representation that helps to determine the numerical index. This paper aims to extend this approach for the analysis, quantification and comparison of factors in web 2.0 environment.

4. Development of Graph Theoretic Model

As suggested by the literature review on web quality dimensions we can broadly classify them under five major headings viz. interface, information, performance, service and emotional.

Thus,

WQE = *f* {web quality dimensions}

= *f* { *f* (interface), *f* (performance), *f* (information), *f* (service), *f* (emotional)}

Where,

f (interface) = *f* (proximity, compatibility, navigation, appearance, layout)

f (performance) = *f* (Availability, Efficiency, Reliability, Security, Collaboration)

f (information) = *f* (Completeness, Timeliness, Comprehensibility, Trustworthy, Presentation Variability, Architecture, Search Capability)

f (service) = *f* (Customization, Support, Channel Diversity, Responsiveness, Incentive, Communication)

f(emotional) = *f* (Assurance, Empathy, Intimacy, Playfulness, Emotion)

The above dimensions can be represented in the form of 'cause and effect' diagram for website quality in web 2.0 environments as shown in Fig 2.

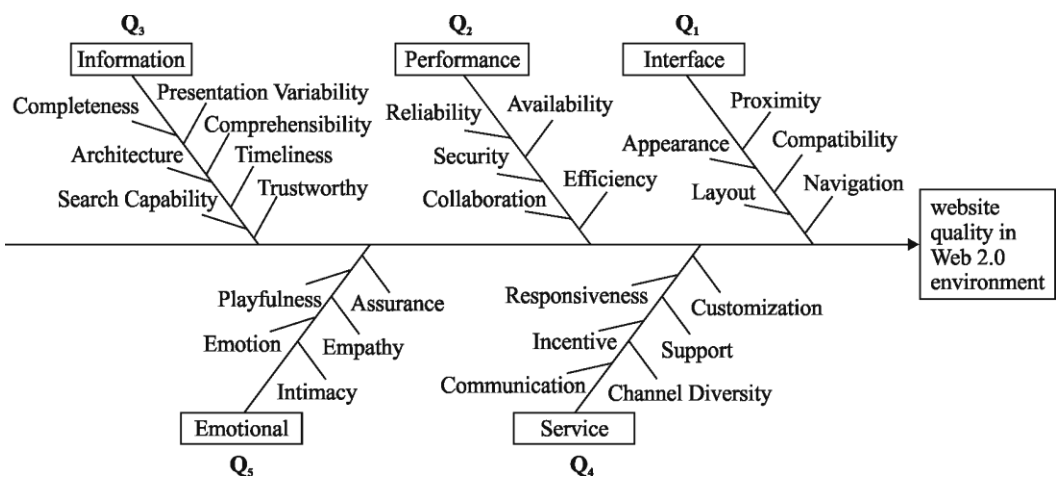

Fig 2 Cause and Effect Diagram for Website Quality in Web 2.0 Environment

4.1 Web Quality Digraph

A digraph consists of a set of nodes N = [Q_i], with i = 1, 2, …, m and a set of directed edges D = [Q_{ij}]. The direction of edge Q_{12} from node Q_1 to node Q_2 indicates the dependency of Q_2 on Q_1 that is, Q_1 impacts Q_2. It is possible that any two variables (Q_i and Q_j) of a variables digraph are interdependent on one another. This is represented by joining two nodes (Q_i and Q_j) by two directed edges (Q_{ij} and Q_{ji}) in the opposite directions forming a close loop. Web quality digraph represents 5 dimensions and factors contained by these dimensions as identified in the 'website quality dimension' section and their degree of interdependencies.

The interdependencies among these dimensions are developed with the help of expert opinion. A small workshop was conducted where experts from the field and academia participated. Before the workshop, visits in website development companies were conducted to comprehend the view of the developers on web quality issues. Further a brief description of

web quality dimensions and related factors as deduced from the literature review was sent to these experts to familiarize them with the formal terminology. The relationships among these variables are then expressed through structural self interaction matrix as given in Table 2 and digraph representation as shown in Fig 3.

Table 2 Structural Self Interaction Matrix

WQE dimensions	Q_2	Q_3	Q_4	Q_5
Q_1 (Interface)	V	V	V	V
Q_2 (Performance)		X	A	A
Q_3 (Information)			X	A
Q_4 (Service)				V
Q_5 (Emotional)				

Four symbols are used to denote the direction of relationship between the dimensions (i & j):

V: variable i will help to achieve variable j;

A: variable i will be achieved by variable j;

X: variable i and j will help achieve each other and

O: variables i and j are unrelated.

