Evaluation of Quality of Service using Factor Analysis Method

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Abstract

Objectives: In recent times Web Service providers are finding difficult to satisfy the requirements of the consumers due to several reasons. We have made an attempt to identify the specific parameters for evaluation of an efficient functioning of Composite Web Services. The study is based on a data set sampled from a large number of Web Service Providers. **Methods/Statistical Analysis:** Random sampling technique was adopted for the preparation of the data set. A multivariate statistical technique viz., Factor analysis is used for identifying the factors. Factor analysis method reduces large number of variables into few factors without sacrificing much of explained variability by the variables. Factor analysis begins with the construction of new set of variables based on the relationship in the correlation matrix. Based on principal component analysis we have identified the factor which determines the effective performance of Web Service providers. **Findings:** The study is based on a data set sampled from a large number of Web Service providers. The results based on the sample data set indicates the components of Web Service Providers Performance factors, Security factors and Trust factors viz., Successability, Best practices and Throughput respectively. These parameters have the higher loadings compared to other extracted QoS parameters. **Application/Improvement:** The research work was confined to the usage of factor analysis method based on principal component analysis approach. As a future work the other approaches in cluster method viz., centroid method and maximum likelihood method may be attempted to make a comparative study of the extraction of QoS parameters for its effectiveness.

Keywords: Factor Analysis, Principal Components, Quality of Service, Varimax Rotation, Web Service Selection

1. Introduction

A self-governing and platform independent computational entity that can be portrayed, registered, selected and dynamically assembled for developing inflict systems is known as a service in Service Oriented Architecture (SOA). The major elements of the SOA are Service consumers, Service providers and Service Registry. Services presented to the consumers by the Service providers are based on their request. Services are registered by Service providers in the Service Registry and Service consumer retrieve the service from the service Registry. Universal Description, Discover and Integration (UDDI) are referred as Service registry. To access the service Simple Object Access Protocol (SOAP) is used.

Web Service Description Language (WSDL) is used for describing the Services.

Web Service Composition is an important application of the Web Services. A single Web Service will not be able to satisfy the requirements of a user in many situations. Therefore they are combined to construct Composite Web Services that meet the needs of the clients. There is a need to select an individual Service that meet the criteria to create a Composite Web Service[1].The Web Services that compose a Service Oriented Architecture are capable to perform a task in particular time may not be available in some other time. All the Quality parameters are essential in order to select the relevant Web Service for composition of a Web Services. Individual Web Service quality is essential to the successful implementation of

Composite Web Service. Nowadays many Web Services with the same functionality are available and they differ in their quality. Identifying the Web Services with better Quality of Service (QoS) is the main research problem need to be focused. A prominent understanding of QoS may help Service providers to provide more suitable services to Service consumers and they will be able to receive the services with better QoS[2]. In this task we use factor analysis technique for identifying the Web Service Providers with the specified QoS parameters.

In[3] the authors have examined the application of QoS to Web Services. They also cautioned that UDDI will face deliberate challenges and will lose its popularity in the industry if UDDI did not consider QoS parameters for searching and selecting of Web Services. Under QoS measurement approach for Web Service selection[4], the authors have considered service providers with reference to historical statistics factors. The fuzzy synthetic evaluation method, non-uniform operator and weighted average method were used to calculate QoS value. The finding of the study has not given clear-cut guidelines on what would be the best choice to some QoS parameters.

Reputation-based Matrix Factorization[5] has been used to predict the unknown QoS parameters of Web Services. First they have calculated the reputation value for consumers based on their QoS. To get more accurate prediction they integrated the user reputation into a Matrix Factorization (MF). Management of QoS in service-oriented architectures is focused[6]. They have concentrated on QoS negotiations among Service providers and Service consumers using service broker. The authors also suggested that QoS could be integrated with the UDDI registry for better management of composed Web Services. A novel approach[7] is proposed for predicting the unknown multidimensional QoS values by using tensor operation. They have also utilized an efficient user preference learning method to learn user preferences based on users' ratings history data. In[8] the authors have evaluated user observed QoS of Web Services from distributed environments. They have considered only three QoS parameters such as response time, throughput and failure rate. They failed to concentrate on other QoS parameters such as successability, availability, reliability and so on in their investigations.