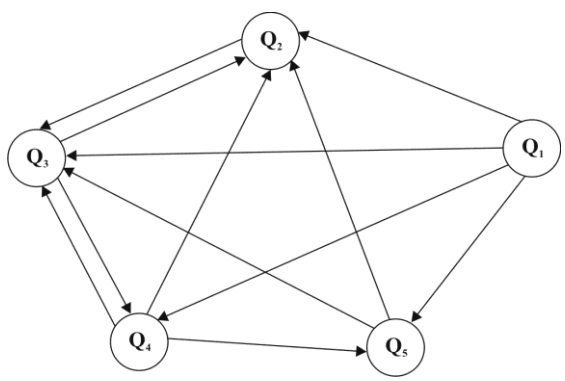

Fig 3 Digraph for Web 2.0 Quality Dimensions

4.2 Web Quality Matrix Representation

Consider a matrix A with off-diagonal elements Q_{ij} representing interactions between WQE dimensions. Other matrix B is taken with diagonal elements Q_i, i = 1, 2, 3, 4, 5 where Q_i represent the effect of individual dimensions. Thus, the variable permanent matrix for web 2.0 quality environment (VPM-WQE) corresponding to the five variables WQE digraph (Fig 3) is given by

$$VPM-WQE=[A+B]=\begin{bmatrix} Q_1 & Q_{12} & Q_{13} & Q_{14} & Q_{15} \\ 0 & Q_2 & Q_{23} & 0 & 0 \\ 0 & Q_{32} & Q_3 & Q_{34} & 0 \\ 0 & Q_{42} & Q_{43} & Q_4 & Q_{45} \\ 0 & Q_{52} & Q_{53} & 0 & Q_5 \end{bmatrix} \quad (1)$$

4.3 Web Quality Variable Permanent Matrix

The permanent is a standard matrix function and is used in combinatorial mathematics [55-56]. The permanent function is obtained in a similar manner as the determinant but unlike in a determinant where a negative sign appears in the calculation, in a variable permanent function positive signs replace these negative signs. Quantitative WQE evaluation of web 2.0 quality environments is obtained from VPF-WQE by substituting numerical values of the Q_i's and Q_{ij}'s which can be obtained analytically or by comparing to ideal cases. This single numerical index is the representation of a typical web 2.0 quality environment in quantitative terms. The VPF-WQE expression corresponding to the five-factors is given by

$$
\begin{aligned}
VPF-WQE = Per(Q) &= \prod_{i=1}^{5} Q_i + \sum_1\sum_2\sum_3\sum_4\sum_5 (Q_{12}Q_{21})Q_3Q_4Q_5 \\
&+ \sum_1\sum_2\sum_3\sum_4\sum_5 (Q_{12}Q_{23}Q_{31} + Q_{13}Q_{32}Q_{21})Q_4Q_5 \\
&+ \left\{ \begin{array}{l} \sum_1\sum_2\sum_3\sum_4\sum_5 (Q_{12}Q_{21})(Q_{34}Q_{43})Q_5 \\ + \sum_1\sum_2\sum_3\sum_4\sum_5 (Q_{12}Q_{23}Q_{34}Q_{41} + Q_{14}Q_{43}Q_{32}Q_{21})Q_5 \end{array} \right\} \\
&+ \left\{ \begin{array}{l} \sum_1\sum_2\sum_3\sum_4\sum_5 (Q_{12}Q_{21})(Q_{34}Q_{45}Q_{53} + Q_{35}Q_{54}Q_{43}) \\ + \sum_1\sum_2\sum_3\sum_4\sum_5 (Q_{12}Q_{23}Q_{34}Q_{45}Q_{51} + Q_{15}Q_{54}Q_{43}Q_{32}Q_{21}) \end{array} \right\}
\end{aligned}
\tag{2}
$$

Each term serves as a test for the effectiveness of the relevant group in Per (Q).

Equation II contains terms arranged in 5 groups. The physical significance of various grouping is explained as follows.

– The first term (grouping) represents a set of 5 unconnected elements, i.e. Q_1, Q_2, Q_3, Q_4, Q_5.

– The second grouping is absent in the absence of self-loops.

– Each term of the third grouping represents a set of two-element WQE loops (i.e. Q_{12} Q_{21}) and is the resultant WQE dependence of characteristics i and j and the WQE measure of the remaining 3 unconnected elements.

– Each term of the fourth grouping represents a set of three-element WQE loops (Q_{12} Q_{23} Q_{31} or its pair Q_{13} Q_{32} Q_{21}) and the WQE measure of the remaining 2 unconnected elements.

– The fifth grouping contains two subgroups. The terms of the first sub-group consist of two-element WQE loops (i.e. $Q_{12}Q_{21}$ and $Q_{34}Q_{43}$) and WQE component (Q_5). The terms of the second sub-group are a product of four-element WQE loops (i.e. Q_{12} Q_{23} Q_{34} Q_{41}) or its pair (i.e. Q_{14} Q_{43} Q_{32} Q_{21}) and WQE component (i.e.Q_5).

– The terms of the sixth grouping are also arranged in two sub-groups. The terms of the first sub-group are a product of a two-element WQE loop (i.e. Q_{12} Q_{21}) and a three-element

WQE loop (i.e. Q_{34} Q_{45} Q_{53}) or its pair (i.e.Q_{35} Q_{54} Q_{43}). The second sub-group consists of a five-component WQE loop (i.e. Q_{12} Q_{23} Q_{34} Q_{45} Q_{51}) or its pair (Q_{15} Q_{54} Q_{43} Q_{32} Q_{21}).

4.4 Quantification of Web Quality Environment

The diagonal elements in VPM-WQE (equation I) representing interactions of dimensions of website quality in web 2.0 environment need to be assigned its importance weight. The quality dimensions identified may not be equally important to achieve website quality in web 2.0 environment. Hence a suitable scale may be used to assign weights to each dimension. A scale has been suggested in Table 3 for the purpose. Similarly each factor identified within each dimension may be assigned weights as suggested in Table 4.

Table 3 Inheritance of Web 2.0 Quality Environment Variables

S. No.	Qualitative measure of web quality dimension	Assigned value of web quality dimension
1	Exceptionally low	1
2	Very low	2
3	Low	3
4	Below average	4
5	Average	5
6	Above average	6
7	High	7
8	Very high	8
9	Exceptionally high	9

Table 4 Interdependence of Web 2.0 Quality Environment Variables

S. No	Qualitative measure of interdependencies	q_{ij}
1	Very strong	5
2	Strong	4
3	Medium	3
4	Weak	2
5	Very weak	1

5. Demonstration

For demonstration of the proposed methodology, consider a website as an example (say http://www.facebook.com). It is proposed to find the value of web quality index. For determining the index we require numerical values of all variables and their interdependencies, i.e. all values in web quality environment - variable permanent matrix (equation 1). The value of diagonal elements in the VPM-WQE, i.e. the value of web quality variables Q_1,Q_2. . .Q_6 are evaluated by applying graph theoretic methodology. The evaluation of web quality dimension is done as discussed in previous section.

Step 1: The various dimensions affecting website quality in web 2.0 environment are identified in Fig 2.

Table 5 Interdependency of Web Quality Dimensions in Web 2.0 Environment

S.No.	Dimension	Factors	Degree of influence of web quality dimension j on i				
			very strong (q_{ij} = 5)	Strong (q_{ij} = 4)	Medium (q_{ij} = 3)	Weak (q_{ij} = 2)	very weak (q_{ij} = 1)
Q_1	Interface	Proximity Compatibility Navigation Appearance Layout					
Q_2	Performance	Availability Efficiency Reliability Security Collaboration	Q_3, Q_4, Q_5	Q_1			
Q_3	Information	Completeness Timeliness Comprehensibility Trustworthy Presentation Variability Architecture Search Capability			Q_5	Q_1, Q_2	Q_4
Q_4	Service	Customization Support Channel Diversity Responsiveness Incentive Communication		Q_1	Q_3		
Q_5	Emotional	Assurance Empathy Intimacy Playfulness Emotion	Q_4		Q_1		

Step 2: The factors affecting the website quality dimensions have been discussed earlier in 'website quality dimension' section in this paper and are listed in Table 5, showing the degree of influence of web quality dimensions on each other.

Equation 1 may thus be filled with numeric values using Table 5 as shown below:

$$VPM - WQE = \begin{bmatrix} Q_1 & 4 & 2 & 4 & 3 \\ 0 & Q_2 & 2 & 0 & 0 \\ 0 & 5 & Q_3 & 3 & 0 \\ 0 & 5 & 1 & Q_4 & 5 \\ 0 & 5 & 3 & 0 & Q_5 \end{bmatrix} \quad (3)$$

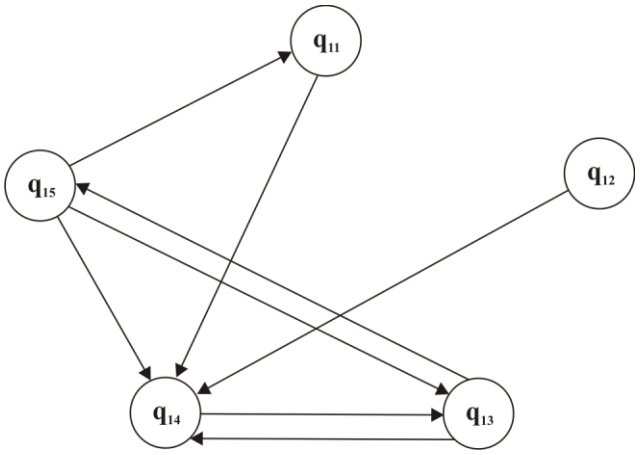

Fig 4 Digraph for factors of interface dimension

Step 3: The dependencies of factors at subsystem level are visualized through digraphs shown in Fig 4 to Fig 8. The first digit of the subscript indicates the website quality dimension while second digit indicates the factor affecting the dimension. As explained the nodes in the digraph represent attributes identified in each factor. The interaction among attributes is represented by edges.