The Pareto set model[9] for service compositions have been proposed. In this work a partial selection technique is used for the reduction of the search space and a distributed service composition algorithm is developed. The performance analysis based on transactional properties of a candidate Web Service and Composite Web Service was conducted[10]. The sequential, parallel, selectable, and loop workflow patterns were considered for the analysis. They have proposed a selection algorithm to obtain functional and transactional QoS properties at run time. They stressed the necessity for service selection algorithm based on QoS evaluations. The authors[11] addressed the issues in Web service selection and composition not only according to their functional requirements but also to their transactional properties and QoS parameters. The study[12] on factor analysis in measurement information extraction and reconstruction has been attempted. They have attempted four methods of factor extraction, viz. principal component, unweighted least squares, and generalized least squares and maximum likelihood. In order to simplify the structure and explain common factors, they have carried out Varimax method to obtain the rotated factor matrix which will give less number of variables for each factor with high load. The Quality of Experience assessment approaches for web service selection have been proposed[13].

To understand the users' experiences in a Web services environment the authors have incorporated the comprehensive set of Metrics with the factor analysis. They have highlighted the usage of factor analysis tool[14] in the development, enhancement, tests evaluation, scales and measures in various applications. They have explained the stepwise approach that simplifies the guidelines and options associated with exploratory factor analysis. The factor analysis method[15] used to find competitiveness of service industries in Liaoning. The factors[16] that could affect the intention of continuous usage of a firm with the help of services in Web Analytics service is identified and empirically validated. The three factors such as satisfaction of service, usage period and switching costs were utilized to predict the results. In[17–19] detailed the QoS metrics for Web Services approaches are presented.

The authors have established usage of social networking sites[20] by the students for communicating into peers, faculties and other professionals to improve their social values for fulfilling their social and academic needs. They have used principal component analysis method and identified three important latent factors. A novel anomaly detection algorithm[21] based on factor analysis has been proposed. In[22] a service equality model with

higher order factor analysis approach for finding whether or not second order components of service equality in the context of information system use has been validated. The determinants of the equality factors that influence the effectiveness of web based information system was investigated[23] and it was concluded that level of contextual performance will significantly increase if the level of information and service equality are increased. The impact of quality parameters of web based information system have been evaluated[24].

2. Materials and Methods

2.1 Motivations for the study

Most of the researchers concentrate on all the parameters for selecting the Web Service Providers. This involves enormous efforts for integrating the different QoS parameters. In this study an attempt is made to identify the QoS parameters which are helpful for effective functioning of Composite Web Services.

2.2 Methodological Aspects of QoS and Associated Theories

Several abstract Services[25] that provide the similar functionality compose the Composite Web Service. QoS Service is an important aspect for distinguishing the success of service providers. A set of non functional attributes that helps to find the best Web Services that meets clients' requirements are known as Web Services QoS. The composite services are formed by appropriate selection of a component service from the collection of candidate services. Selecting the service based on functional and nonfunctional requirements of the user is termed as Web Service selection. The non functional parameters based selection needs to be evaluated to satisfy the requirements of the user[26]. When service consumers multiple requirements were not provided by a single web service, multiple Web Services need to be combined together to form a CWS to satisfy both the functional and nonfunctional requirements.