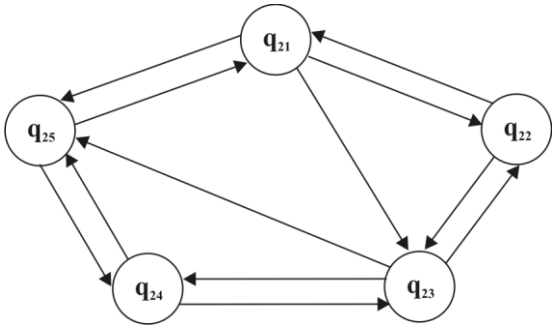

Fig 5 Digraph for factors of performance dimension

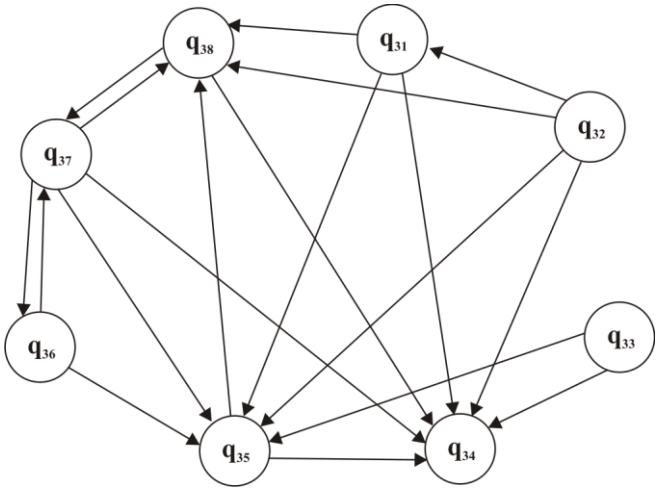

Fig 6 Digraph for factors of information dimension

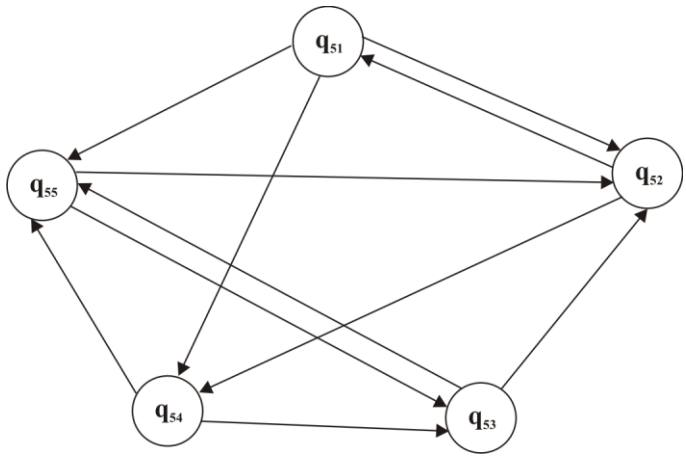

Fig 7 Digraph for factors of service dimension

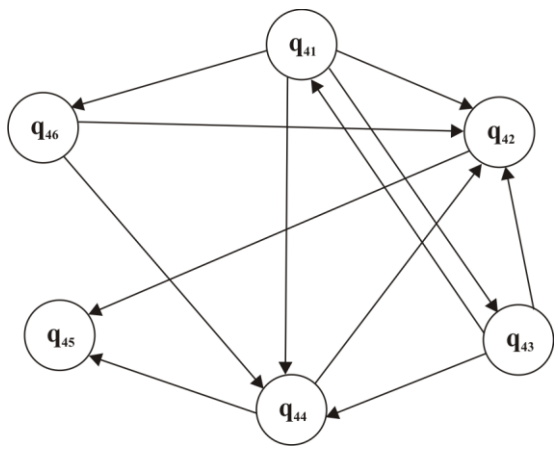

Fig 8 Digraph for factors of emotional dimension

Step 4: At subsystem level, the variable permanent matrix needs to be calculated for each subsystem based on their digraphs. For subsystem 1 (Fig 4), the values taken from Table 3 are $Q_1 = 3$, $Q_2 = 8$, $Q_3 = 6$, $Q_4 = 8$, $Q_5 = 7$. The values taken from Table 4 are $Q_{14} = 3$, $Q_{24} = 3$, $Q_{34} = 2$, $Q_{35} = 5$, $Q_{43} = 2$, $Q_{51} = 2$, $Q_{53} = 3$, $Q_{54} = 5$. The variable permanent matrix for subsystem 1 after substituting these values is written as shown in equation 4.

$$VPM - WQE_1 = \begin{array}{c|c} \begin{matrix} 1 & 2 & 3 & 4 & 5 \end{matrix} & Factor \\ \begin{bmatrix} 3 & 0 & 0 & 3 & 0 \\ 0 & 8 & 0 & 3 & 0 \\ 0 & 0 & 6 & 2 & 5 \\ 0 & 0 & 2 & 8 & 0 \\ 2 & 0 & 3 & 5 & 7 \end{bmatrix} & \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{matrix} \end{array} \tag{4}$$

Similarly, variable permanent matrix for other subsystem (Fig 5 – 8) has been written below (Eq. 5 – 8)

$$VPM-WQE_2 = \begin{array}{c|c} \begin{matrix} 1 & 2 & 3 & 4 & 5 \end{matrix} & Factor \\ \hline \begin{bmatrix} 8 & 3 & 5 & 0 & 4 \\ 3 & 5 & 4 & 0 & 0 \\ 0 & 5 & 6 & 2 & 3 \\ 0 & 0 & 5 & 5 & 3 \\ 1 & 0 & 0 & 1 & 3 \end{bmatrix} & \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{matrix} \end{array} \tag{5}$$

$$VPM-WQE_3 = \begin{array}{c|c} \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \end{matrix} & Factors \\ \hline \begin{bmatrix} 8 & 0 & 0 & 3 & 3 & 0 & 0 & 5 \\ 2 & 7 & 0 & 4 & 3 & 0 & 0 & 3 \\ 0 & 0 & 8 & 5 & 2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3 & 5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 3 & 3 & 2 & 0 \\ 0 & 0 & 0 & 2 & 2 & 2 & 5 & 5 \\ 0 & 0 & 0 & 4 & 0 & 0 & 3 & 7 \end{bmatrix} & \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{matrix} \end{array} \tag{6}$$

$$VPM-WQE_4 = \begin{array}{c|c} \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \end{matrix} & Factor \\ \hline \begin{bmatrix} 5 & 2 & 2 & 3 & 0 & 3 \\ 0 & 7 & 0 & 0 & 2 & 0 \\ 2 & 2 & 5 & 3 & 0 & 0 \\ 0 & 3 & 0 & 7 & 2 & 0 \\ 0 & 0 & 0 & 0 & 3 & 0 \\ 0 & 3 & 0 & 5 & 0 & 5 \end{bmatrix} & \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix} \end{array} \tag{7}$$

$$VPM-WQE_5 = \begin{array}{c|c} \begin{matrix} 1 & 2 & 3 & 4 & 5 \end{matrix} & Factor \\ \hline \begin{bmatrix} 7 & 3 & 0 & 2 & 3 \\ 3 & 8 & 0 & 1 & 0 \\ 0 & 2 & 7 & 0 & 4 \\ 0 & 0 & 3 & 4 & 3 \\ 0 & 3 & 4 & 4 & 7 \end{bmatrix} & \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{matrix} \end{array} \tag{8}$$

Step 5: Evaluating variable permanent matrix at subsystem level (Eq. 4 – 8) the current value obtained for each may be summarized as:

$VPM\text{-}WQE_1 = 13296$

$VPM\text{-}WQE_2 = 14004$

$VPM\text{-}WQE_3 = 1.9936 \times 10^6$

$VPM\text{-}WQE_4 = 21315$

$VPM\text{-}WQE_5 = 28885$

To obtain value of website quality in web 2.0 environment, above values may be substituted in Eq. 3, replacing Q_1 with value of $VPM\text{-}WQE_1$ and so on. The value obtained is

$VPM\text{-}WQE = 2.28543 \times 10^{23}$

Step 6: For the scope of further improvement, it is suggested to find hypothetical best and hypothetical worst value of website quality index in web 2.0 environment. This can be done by substituting highest assigned value of website quality dimension from Table 3 for inheritance (i.e. 9) at subsystem level to obtain maximum value. Similarly substitute lowest value from Table 3 for inheritance (i.e. 1) at subsystem level to obtain minimum value. The values thus obtained have been summarized in Table 6.

Table 6 Values for Current, maximum and minimum website quality index in web 2.0 environment

System/Subsystem	Current value	Maximum value	Minimum value
WQE_1	13296	77490	130
WQE_2	14004	105087	1247
WQE_3	1.9936×10^6	5.3144×10^7	20
WQE_4	21315	557685	9
WQE_5	28885	98586	1610
WQE	2.28543×10^{23}	2.3793×10^{28}	4.7795×10^{10}

6. Conclusion

This paper tries to model website quality in web 2.0 environment using graph theory and matrix method. This is a simple tool by which website designers and developers can easily analyze the variables responsible for website quality in web 2.0 environment. The quantification of website quality in web 2.0 environment by single numerical index is an effective aid in improving the understanding of various dimensions and underlying factors. The suggested methodology would also help to benchmark and compare various websites quality in web 2.0 environment.

The proposed selection procedure using digraph and matrix methods can be used for any type of decision making situation and has an edge over the multiple attribute decision making (MADM) methods. The computation used is straight forward as compared to MADM methods. Also, it enables a more critical analysis than the MADM methods since any number of quantitative and qualitative attributes can be conveniently considered. In the permanent procedure, even a small variation in the attributes leads to a significant difference in the selection index and hence it is easy to rank the alternatives in the descending order with clear-cut difference in the selection index. Further, the proposed procedure not only provides the analysis of the alternatives, but also enables the visualization of various attributes present and their interrelations, using the graphical representation. The measures of the attributes and their relative importance are used together to rank the alternatives and hence it provides a better evaluation of the alternatives. The check for the consistency made in the judgments of relative importance adds advantage to the proposed selection procedure. The use of permanent concept helps in better appreciation of the attributes and it characterizes the considered selection problem as it contains all possible structural components of the attributes and their relative importance.