QoS is an important factor for business transactions and thus it is a imperative element in Web Services. The various QoS parameters such as Availability, Response time, Throughput, Successability, Reliability, Compliance, Best Practices, Latency and Documentation need to be addressed in the implementation of Web Service

applications. In this paper we use factor analysis to explore the dimensionality of Web Services QoS by finding the smallest number of interpretable factors to explain the correlations among them as shown in Figure 1. This in turn helps to improve the selection approach for composite Web Service. The QoS parameters considered for analysis are
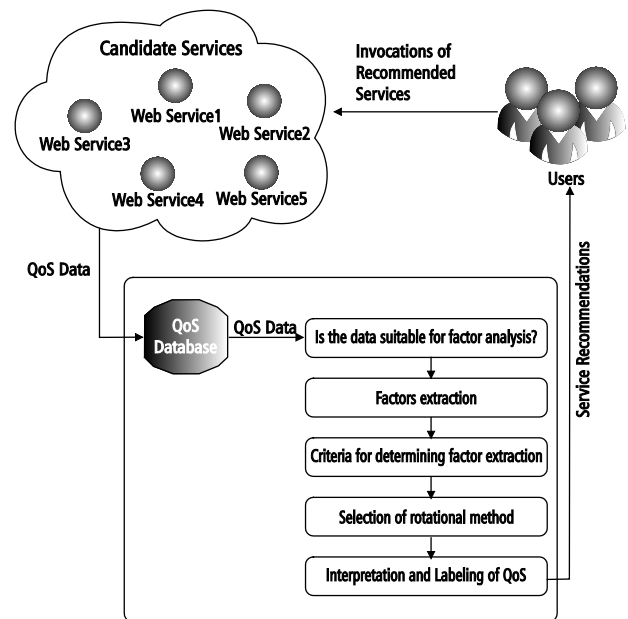

Figure 1. Factor analysis of QoS.

- **Availability (AV):** A period of time Web Service is available for the consumer (Unit: %/3-days period).
- **Response Time (RT):** The time taken between Web Service consumer request and the Web Service provider response (Unit: ms).
- **Throughput (TP):** Request handled in a given time (Unit: No. of requests/Sec).
- **Successability (SU):** Number of response / request messages (Unit: %).
- **Reliability (RE):** Proportion of the total messages and error messages (Unit: %)
- **Compliance (COMP):** The percentage of utilizations of WSDL document (Unit: %)
- **Best Practices (BP):** The degree of WS-I basic profile usage in Web Service (Unit: %)
- **Latency (LA):** Processing time of the server (Unit: milliseconds).
- **Documentation (DOC):** Volume of description tags in Web Service Description Language (Unit: %)
  Based on the descriptive statistics for the QoS

parameters of Web Service Providers only six parameters among nine were taken into consideration for the evaluation.

2.3 Factor Analysis: Principal Component Approach

For the study of underlying the structure of the variables in this study we use factor analysis. This factor analysis method is a data reduction technique which in turn helps us to reduce the complexity involved in the data structure. It also helps to attain the manageable number of factors among the factors included initially. The variations present in these factors are studied.

To start with we construct the correlation matrix initially. Then we adopt Principal Component method for the subsequent analysis.

The Principal Component method maximizes the sum of squared loadings of each factor. Principal Component factors account for larger variability in the data than that is accounted for using any other factoring method.

Under this Principal Component method we construct for a given set of variables X_j's (j=1,2,3,…k) of new variables (P_i) called principal components. The P_i's are linear combination of the X_j's.

$P_1 = a_{11}X_1 + a_{12}X_2 + …….. + a_{1k}X_k$
$P2 = a_{21}X_1 + a_{22}X_2 + …….. + a_{2k}X_k$
$P_k = a_{k1}X_1 + a_{k2}X_2 + …….. + a_{kk}X_k$

We standardized the X_j's for making uniformity in the data set, because the data set contains different units of measurement. It is given by $Z_j = \dfrac{x_j - \bar{x}_j}{\sigma}$

The coefficients viz., a_{ij} are called factor loadings. The extracted principal components satisfy the following:

- Principal components are uncorrelated (Orthogonal) and
- The first principal component (P_1) has the maximum variance; the next principal component (P_2) has the next maximum variance and so on.

2.4 Data Structure of the Study and Standardization of Qos Parameters

The dataset contains 2507 Web Services providers. Simple random samples of 50 Web Service Providers were chosen and the data are presented in Table 1 for the specified parameters. The sample size of the study has been fixed on the condition that all Web Service Providers attend the same functionalities.

The QoS parameters in the study are in different units and these are to be standardized. The standardization is done using the following formula.

Table 1. QoS Raw Data

WS.No	AV	TP	SU	RE	COMP	BP
1.	85	16	95	73	100	84
2.	88	21.2	96	73	100	84
3.	72	1.4	72	80	100	83
4.	96	28	99	73	100	84
5.	90	17.6	97	73	100	80
6.	91	6.3	97	73	100	84
7.	87	8	87	67	100	77
8.	89	24.5	96	67	100	82
9.	96	4.2	99	73	78	80
10.	89	10.9	89	67	78	72
11.	56	11.8	56	78	78	89
12.	83	24	84	83	89	91
13.	100	19.7	100	73	78	80
14.	87	8.9	95	73	78	84
15.	96	16.2	99	73	78	84
16.	83	5.6	84	83	89	91
17.	97	5.7	99	58	89	69
18.	27	11.2	27	67	78	82
19.	96	8.7	99	73	100	80
20.	86	4.5	86	73	89	84
21.	87	1.4	88	53	89	66
22.	95	1.6	98	73	100	84
23.	72	17.2	72	50	78	77
24.	83	15.3	84	83	89	91
25.	97	22.5	99	67	78	72
26.	8	5.4	9	60	89	69
27.	93	10.3	98	73	100	84
28.	72	13.5	72	73	78	84
29.	91	9.2	97	67	78	82
30.	60	7.5	61	60	89	74
31.	86	16.9	86	73	89	84
32.	94	17.1	98	73	100	80
33.	95	15.9	98	73	100	84
34.	32	3.1	33	60	78	79
35.	91	1.1	97	73	100	84
36.	50	6.5	51	67	100	77
37.	90	4.1	96	73	78	62
38.	90	4.5	90	53	89	66
39.	97	14.6	99	73	100	84
40.	83	24.3	84	78	89	89
41.	91	1.8	97	67	100	82
42.	94	2.1	98	73	100	84
43.	91	7.3	91	67	100	77
44.	95	1.3	98	73	100	84
45.	32	3.1	33	60	78	79
46.	56	6.2	56	83	89	91
47.	73	7.5	74	73	89	84
48.	88	18.5	96	73	78	80
49.	85	12.5	95	73	100	84
50.	98	1	98	60	100	72

The results relating to the mean and standard deviation of the QoS parameters are presented in Table 2.

Table 2. Mean and standard deviation for the QoS parameters of web service providers

	AV	TP	SU	RE	COMP	BP
Mean	81.260	10.554	84.040	70.200	90.540	80.660
N	50	50	50	50	50	50
Std. Deviation	20.4867	7.4128	21.6295	7.5997	9.4312	6.6413

The values obtained for corresponding QoS after standardization are presented in Table 3.

Initially we would like to evaluate and ensure validity and reliability of the data set used in this research. Cronbach α is used in this for testing the reliability. KMO and Bartlett's Test are used for testing validity.

To analyze the data reliability and validity we use SPSS software. Result shows that α coefficient value is 0.699 which indicates data validity is good.

2.5 Reliability and Validity: KMO and Bartlett's Test

The results relating to KMO and Bartlett's Test are presented in Table 4.

The values of KMO and Bartlett's test are presented in Table 4. It is important to note that the KMO values lies between 0 and 1. For carrying out factor analysis researchers generally accept the KMO value as greater than 0.5. The value of KMO in our analysis is 0.551. This clearly reveals that the sample size considered for the value is adequate.