The current value of website quality index for the considered example is 2.28543 x 10^{23} which is less than the maximum attainable value of 2.3793 x 10^{28} though much better than the minimum value of 4.7795 x 10^{10}. The values obtained suggest overall scope of improvement in website quality as per identified dimensions. The best value for the emotional dimension was obtained for considered website.

$$OpportunityLoss = \frac{MaximumValue - CurrentValue}{MaximumValue - MinimumValue}$$

The result shown in Table 6 may further be evaluated to provide overview of shortcomings in system or subsystem. For this purpose we calculate opportunity loss and opportunity gain in maintaining web quality. Opportunity loss in maintaining web quality shows the percentage by which we lag to reach the maximum value of web quality index. Similarly, opportunity gain in maintaining web quality shows the percentage gained with respect to minimum value of web quality index.

$$OpportunityGain = \frac{CurrentValue - MinimumValue}{MaximumValue - MinimumValue}$$

The maximum value for opportunity gain is 28.126% for WQE5 (Emotional). This maximum value actually depicts the percentage by which it has already treaded the path and need less attention. On the other hand system or subsystem having low value of performance opportunity gain needs more attention to the amount of percentage shown in the performance opportunity loss column. For WQE3 and WQE4, the opportunity loss stands at 96.249% and 96.180% respectively suggesting more attention. The overall value of opportunity loss for web quality index stands at 99.999% which being very low, requires urgent attention towards dimensions having greater opportunity loss.

Table 7 Values for Opportunity loss and gain in maintaining web quality

System / Subsystem	Opportunity Loss	Opportunity Gain
WQE_1	82.981%	17.019%
WQE_2	87.715%	12.285%
WQE_3	96.249%	3.751%
WQE_4	96.180%	3.820%
WQE_5	71.874%	28.126%
WQE	99.999%	0.001%

The proposed structural approach based on digraph and matrix method for the evaluation of website quality in web 2.0 environment has the following features:

- It identifies general factors pertaining to website quality.
- It permits modeling of dependence among factors.
- Application of graph theoretic approach makes it convenient for visual analysis and computer processing.
- The success of an online venture is pronounced by the presence of web quality factors as indicated by the single numerical index.

- It permits self-analysis and comparison of websites.
- Cause and effect analysis is useful in improving the website quality.
- Systematic methodology for conversion of qualitative factors to quantitative values and mathematical modeling gives an edge to the proposed technique over conventional methods.

There were other techniques like Delphi, AHP, ANP, SEM or fuzzy logic that could have been used to deal with critical factors of website performance. But, the quantification of inheritances and interactions is not possible by using these techniques. While using graph theory and matrix method the interactions among the variables can be easily analyzed and they can even be transformed into mathematical equations.

In future, this study can be further continued by studying factors specific to a particular type of domain in web 2.0 environment. A corrective mechanism could also be subject of study by gathering data pertaining to user's pattern and feedback towards underlying dimensions.

References

[1] Murugesan, S.: Understanding Web 2.0. IT Professional, 9(4), 34–41 (2007). doi:10.1109/MITP.2007.78

[2] O'Reilly, T.: What is Web 2.0 design patterns and business models for the next generation of software. http://oreilly.com/web2/archive/what-is-web-20.html. Accessed June 24, 2011.

[3] Ogawa, H., & Goto, Y.: Web 2.0 book. Tokyo, Japan: Impress Japan Corporation. (2006)

[4] http://en.wikipedia.org/wiki/Web_2.0 Accessed June 24, 2011.

[5] Huang, M., Li, X., & Zeng, X.: Service quality in Web 2.0 electronic commerce: An integrative perspective from typical service and technique-adoption. Paper presented at the International Conference on Wireless Communications, Networking and Mobile Computing, 2007. (2007)

[6] Brinck, T., Gergle, D., & Wood, S. D.: Usability for the Web: Designing Web sites that work. London: Academic Press. (2002)

[7] Kim, J., Lee, J., Han, K., & Lee, M.: Businesses as buildings: Metrics for the architectural quality of Internet business. Information Systems Research, 13(3), 239–254. (2002) doi:10.1287/isre.13.3.239.79

[8] Moroney, L.: Silverlight-Get started building a deeper experience across the Web. MSDN MAGAZINE. http://msdn.microsoft.com/en-us/magazine/cc163404.aspx Accessed June 24, 2011.