For testing the null hypothesis that the correlation matrix is an identity matrix we use Bartlett's test of sphericity. The computation carried out shows that the value of Bartlett's test is 0.000 and this value is less than 0.01. This is significant and this in turn reveals that the correlation matrix is not an identity matrix. The above facts help us to justify the appropriateness of factor model used in this study.

Table 3. Standardized QoS parameters

S.No	AV	TP	SU	RE	COMP	BP
1.	0.1825	0.7355	0.5067	0.3684	1.0032	0.503
2.	0.3289	1.4372	0.5529	0.3684	1.0032	0.503
3.	-0.4519	-1.2348	-0.5566	1.2895	1.0032	0.3524
4.	0.7194	2.3549	0.6916	0.3684	1.0032	0.503
5.	0.4265	0.9514	0.5992	0.3684	1.0032	-0.0994
6.	0.4754	-0.5735	0.5992	0.3684	1.0032	0.503
7.	0.2801	-0.3441	0.1368	-0.4211	1.0032	-0.5512
8.	0.3777	1.8826	0.5529	-0.4211	1.0032	0.2018
9.	0.7194	-0.857	0.6916	0.3684	-1.3298	-0.0994
10.	0.3777	0.0472	0.2293	-0.4211	-1.3298	-1.3042
11.	-1.2328	0.1687	-1.2963	1.0263	-1.3298	1.256
12.	0.0849	1.8151	-0.0018	1.6842	-0.1633	1.5572
13.	0.9146	1.2348	0.7379	0.3684	-1.3298	-0.0994
14.	0.2801	-0.2227	0.5067	0.3684	-1.3298	0.503
15.	0.7194	0.7625	0.6916	0.3684	-1.3298	0.503
16.	0.0849	-0.668	-0.0018	1.6842	-0.1633	1.5572
17.	0.7682	-0.6545	0.6916	-1.6053	-0.1633	-1.756
18.	-2.6481	0.0877	-2.6371	-0.4211	-1.3298	0.2018
19.	0.7194	-0.2497	0.6916	0.3684	1.0032	-0.0994
20.	0.2313	-0.8165	0.0906	0.3684	-0.1633	0.503
21.	0.2801	-1.2348	0.1831	-2.2632	-0.1633	-2.2078
22.	0.6706	-1.2078	0.6454	0.3684	1.0032	0.503
23.	-0.4519	0.8974	-0.5566	-2.6579	-1.3298	-0.5512
24.	0.0849	0.641	-0.0018	1.6842	-0.1633	1.5572
25.	0.7682	1.6127	0.6916	-0.4211	-1.3298	-1.3042
26.	-3.5754	-0.695	-3.4693	-1.3421	-0.1633	-1.756
27.	0.573	-0.0337	0.6454	0.3684	1.0032	0.503
28.	-0.4519	0.3981	-0.5566	0.3684	-1.3298	0.503
29.	0.4754	-0.1822	0.5992	-0.4211	-1.3298	0.2018
30.	-1.0376	-0.4116	-1.0652	-1.3421	-0.1633	-1.003
31.	0.2313	0.857	0.0906	0.3684	-0.1633	0.503
32.	0.6218	0.8839	0.6454	0.3684	1.0032	-0.0994
33.	0.6706	0.722	0.6454	0.3684	1.0032	0.503
34.	-2.4041	-1.0054	-2.3597	-1.3421	-1.3298	-0.25
35.	0.4754	-1.2753	0.5992	0.3684	1.0032	0.503
36.	-1.5256	-0.5466	-1.5275	-0.4211	1.0032	-0.5512
37.	0.4265	-0.8704	0.5529	0.3684	-1.3298	-2.8102
38.	0.4265	-0.8165	0.2755	-2.2632	-0.1633	-2.2078
39.	0.7682	0.5466	0.6916	0.3684	1.0032	0.503
40.	0.0849	1.8556	-0.0018	1.0263	-0.1633	1.256
41.	0.4754	-1.1808	0.5992	-0.4211	1.0032	0.2018
42.	0.6218	-1.1404	0.6454	0.3684	1.0032	0.503
43.	0.4754	-0.4386	0.3218	-0.4211	1.0032	-0.5512
44.	0.6706	-1.2483	0.6454	0.3684	1.0032	0.503
45.	-2.4041	-1.0054	-2.3597	-1.3421	-1.3298	-0.25
46.	-1.2328	-0.587	-1.2963	1.6842	-0.1633	1.5572
47.	-0.4031	-0.4116	-0.4642	0.3684	-0.1633	0.503
48.	0.3289	1.0729	0.5529	0.3684	-1.3298	-0.0994
49.	0.1825	0.2632	0.5067	0.3684	1.0032	0.503
50.	0.817	-1.2888	0.6454	-1.3421	1.0032	-1.3042

Table 4. KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.551
Bartlett's Test of Sphericity	Approx. Chi-Square	250.834
	df	15
	Sig.	.000

2.6 Correlation Matrix

The correlation matrix is given in Table 5. It is observed that many of the factors exhibits high correlation and hence it is necessary to proceed with the factor analysis.

2.7 Communalities of QoS Parameters

Table 6 contains the communalities of all QoS parameters. The initial values of the communalities of all the parameters are unity. The higher the value of the communality of a parameter the more the variability is explained by the parameter. The values obtained in respect of all the parameters after extraction is greater than 0.4. Hence we can conclude that the factors considered are useful in the model.

Table 6. Communalities of all the QoS parameters

S.No	QoS	Initial	Extraction
1	Availability	1.000	.967
2	Throughput	1.000	.744
3	Successability	1.000	.974
4	Reliability	1.000	.838
5	Compliance	1.000	.736
6	Best Practices	1.000	.893

Extraction Method: Principal Component Analysis.

2.8 Total Variance Explained

The initial eigen values, extraction sums of squared loadings and rotation sums of squared loadings are presented in Table 7. After rotations the first three components accounts for 85.863% of total variance.

The table contains the eigen values of all components. We have retained the only components whose eigen values are greater than one viz., components 1, 2 and 3.

Table 5. Correlation matrix for the QoS parameters of web service providers

	Availability	Throughput	Successability	Reliability	Compliance	Best Practices
Availability	1.000	.201	.992	.224	.313	.046
Throughput	.201	1.000	.213	.256	-.074	.294
Successability	.992	.213	1.000	.236	.333	.059
Reliability	.224	.256	.236	1.000	.162	.764
Compliance	.313	-.074	.333	.162	1.000	.170
Best Practices	.046	.294	.059	.764	.170	1.000

Table 7. Total variance explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.493	41.545	41.545	2.493	41.545	41.545	2.181	36.358	36.358
2	1.630	27.160	68.705	1.630	27.160	68.705	1.902	31.699	68.057
3	1.029	17.158	85.863	1.029	17.158	85.863	1.068	17.806	85.863
4	.633	10.548	96.411						
5	.207	3.457	99.867						
6	.008	.133	100.000						

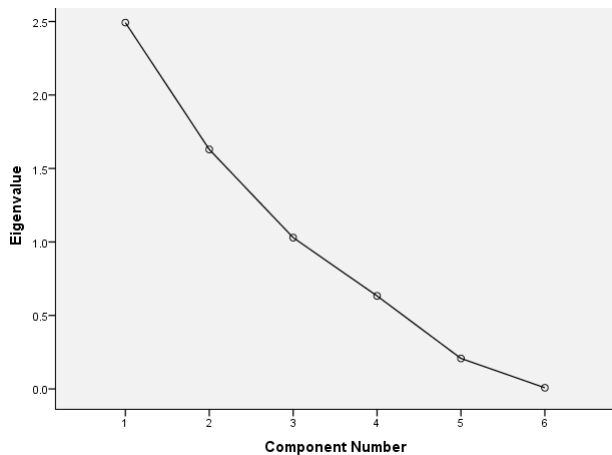Extraction Method: Principal Component Analysis.