[9] Brown, D. M.: Communicating design: Developing Web site documentation for design and planning. Berkely, CA: New Riders. (2007)

[10] Dustin, E., Rashka, J., & McDiarmid, D.: Quality Web systems: Performance, security, and usability. Upper Saddle River, NJ: Addison-Wesley. (2002)

[11] Palmer, J. W.: Web site usability, design, and performance metrics. Information Systems Research, 13(2), 151–167. (2002) doi:10.1287/isre.13.2.151.88

[12] Madu, C. N., & Madu, A. A.: Dimensions of e-quality. International Journal of Quality & Reliability Management, 19(3), 246–258. (2002) doi:10.1108/02656710210415668

[13] Ritchie, P.: The security risks of AJAX/Web 2.0 applications. Network Security, (3): 4–8. (2007) doi:10.1016/S1353-4858(07)70025-9

[14] Espiner, T.: Business warned over Web 2.0 security. http://www.zdnet.co.uk/news/security-management/2007/03/26/businesses-warned-over-web-20-security-39286468/ Accessed June 26, 2011.

[15] Zhang, Y., Zhu, H., Greenwood, S., & Huo, Q.: Quality modeling for Web-based information systems. Paper presented at the 8th IEEE Workshop on Future Trends of Distributed Computing Systems. (2001)

[16] Webb, H. W., & Webb, L. A.: SiteQual: An integrated measure of Web site quality. The Journal of Enterprise Information System, 17(6), 430–440. (2004)

[17] Moustakis, V., Tsironis, L., & Litos, C.: A model of Web site quality assessment. The Quality Management Journal, 13(2), 22–37. (2006)

[18] Agarwal, R., & Venkatesh, V.: Assessing a firm's Web presence: A heuristic evaluation procedure for the measurement of usability. Information Systems Research, 13(2), 168–186. (2002) doi:10.1287/isre.13.2.168.84

[19] Kim, S., & Stoel, L.: Dimensional hierarchy of retail Web site quality. Information & Management, 41, 619–633. (2004) doi:10.1016/j.im.2003.07.002

[20] Parasuraman, A., Zeithaml, V. A., & Malhotra, A.: E-S-QUAL: A multiple-items scale for assessing electronic service quality. Journal of Service Research, 7(3), 213–233. (2005) doi:10.1177/1094670504271156

[21] Jarvenpaa, S. L., & Todd, P. A.: Consumer reactions to electornic shopping on the World Wide Web. International Journal of Electronic Commerce, 2(1), 59–88. (1997)

[22] Heijden, H. d.: User acceptance of hedonic information systems. MIS Quarterly, 28(4), 695–704. (2004)

[23] Boulos, M. N. K., & Wheeler, S.: The emerging Web 2.0 social software: An enabling suite of sociable technologies in health and healthcare education. Health Information and Libraries Journal, 24(1), 2–23. (2007) doi:10.1111/j.1471-1842.2007.00701.x

[24] Liu, C., & Arnett, K. P.: Exploring the factors associated with Web site success in the context of electronic commerce. Information & Management, 38, 23–33. (2000) doi:10.1016/S0378-7206(00)00049-5

[25] Pang, M., Suh, W., Hong, J., Kim, J., Lee, H.: A New Web Site Quality Assessment Model for the Web 2.0 Era. In: Murugesan S. (ed.) Handbook of research on Web 2.0, 3.0, and X.0: technologies, business, and social applications, pp. 387-410. Information Science Reference. (2010)

[26] Bell, H., & Tang, N. K. H.: The effectiveness of commercial Internet Web sites: A user's perspective. Internet Research: Electronic Networking Applications and Policy, 8(3), 219–228. (1998) doi:10.1108/10662249810217768

[27] Bauer, C., & Scharl, A.: Quantitative evaluation of Web site content and structure. Internet Research: Electronic Networking Applications and Policy, 10(1), 31–43. (2000) doi: 10.1108/10662240010312138

[28] Wulf, K. D., Schillewaert, N., Muylle, S., & Rangarajan, D.: The role of pleasure in Web site success. Information & Management, 43(4), 434–446. (2006) doi:10.1016/j.im.2005.10.005

[29] Albuquerque, A. B., & Belchior, A. D.: E-Commerce Website Quality Evaluation. In EUROMICRO'02. (2002)

[30] Olsina, L. and Rossi, G.: "Measuring Web Application Quality with WebQEM," IEEE Multimedia, vol. 9, no. 4, pp. 20-29. (2002)

[31] Moraga M. Á., Calero C., Piattini M.: A First Proposal of a Portal Quality Model. IADIS International Conference e-Society, pp. 630-638. (2004)

[32] Calero C., Ruiz J., Piattini M.: Classifying website metrics using the website quality model. Online Information Review 29(3):227-248. (2005)

[33] Aladwani, A. M.: An empirical test of the link between web site quality and forward enterprise integration with web consumers. Business Process Management Journal, 12(2):178-190. (2006)

[34] Barnes, S. J., & Vidgen, R. T.: Data triangulation and web quality metrics: A case study in e-government. Information & Management, 43, 767-777. (2006)

[35] Abels, E. G., White, M. D., & Hahn, K.: A user-based design process for Web sites. OCLC Systems & Services, 15(1), 35–44. (1999) doi:10.1108/10650759910257850

[36] Santos, J.: E-service quality: A model of virtual service quality dimensions. Managing Service Quality, 13(3), 233–246. (2003) doi:10.1108/09604520310476490

[37] Grigoroudis, E., Litos, C., Moustakis, V. A., Politis, Y., & Tsironis, L.: The assessment of user perceived Web quality: Application of a satisfaction benchmarking approach. European Journal of Operational Research, 187(3), 1346–1357. (2008) doi:10.1016/j.ejor.2006.09.017

[38] DeLone, W. H., & McLean, E. R.: The DeLone and McLean model of information systems success: A ten-year update. Journal of Management Information Systems, 19(4), 9–30. (2003)

[39] Cox J., Dale B. G.: Key quality factors in Web site design and use: an examination. International Journal of Quality & Reliability Management, 19(7):862-888. (2002)

[40] Menasce D. A.: QoS Issues in Web Services, IEEE Internet Computing, Vol. 6, No. 6. (2002)

[41] Patel C., Supekar K., Lee Y.: A QoS Oriented Framework for Adaptive Management of Web Service based Workflows, Database and Expert Systems Conference, Prague, Czech Republic. (2003)

[42] Bilgin A. S., Singh M. P.: A DAML-Based Repository for QoS-Aware Semantic Web Service Selection, 2nd ICWS, San Diego, IEEE Press, 368-375. (2004)

[43] Yoon S. H., Kim D. J., Han S. Y. (2004), WS-QDL containing static, dynamic and statistical factors of WS quality, Proceedings of the IEEE International Conference on WS.

[44] Kim H. M., Sengupta A., Evermann J.: MOQ: Web Services Ontologies for QOS and General Quality Evaluations, European Conference on Information Systems (ECIS), Regensburg, Germany, 2005. (2005)

[45] Abramowicz W., Kaczmarek M., Zyskowski D., Duality in Web Services Reliability, Guadeloupe, French Caribbean, 2006

[46] Abramowicz W., Hofman R., Suryn W., & Zyskowski D.: SQuaRE based Web Services Quality Model. Proceedings of the IMECS 2008, Vol. I, pp. 19-21. (2008)

[47] Behshid, B., Mohsen, K., Kazem, A.M.: Customizing ISO 9126 quality model for evaluation of B2B applications. Information and Software Technology 51:599–609. (2009)

[48] Olsina, L., Sassano, R., & Mich, L.: Towards the Quality for Web 2.0 Applications. IWWOST 2009, pp. 3-15. (2009)

[49] Gounaris, S., & Dimitriadis, S.: Assessing service quality on the Web: Evidence from business-to-consumer portals. Journal of Services Marketing, 17(5), 529–548. (2003) doi:10.1108/08876040310486302

[50] Lee, Y., & Kozar, K. A.: Investigating the effect of Web site quality on e-business success: An analytic hierarchy process (AHP) approach. Decision Support Systems, 42(3), 1383–1401. (2006) doi:10.1016/j.dss.2005.11.005

[51] Fernandez A., Insfran E., & Abrahão S.: Towards a Usability Evaluation Process for Model- Driven Web Development. I-USED ’09, August 24, 2009, Upssala, Sweeden. (2009)

[52] Ranganathan, C., & Ganapathy, S.: Key dimensions of business-to-consumer Web sites. Information & Management, 39(6), 457–465. (2002) doi:10.1016/S0378-7206(01)00112-4

[53] Lin, H.-F.: The impact of Web site quality dimensions on customer satisfaction in the B2C E-commerce context. Total Quality Management & Business Excellence, 18(3), 363–378. (2007) doi:10.1080/14783360701231302

[54] Fink, D., Nyaga C.: "Evaluating web site quality: the value of a multi paradigm approach", Benchmarking: An International Journal, Vol. 16(2), pp.259 - 273. (2009)

[55] Deo, N.: Graph Theory with application to Engineering and Computer Science, New Delhi: Prentice Hall. (2000)

[56] Jense, J.B. and Gutin, G.: Digraph Theory, Algorithms and Organizations, London: Springer. (2000)

Authors

Rajeev Saha. He is working as Assistant Professor at YMCA University of Science and Technology, Faridabad. He is having around 10 years of experience in IT industry specifically with web related design and development.

Dr. Sandeep Grover has obtained bachelor's degree in Engineering, Master's degree in Technology, Master's degree in Business Administration and PhD in the field of Total Quality Management. He has authored about 80 papers in national and international journals and conferences. He guides research at postgraduate and doctorate levels and his research areas include TQM, Education Quality, HRD and CSR. With more than two decades of teaching and research experience presently he is working as Professor and Chairman, Deptt. of Mechanical Engineering at the YMCA University of Science and Technology, Faridabad, India.