Figure 2. Scree plot.

We have constructed a scree plot and the same is given in Figure 2 (Representing the component number in X-axis and eigen value in Y- axis). It is noted that only 3 components have eigen value above the elbow point. This has resulted to retain only three components.

2.9 Unrotated Component Matrix

The computations relating to first initial unrotated solution are given in Table 8. Three factor components have been extracted and the Factor loadings on each of the three factors for the QoS parameters under study are given in the Table.

Table 8. Component matrixa unrotated factor solution

S.No	QoS	Component		
		1	2	3
1	Availability	.827	-.516	-.129
2	Throughput	.424	.299	-.689
3	Successability	.839	-.506	-.121
4	Reliability	.652	.628	.134
5	Compliance	.470	-.192	.692
6	Best Practices	.529	.766	.165

Extraction Method: Principal Component Analysis. 3 components extracted.

2.10 Varimax Rotated Component Matrix

Under unrotated solution set up some of the QoS parameters show their contribution in more than one factor component. This has necessitated us to use Varimax rotation method which is considered to be more efficient than unrotated method. It is generally accepted that Varimax rotation method is a best analytic approach for obtaining an orthogonal rotation of factors. The computations obtained under Varimax rotation are presented in Table 9.

Table 9. Varimax rotated component matrixa

S.No	QoS	Component		
		1	2	3
1	Availability	.982	.053	-.014
2	Throughput	.282	.345	.738
3	Successability	.984	.070	-.020
4	Reliability	.152	.902	.023
5	Compliance	.381	.264	-.722
6	Best Practices	-.030	.944	.030

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.[a] Rotation converged in 5 iterations.

3. Results and Discussion

The final solution emerges clearly under the Varimax rotation set up. The Varimax rotation facilitates the QoS parameters to appear in one and only direction. The identification of QoS parameter is purely based on the maximum factor loading 0.7 or more. In our study we have adopted a reduced threshold value and the value taken is 0.6 and above.

Based on this criterion we have grouped QoS parameters in three factors viz., Performance factors, Security factors and Trust factors and the same are given in Table 10, Table 11 and Table 12.

Table 10 contains the QoS parameters which measure the performance of Web Service providers and therefore it may be termed as "Performance Factors".

Table 10. Naming factor 1 - performance factors

QoS	Loadings
Successability	0.984
Availability	0.982

In Table 11 we have given the QoS parameters which measure the security aspects and the same is termed as "Security Factors".

Table 11. Naming factor 2 - security factors

QoS	Loadings
Best Practices	0.902
Reliability	0.944

Table 12 contains the QoS parameter and they measure the performance of trustworthiness of Web Service providers and it may be termed as "Trust Factors".

Table 12. Naming factor 3 - trust factors

QoS	Loadings
Throughput	0.738
Compliance	0.722

In the final analysis one has to construct a Test Battery. The Test Battery will measure the efficiency of QoS parameters. We have to select one QoS parameter from the QoS parameters which has the highest loadings under each factor group. The results relating to this are presented in Table 13.

Table 13. Test battery for measuring the efficiency of QoS parameters

Factor Group	Items	Loadings
Performance Factors	Successability	0.984
Security Factors	Best Practices	0.902
Trust Factors	Throughput	0.738

4. Conclusion

The results based on the sampled data set emphasis that successability emerges as a leading QoS parameter which is classified under the performance factors and the loading value is highest for this parameter. Best Practices is termed as the second QoS parameter under the security factors with a higher loading factor value. Throughput which has the least loading comes next to Successability and Best Practices under Trust factors. Based on the above analysis the authors are of the opinion that the factors identified are useful in the selection of Web Service Providers for effective functioning of Composite Web Services.

5. Acknowledgements

6. References

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